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March 29, 2017

VIA RESS, EMAIL and COURIER

Ms. Kirsten Walli
Board Secretary
Ontario Energy Board
2300 Yonge Street, Suite 2700
Toronto, Ontario, M4P 1E4

Dear Ms. Walli:

Re: Enbridge Gas Distribution Inc. ("Enbridge") and Union Gas Limited ("Union"
Ontario Energy Board ("Board") File Number EB-2016-0246
New and Updated DSM Measures and the Technical Reference Manual
Joint Interrogatory Responses of Enbridge and Union

In accordance with the Board's Procedural Order dated February 28, 2016, enclosed please find Enbridge and Union's joint interrogatory responses for the above noted proceeding.

The Attachment listed below included in the Interrogatory responses has been redacted. Confidential copies of this Attachment are being filed with the Ontario Energy Board under separate cover as it contains confidential information.

I.EGDI.SEC.4_Attachment

The interrogatory responses have been filed through the Board's Regulatory Electronic Submission System and will be available on the Enbridge website at:

www.enbridgegas.com/ratecase

Please contact the undersigned if you have any questions.

Yours truly,

(Original Signed)

Stephanie Allman
Regulatory Coordinator

cc: Mr. D. O'Leary, Aird & Berlis LLP (via email)
Mr. C. Smith, Torys (via email)
Adam Stiers, (Union Gas Limited) (via email)
Intervenors EB-2016-0246 (via email)

BOARD STAFF INTERROGATORY #1

INTERROGATORY

Ref: General

Questions:

a) Please provide a full status update of the ongoing work related to the boiler baseline study, including planned deliverable dates.

RESPONSE

A full status update of the ongoing work related to the Boiler Baseline Study and planned deliverables follows, organized into three sections:

1) Contractor Selection Process;
2) Key Deliverables and Work Plan; and,
3) Accomplishments to Date.

1) Contractor Selection Process

Union and Enbridge worked collaboratively with the Technical Evaluation Committee ("TEC") to develop the boiler baseline study Request for Proposal ("RFP") for a competitive bidding process and issued the RFP in November 2015. Due to a limited response to the original RFP, the TEC extended the proposal submission date and reposted the RFP. By the new closing date of December 18, 2015, five bidder proposals were received. The TEC did not proceed with the evaluation of the proposals as it was awaiting further instructions from the Board on the selection process and/or transition to the Evaluation Advisory Committee ("EAC").

On March 4, 2016 Board Staff issued a memo entitled, "Transition of Technical Evaluation Committee Activities to the OEB EB-2015-0245" ("Memorandum"). Page 3 of the memorandum stated the following:

Witnesses: D. Bullock
L. Kulperger

Boiler Baseline Study

This study was the result of OEB decisions for both Enbridge and Union Gas and therefore the utilities are expected to complete it. Once the proposals have been evaluated and the consultant selected for the Boiler Baseline Study, in order to transition to the new framework, input on the study will be provided to the utilities by the EAC and OEB Staff instead of the TEC.

Subsequent to the release of the Memorandum, a TEC meeting was held on March 10, 2016. At this meeting Board Staff advised that the Utilities should assume administrative responsibility and accountability for the Study following the selection of the winning consultant. Further, Board Staff indicated that the EAC will provide advice to the Utilities on the Study and that while the EAC will endeavor to achieve consensus, final decision-making authority rests with the Utilities. A subsequent TEC meeting to select the winning bidder was scheduled for April 13, 2016. However, two intervenor representatives notified the TEC that they would not be participating in the selection process. The Utilities noted this would represent a departure from the quorum that was achieved with all previous TEC projects as per the Joint Terms of Reference[1]. Board Staff, the remaining intervenor representative and independent representatives agreed the project should proceed absent a quorum. As such, the Utilities continued to proceed with the selection process with input from the remaining TEC members and Board Staff. The above was communicated in a joint letter from the Utilities to the Board on June 9, 2016 in the 2015 to 2020 Demand Side Management Evaluation Process of Program Results (EB-2015-0245) proceeding.

Subsequent to the April 13, 2016 meeting, notification was sent to the firms that were selected to participate in a “Best and Final” presentation. Written responses were provided on May 6, 2016, and oral presentations to the Utilities, remaining TEC members and Board Staff (the “Boiler Baseline Committee”), took place on May 18, 2016 and May 19, 2016.

The group selected ICF International to conduct the study, but also requested that ICF include Mr. Bob Bach in their proposal and the completion of the study to benefit from the additional technical expertise Mr. Bach could bring to the project. Mr. Bach is a boiler expert and Senior Associate with Energy Profiles based in Toronto, Ontario. Discussions proceeded in June 2016 between ICF and Mr. Bach to reach an agreement to work together and subsequently ICF was asked to submit a revised proposal on that basis.

[1] Joint Terms of Reference on Stakeholder Engagement for DSM Activities by Enbridge Gas Distribution Inc. and Union Gas Limited, November 4, 2011.

Witnesses: D. Bullock
L. Kulperger

The Boiler Baseline Committee convened on August 17, 2016 to discuss ICF's revised proposal dated July 29, 2016. The committee recommended some modifications to ICF's proposal and a finalized proposal was submitted on October 14, 2016.

The next step involved the execution of a tri-party legal agreement between the two Utilities and ICF. Additionally, given that the study would require on-site visits to boiler room facilities with inherent safety risks, Enbridge policy required ICF to apply for and obtain ISNetworld safety certification. ISNetworld is an international organization that certifies that contractors have proper safety programs in place.

ICF successfully obtained ISNetworld certification that complied with Enbridge's policy requirements on January 6, 2017. Subsequently the tri-party agreement was executed and the project commenced in January, 2017.

2) Key Deliverables and Work Plan

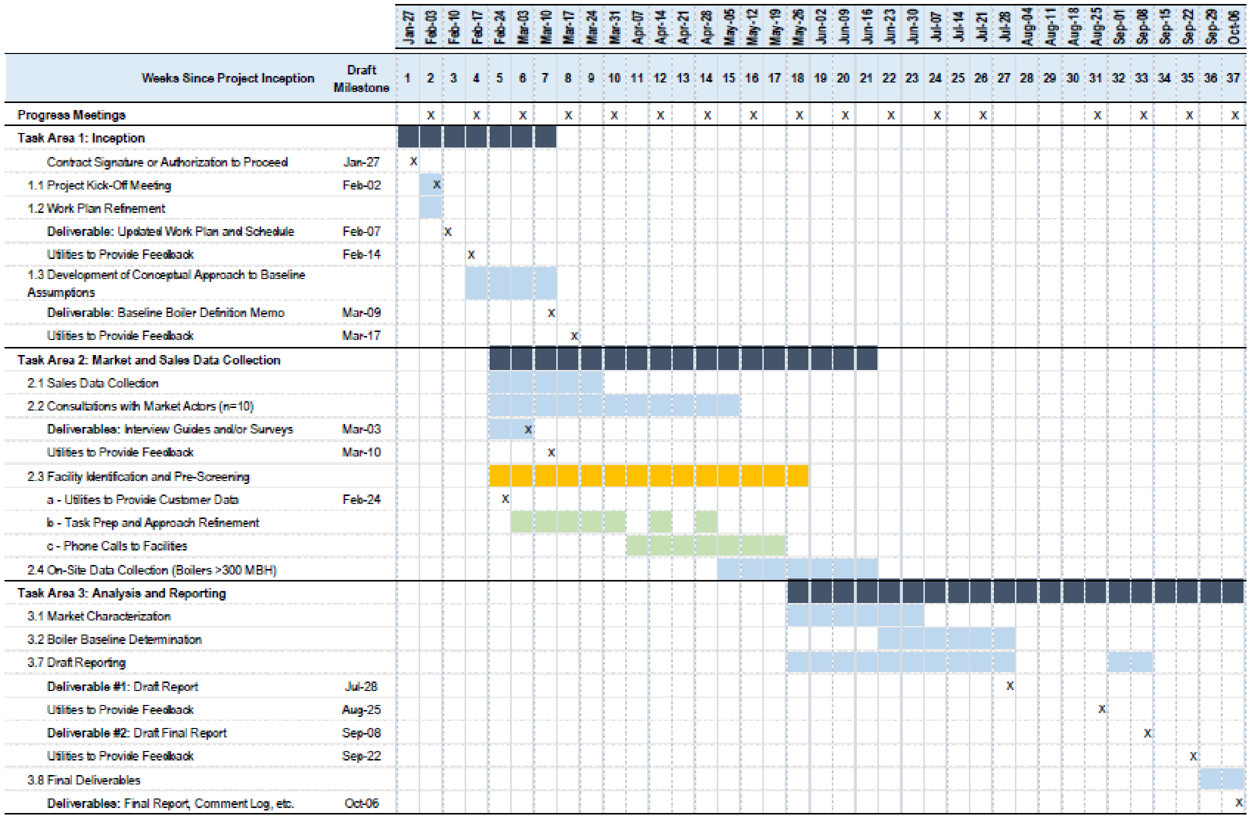
The key deliverable for this study is to characterize the standard efficiency commercial boiler and associated features in a natural replacement scenario in the absence of a DSM (or other) incentive program. The consultant has proposed, that in order to meet the minimum statistical requirements, a sample size of 70 standard performance boilers are required. This study plans to go beyond this requirement and collect a sample of 140 boilers that will provide a 95% statistical confidence interval with a precision of 10%. This will involve collecting on-site boiler system technical information.

The results from this study will be used to determine the baseline thermal efficiency and associated features of a standard efficiency boiler.

The consultant has indicated that it will be challenging to identify customer sites that have installed a commercial boiler system in the last few years but did not participate in a DSM program. As a result of this challenge, based on ICF's estimation, the Utilities expect ICF to contact approximately 5,000 customers to meet the 140 boiler target.

Targeting, collecting and analyzing the data is expected to take a number of months. Based on ICF's work plan, completion of the final report is expected in the fall of 2017. The project schedule provided by the consultant is included below.

Witnesses: D. Bullock
L. Kulperger



3) <u>2017 Accomplishments To Date</u>

Since the project kick off meeting in January 2017, the following accomplishments have been made:

- ICF provided utility customer data requirements
- Utilities commenced collection of data for targeting and contacting customers
- ICF completed several draft questionnaires for different market actors, including customers

Current efforts are focused on the provision of utility data. Next steps will involve ICF contacting customers and undertaking site visits.

Witnesses: D. Bullock
L. Kulperger

BOARD STAFF INTERROGATORY #2

INTERROGATORY

Ref: General

Preamble:
There is limited reference to measure level penetration in the Technical Resource Manual.

Questions:

a) Please discuss if there are any ongoing or future planned penetration end-use surveys being done by the utilities. i. If the utilities are currently undertaking any market penetration studies, please provide a status update, the specific areas being investigated and if there is any collaboration opportunities with the Independent Electricity System Operator.

RESPONSE

While the Utilities endeavor to approach Demand Side Management ("DSM") programming based on market intelligence, neither Union nor Enbridge have any ongoing or future planned end-use surveys to assess Technical Reference Manual ("TRM") measure-level market penetration across Ontario.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #1

INTERROGATORY

Ref: Exhibit B, Tab 1, Schedule 1, p5 of 5

Preamble:

> *"Union's Custom EUL Table included in this evidence is the updated version reflecting best available substantiating references as per the Union Gas 2015-2020 DSM Plan (EB-2015-0029).*
>
> *Enbridge's Measure Life Guide for Custom Offers included in this evidence provides updates reflecting best available substantiating references."*

Why do Union's Customer EUL table and Enbridge Measure Life Guide differ both in title and in equipment/measure life?

RESPONSE

The Utilities' Custom measure life guides differ both in name and values as a result of separate DSM evaluation activities since the inception of program offerings to their respective customers. Historically, each of the Utilities' Custom guides has been subject to separate audit processes conducted by independent auditors, engaged by audit committees unique to each utility. In light of diverging recommendations, some values in the tables differ.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #2

INTERROGATORY

Ref: Exhibit B, Tab 1, Schedule 3, p1 of 8

Preamble:

> *"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."*

Which measures included in the current version of the TRM are NOT included in either Union's or Enbridge's current programs? What is the criteria to exclude a given measure?

RESPONSE

The respective Utilities' 2017 Demand Side Management ("DSM") prescriptive offerings do not currently include the following Technical Reference Manual ("TRM") measures:

Enbridge	**Union**
Commercial Pre-rinse Spray Nozzle (New Construction/Time of Natural Replacement/Retrofit)	Commercial Pre-rinse Spray Nozzle (New Construction/Time of Natural Replacement/Retrofit)
Commercial ENERGY STAR Convection Oven (New Construction/Time of Natural Replacement)	Commercial ENERGY STAR Convection Oven (New Construction/Time of Natural Replacement)
Residential Tankless Water Heater (New Construction/Time of Natural Replacement)	Residential Tankless Water Heater (New Construction/Time of Natural Replacement)
Residential High Efficiency Water Heaters (New Construction)	Residential High Efficiency Water Heater (New Construction)
Residential High Efficiency Condensing Furnace (New Construction/Time of Natural Replacement)	Commercial Destratification Fans (New Construction/Retrofit)
Commercial Air Curtains (New Construction/Retrofit)	Residential Heat Reflector Panels
Residential Pipe Wrap (Retrofit)	Residential Adaptive Thermostat (New Construction/Retrofit)

Witnesses: D. Bullock
L. Kulperger

When determining which measures are included in program offerings the Utilities consider the key priorities and guiding principles outlined by the Board[1]. These considerations balance pursuing long-term energy savings, program cost-effectiveness, and available budget, while seeking broader participation from non-participants. As outlined in the Board's current DSM guidelines, the gas utilities have flexibility in deciding what programs to include in their proposed DSM plans with consideration of ensuring the Utilities' respective DSM plans are cost-effective.

[1] DSM Framework for Natural Gas Distributors (2015-2020) and Filing Guidelines to the DSM Framework for Natural Gas Distributors (2015-2020), EB-2014-0134.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #3

INTERROGATORY

Ref: Exhibit B, Tab 1, Schedule 3, p4 of 8

Preamble:

> *"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."*

Which measures may be made ineligible for DSM Programs due to future changes to building codes and equipment standards? How do Enbridge and Union determine predominant industry practice?

RESPONSE

The above definition of “New Construction” was recommended by the Technical Reference Manual (“TRM”) consultant for the purposes of developing a glossary to support the TRM. The following response is provided accordingly:

The Utilities recognize that updates to future codes, standards and predominant industry practice could affect some New Construction measures contained in the proposed TRM. As outlined in the August 21, 2015 Board letter (EB-2015-0245), it is the role of the Evaluation Contractor to update the input assumptions, including consideration of future changes to building codes and equipment standards.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #4

INTERROGATORY

Ref: Exhibit B, Tab 1, Schedule 1, p2 of 5

Preamble:

> *"The 2008 DSM Guidelines requested that a Terms of Reference for Stakeholder Engagement ("Terms of Reference"; EB-2011-0295 Exhibit B, Tab 2, Schedule 9, Appendix A) be developed by the natural gas utilities in cooperation with stakeholders for the multi-year plan period. The Terms of Reference for Stakeholder Engagement mandated the TEC to develop a Technical Reference Manual ("TRM") for natural gas DSM activities. In 2013, the utilities, through the TEC, engaged a third-party consultant to begin development of the TRM."*

The terms of reference states that the TRM is to cover natural gas DSM activities. However, it appears that the manual focuses exclusively on replacing a given piece of equipment for a more efficient device. BOMA Toronto members increasing find that a more holistic "performance based" approach to energy conservation is more successful than a purely equipment based approach to reduce the energy intensity on a per square meter basis. Please indicate what efforts both Enbridge and Union are pursuing to adapt to these market based changes.

RESPONSE

As outlined in this application, the Technical Evaluation Committee ("TEC") was mandated to commission the development of a joint Technical Reference Manual ("TRM") containing input assumptions for prescriptive and quasi-prescriptive energy efficiency technologies.

Energy savings realized through a "performance based" approach are addressed by other Demand Side Management ("DSM") offerings. Examples include Enbridge's Run it Right and Comprehensive Energy Management offerings and Union's corresponding RunSmart and Strategic Energy Management offerings.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #5

INTERROGATORY

Ref: Exhibit B, Tab 1, Schedule 3, p3 of 8

Preamble:

> *"Sector" refers to the market categories (Residential, Multi-Residential, Commercial) 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.*

Please describe how custom projects apply to the non-industrial facilities in the Commercial Sector.

RESPONSE

In developing the Technical Reference Manual ("TRM"), the Technical Evaluation Committee ("TEC") agreed that a glossary of terms would be a useful addition. The TRM consultant was directed to develop this glossary in the context of this project. The definition above is included in this TRM glossary. With regard to custom projects, in addition to relevant prescriptive measures, both Utilities have program offerings for the Industrial and Commercial markets (including non-industrial facilities) that are intended to support the particular needs of the customer and *"provide tailored services and varying financial incentives based on overall natural gas savings realized by the customer".*[1]

[1] EB-2015-0029/EB-2015-0049, Decision and Order, Section 5.2.6, p. 19.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #6

INTERROGATORY

Ref: Exhibit B, Tab 1, Schedule 3, p4 of 8

Preamble:

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

Dictionary.com defines technology as:

"1. the branch of knowledge that deals with the creation and use of technical means and their interrelation with life, society, and the environment, drawing upon such subjects as industrial arts, engineering, applied science, and pure science.
2. the application of this knowledge for practical ends.
3. the terminology of an art, science, etc.; technical nomenclature.
4. a scientific or industrial process, invention, method, or the like.
5. the sum of the ways in which social groups provide themselves with the material objects of their civilization."

Why does the TRM use such a narrow definition of technology, thereby limiting the potential measures that could be used in DSM?

RESPONSE

The description of "Technology" referenced above is not provided as part of the Glossary of Terms, and not meant to offer a comprehensive definition. Rather, the description was provided in the Technical Reference Manual ("TRM") Front Section and serves to briefly explain the type of information that should be included in the 'technology' field in the Version History Header Table at the beginning of each substantiation document.

Below is the Version History Header Table template applied in each substantiation document and as an example the same template completed for the Adaptive Thermostats substantiation document:

Witnesses: D. Bullock
L. Kulperger

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

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

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #7

INTERROGATORY

Ref: Exhibit B, Tab 1, Schedule 2, pp1-15

(a) What is the forecast volume of targeted savings in each year of the six-year conservation term that will be determined by the application of the estimated measure savings contained in the application, together with measure savings estimates that have already been approved and are in use? What percentage of forecast annual savings do they represent?

(b) What was the comparable actual volume of 2015 and 2016 savings that were estimated using the measures, and what percentage of total achieved savings did they constitute?

(c) Did the utilities conduct sample measurements to determine the accuracy of the engineering estimates for the 2015 and 2016 savings (i.e. to see how they compared with actual savings for the buildings in which the measures were installed)? If not, why not? If yes, please describe the sample size and how the measurements were carried out, and the actual results achieved compared to the forecast results.

(d) Do the utilities plan to conduct similar sample studies in the remaining four years of the program to verify the validity of the demand savings forecast methodology, described in the TRM? If so, please describe the sample size, the measures that will be sampled, and how the measurements will be carried out. If not, why not?

RESPONSE

a) In the Utilities' respective 2015 Demand Side Management ("DSM") Draft Annual Reports, forecasted volumes of targeted savings were presented in Section 3, Table 3.6. The Utilities have used this information to inform the response.

Witnesses: D. Bullock
L. Kulperger

Union:

Annual natural gas savings targets (m3) [1]

Scorecard	2015	2016	2017	2018	2019	2020
Resource Acquisition	816,561,818	1,214,104,360	1,496,939,054[3]	1,700,748,492[3]	1,715,289,268[3,4]	1,749,595,053[3,4]
Low-Income	43,600,000	56,642,187	64,186,528[3]	71,499,683[3]	76,151,889[3,4]	83,580,811[3,4]
Large Volume	1,236,097,404	1,058,588,072[2]	996,825,303[3]	1,005,036,313[3]	1,040,552,894[3,4]	1,034,420,933[3,4]

1 – Values are cumulative gas savings at the target (100%) band for programs launched in indicated year.

2 – Draft.

3 – Target is formulaic based on performance in previous year(s). Draft value presented here assumes Union achieves 100% of its cumulative gas savings target in previous year(s) and spends 100% of its budget.

4- Target setting methodology for 2019 and 2020 assumes same approach as outlined in Decision for 2016-2018 scorecards.

Note: Targets presented do not depend on the measure savings estimates provided in this Application.

Over the past two years, prescriptive measures have contributed an average of 19% towards Union's Resource Acquisition Scorecard and 22% towards Union's Low-Income Scorecard.

For illustrative purposes, the average prescriptive contribution percentages have been applied to the estimated 100% cumulative gas savings targets from Table 3.6.

Scorecard	2015	2016	2017	2018	2019	2020
Resource Acquisition	157,160,858	233,674,510	2,881,107,360	3,273,372,409	330,135,854	336,738,571
Low-Income	9,787,793	12,715,642	144,092,761	160,510,111	17,095,388	18,763,111

Enbridge:

2017 to 2020 targets are formulaic based on performance in previous year(s). Draft values presented below assume Enbridge achieves 100% of its cumulative gas savings target in previous year(s) and spends 100% of its total budget.

Over the past 4 years, on average, prescriptive measures have historically contributed approximately 15% to Enbridge's Resource Acquisition Scorecard and 8% towards Enbridge's Low-Income Scorecard.

Witnesses: D. Bullock
L. Kulperger

Annual natural gas savings targets (m^3)[1]

Scorecard	2015	2016	2017	2018	2019	2020
Resource Acquisition	1,011,901,200[2]	983,790,685[2]	1,154,031,305[3]	1,286,622,037[3]	1,278,720,893[3,4]	1,330,726,132[3,4]
Low-Income	92,800,000[2]	96,690,000[2]	103,428,996[3]	110,312,532[3]	116,621,767[3,4]	118,966,883[3,4]

[1] For illustrative purposes, values are cumulative cubic meters savings at 100% target achievement. Total program budgets were utilized in the calculation of the following year's targets.
[2] OEB *Decision and Orders* (EB-2015-0049)
[3] Target is formulaic based on performance in previous year. Values assume Enbridge achieves 100% of its cumulative gas savings target and spends 100% of its total budget in previous year.
[4] Target setting methodology for 2019 and 2020 assumes same approach as outlined in Decision for 2016-2018 scorecards.

For illustrative purposes, the average prescriptive contribution percentages noted above have been applied to the estimated 100% cumulative gas savings targets from Table 3.6 above.

Scorecard	2015	2016	2017	2018	2019	2020
Resource Acquisition	151,785,180	147,568,603	173,104,696	192,993,306	191,808,134	199,608,920
Low-Income	7,424,000	7,735,200	8,274,320	8,825,003	9,146,805	9,517,351

b) Consistent with Section 9.5 of the Board's EB-2015-0029/EB-2015-0049 Decision and Order, updated Technical Reference Manual ("TRM") assumptions in this filing will be applied prospectively and were not used in determining 2015 and 2016 scorecard achievement, except in the case of new measures added to the TRM or TRM measures filed and approved in the joint input assumptions filing, EB-2014-0354, filed March 27, 2015.

   In general, prescriptive measures represented 14% of Union's total achieved savings in 2015 and 13% in 2016, pre-audit. For Enbridge, prescriptive measures represent 16% of achieved savings in 2015 and approximately 22% in 2016, pre-audit.

c) No, the Utilities did not conduct sample measurements to determine the accuracy of the engineering estimates for 2015 and 2016 savings.

   As outlined in the Filing Guidelines to the DSM Framework for Natural Gas Distributors (2015 to 2020), (EB-2014-0134), Section 7.1, and further detailed in the August 21, 2015 letter from the Board in the 2015 to 2020 DSM Evaluation Process of Program Results (EB-2015-0245), the new DSM evaluation governance involves

Witnesses: D. Bullock
L. Kulperger

a third party Evaluation Contractor ("EC") retained by the Board. The EC will carry out the evaluation and audit processes of all DSM programs.

In executing these duties, the EC has drafted an Evaluation, Measurement & Verification ("EM&V") Plan for the natural gas utilities' DSM programs, with input from the Evaluation Advisory Committee ("EAC").

The EM&V Plan has made a number of recommendations on activities to be undertaken in verifying assumptions used for energy savings. The prioritization, timing and method of this work are the responsibility of the EC.

d) Please see the response to part c) above. The EM&V Plans are for the period of 2016 to 2018.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #8

INTERROGATORY

1. Ref: Exhibit B, Tab 1, Schedule 6

(a) To what extent are the measures that are the contained in this application updated measures for which prescribed calculation of savings have already been made, and if so, how do they update those calculations, as opposed to calculations for new measures for which savings calculations are being made for the first time? Please be specific in your answer, in other words, address each of the measures listed and for which savings calculation formulae are already being provided, in your answer.

(b) How do the savings calculation formulae for the residential measures compare to the calculation prescribed for the Ontario MOEEC Total Home Retrofit Program?

(c) Preamble - EB-2014-0134 Guidelines, p25:

> *"Where feasible and economically practical, the preference to determine LRAM and shareholder incentive amounts should be to use measured actual results, instead of input assumptions. For example, it may be feasible and economically practical to measure the natural gas savings of weatherization programs based on the results of the pre- and post-energy audits conducted by certified energy auditors on a custom basis, as opposed to input assumptions associated with the individual measures installed."*

Please provide copies of any studies (in particular, more recent studies) undertaken by either the utilities, third parties contracted by the utilities, auditors, the Board staff, the TEC, or any other player in the DSM measure creation/approval process which, since the use of prescriptive or quasi-prescriptive savings determination began, that assess the accuracy of the engineering forecast equations, by measuring the before and after gas consumption of the structure, or facility. Please identify which of those studies were done of Ontario installations and structures.

Witnesses: D. Bullock
L. Kulperger

RESPONSE

a) Other than Adaptive Thermostats, all prescriptive measures updated in the Technical Reference Manual ("TRM") are measures for which prescribed calculation of savings had already been developed and outlined in pre-existing substantiation documents.

   Consideration of input assumptions, calculations and baselines for both new and existing measures were assessed per a Technical Evaluation Committee ("TEC") endorsed TRM work plan. Energy and Resource Solutions Inc. ("ERS") was directed to review, validate / update existing measure assumptions, enhance the content of existing substantiation documents and develop assumptions for new measures based on industry best practice and best available information.

b) The Utilities interpret this to refer to a residential retrofit program funded by Ministry of the Environment and Climate Change through the Green Investment Fund. The program in question calculates energy savings using energy consumption modelling software. Based on energy audits, this software compares the energy consumption previous to and following energy efficiency upgrades. In contrast, the residential prescriptive Demand Side Management ("DSM") measures apply a deemed value for energy savings determined with standardized assumptions and algorithms.

c) The Utilities include programs that rely on pre and post energy audits in their respective DSM portfolios, specifically, the weatherization programs. Inclusion of TRM prescriptive and quasi-prescriptive measures allows the Utilities to address key priorities and guiding principles of the Board. These priorities include: increasing customer participation; pursuing long-term energy savings; and minimizing lost opportunities. This is done while balancing program cost-effectiveness and Board guidelines for rate impacts.

   "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." (Exhibit B, Tab 1, Schedule 3, p.18). However, all savings claimed by the Utilities are subject to verification and audit.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #9

INTERROGATORY

Ref: Exhibit B, Tab 1, Schedule 3, p4

Are the programs sufficiently flexible to allow the utilities to advance the installation of a new, higher efficiency piece of equipment before the natural replacement date of equipment, in cases where it would pass the TRM plus test. If not, why not? How would installment at that time affect the cost benefit analysis of the measure?

RESPONSE

Early replacement installation of higher efficiency equipment was considered by the Technical Reference Manual ("TRM") consultant along with the Technical Evaluation Committee ("TEC") and TRM subcommittee. In the context of the measures included in the TRM and the associated gas savings claimed, the calculations do not incorporate a dual baseline approach to calculating savings used in early replacement scenarios.

For the purposes of TRC-Plus cost-effectiveness screening in an early replacement scenario, unlike a natural replacement situation, savings would be determined over two time periods, applying a dual baseline approach. Costs would also be determined differently from natural replacement scenarios. In natural replacement, incremental cost is the difference between the cost of the new efficient equipment minus cost of the code/standard equipment. In advancement scenarios, the calculation recognizes that while the customer purchased efficient equipment with the assistance of the program, the customer would have purchased code/standard equipment at some time in the future (at the end of the remaining useful life of the existing equipment, in the absence of the program).

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #10

INTERROGATORY

Ref: Exhibit B, Tab 1, Schedule 3

The evidence states that the purpose of the TRM is not to determine free ridership or spillover effects. Who determines the free ridership ratios and spillover effects, when in the process are they determined, and what evidence are they based on? Please provide examples.

RESPONSE

The determination of currently filed free rider rates was informed by third party research, market penetration studies, prior evaluation processes or discussion and endorsement by the Technical Evaluation Committee ("TEC") or previously, the Evaluation & Audit Committee. Free ridership values have been filed with the Board for approval in prior annual Input Assumptions filings and/or DSM Plans.

As outlined in the current DSM Framework and further in the Board's letter of August 21, 2015, regarding the 2015-2020 Demand Side Management Evaluation Process of Program Results (EB-2015-0245), the Board is responsible for coordinating and overseeing the evaluation and audit process, including selecting a third party Evaluation Contractor who will carry out the evaluation and audit processes of all Demand Side Management ("DSM") programs. As such, with guidance from the Evaluation Advisory Committee, the Evaluation Contractor will be responsible for undertaking studies which may include investigating free ridership rates and spillover effects as part of its multi-year impact assessments and targeted evaluations of selected natural gas DSM programs.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #11

INTERROGATORY

Ref: December 21, 2016 EGD/Union Letter to Board

(a) Please provide a copy of the prioritized list of measures provided to Energy and Resource Solutions Inc.

RESPONSE

Please see SEC Interrogatory response #6 found at Exhibit I.EGDI.SEC.6.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #12

INTERROGATORY

Ref: General

Does Energy and Resource Solution Inc. have Canadian (Ontario) offices, or are they an American firm? If an American firm, why was an Ontario or Canadian firm not contracted to do the work? Please explain fully.

RESPONSE

Energy and Resource Solutions Inc. ("ERS") is headquartered in Massachusetts, US, with offices in Mississauga, Ontario.

Following development and issuance of a Request for Proposal ("RFP") by the Technical Evaluation Committee ("TEC"), a comprehensive selection process was conducted by the TEC, emphasizing transparency and consensus-based decision-making.

The TEC-led selection process involved a number of stages, including:

1. Development of a Technical Reference Manual ("TRM") RFP;
2. Public issuance of the RFP on relevant industry websites (American Council for an Energy-Efficient Economy, International Energy Program Evaluation Conference);
3. Preliminary review of proposals and shortlisting of candidates;
4. Development of a customized scoring rubric;
5. Interviews with shortlisted proponents; and
6. Deliberation and final consensus-based selection.

Selection of the successful TRM proponent is the result of the evaluation of each project proposal by TEC members against the following set of criteria:

- Proposed TRM concept and likelihood that the concept will meet the requirements as described;
- Proposed methodology for completing the design and development of the TRM and likelihood of meeting requirements within the allotted schedule;

Witnesses: D. Bullock
L. Kulperger

- Proposed approach for collaborating and communicating with the TEC to enhance the overall approach to the project (i.e. TRM update and maintenance process);
- Ability to understand the Ontario market and appropriately apply TRM measure assumptions in that context;
- Demonstrated experience with natural gas technologies related to space and water heating in all sectors and to industrial process heating;
- Previous experience in developing TRMs and examples of completed TRMs; and,
- Reasonableness of cost proposal including allocation of dollars per task and team member

BOMA INTERROGATORY #13

INTERROGATORY

Ref: Exhibit B, Schedule 6, p126

What is the source for the transfer co-efficient of the warehouse roof?

RESPONSE

The sources for the transfer co-efficient of the warehouse roof are relevant codes and engineering judgment, as noted in Exhibit B, Tab 1, Schedule 6, p. 125. Footnote 2, on p. 125, further expands that no survey data on Ontario warehouse roof U-values was available for consideration and the current (IEC-2012) code minimum U-value for new construction is 0.032.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #14

INTERROGATORY

Ref: Ibid

Page 125 – Why would London weather be used when the vast majority of the warehouses would be located in the Greater Toronto Area (GTA), which has warmer temperatures and less snow than London? What would the impact on savings be if GTA weather were used?

RESPONSE

To create a set of standardized assumptions for application throughout the Technical Reference Manual ("TRM") (Exhibit B, Tab 1, Schedule 4, Appendix A), Energy and Resource Solutions Inc. ("ERS") reviewed available research on the 10 most populous cities in Ontario to identify a climate zone that was representative of the Utilities' franchise areas. Based on a weighted average of Heating Degree Day calculations from multiple sources, London was found to be the most appropriate and representative location.

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #15

INTERROGATORY

Ref: Pages 133, 143

Preamble:

> *"The evidence does not provide a Baseline Technology for the Heat and Energy Recovery Ventilation measures on the grounds that the Ontario Building Code does not require them."*

(a) Have the utilities examined current construction practices to determine whether builders/owners are including these systems in their buildings? If not, why not? If they are using the systems, should they not be the baseline?

(b) With no baseline, how do you compute the savings?

(c) The evidence states (p154) that the recovery efficiency varies with the outside temperatures. What outside winter temperature conditions are being assumed for the two utilities, London, GTA, or a third measure?

RESPONSE

a) Please see SEC Interrogatory response #15 c) found at Exhibit I.EGDI.SEC.15, c).

b) As stipulated in the substantiation document (Exhibit B, Tab 1, Schedule 6, p.133 and 143), the savings are based on buildings with heating systems that do not recover heat through the ventilation process, thereby enabling heat loss. The savings are established using a number of input variables outlined within the documents, including the indoor temperature of the space and the exterior temperature of the building.

c) Energy and Resource Solutions Inc. (“ERS”) has used London, Ontario as a representative temperature input for the Ontario Technical Reference Manual (“TRM”).

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #16

INTERROGATORY

Ref: Page 189

Please explain fully what is meant by "in order to achieve an efficiency level that falls within the OB CSB-12 required compliance path".

RESPONSE

The page referenced relates to the baseline technology for the Residential High Efficiency Gas Storage Water Heater substantiation document for New Construction. The Ontario Building Code (“OBC”) Supplementary Standard SB-12 requires new residential buildings achieve a certain level of efficiency overall, and outlines how that efficiency can be achieved through a number of methods.[1] The Technical Reference Manual (“TRM”) consultant (Energy and Resource Solutions Inc.) recommended a 0.67 Energy Factor for the base case.

[1] http://www.mah.gov.on.ca/Asset15947.aspx?method=1, p.13

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #17

INTERROGATORY

Ref: General

In establishing the baseline technology for each new measure, were studies or surveys done to establish the technology in use, or was a particular technology deemed to be in general use? Please discuss.

RESPONSE

Energy and Resource Solutions Inc. ("ERS") substantiated each key assumption with relevant research, studies and efficiency program evaluations from third-party sources and data specific or representative of Ontario. At Exhibit B, Tab 1, Schedule 3, p.8, the Technical Reference Manual ("TRM") states, *"In general, the baselines included in the TRM are intended to reflect average practices and conditions in Ontario."*

Witnesses: D. Bullock
L. Kulperger

BOMA INTERROGATORY #18

INTERROGATORY

Ref: Exhibit B, Tab 1, Schedule 5, p6; Measure and Savings Persistence

(a) Measure Life is defined as:

> *"The length of time that a measure is expected to provide its estimated annual savings. Measure Life is a function of equipment life and measure persistence (not savings persistence)."*

BOMA is not sure of how savings persistence is being determined, if at all, in the TRM. Please describe how the TRM deals with savings persistence (by calculation, assumption, etc.). If TRM does not deal with savings persistence, when and how is savings persistence determined and factored into the benefit cost ratio for the measure, and for measuring its contributions to savings over the period to 2020 and beyond, in subsequent conservation initiative periods? Please explain fully.

(b) The Board Framework and Guidelines (see, for example, EB-2014-0134 Guidelines, p6) emphasize the need for utilities to give priority to measures that will result in long-term (persistent) savings. What studies have the utilities, verifiers, auditors, or the Board done to determine the persistence of savings generated by programs that utilize one or more of the measures contained in the application?

(c) If Measure Life is a function of equipment life and measure persistence, and Measure Life is equivalent to Expected Useful Life, please explain how factors, such as "early retirement" or "reasons measures might be removed or discontinued" are reflected in Measure Life. Please provide a sample of the calculation.

RESPONSE

a) In consultation with the Technical Evaluation Committee (“TEC”) and Technical Reference Manual (“TRM”) subcommittee, a third-party consultant (Energy and Resource Solutions Inc. (“ERS”)) was mandated to recommend a Measure Life for each measure. Per Exhibit B, Tab 1, Schedule 3, p.8 of the current TEC-endorsed

Witnesses: D. Bullock
L. Kulperger

application, ERS indicates “measure lives serve to represent the Ontario market and include measure persistence unless otherwise noted.”

Regarding the inclusion of persistence in cost-benefit calculations and its contribution to future conservations periods, per the Board’s letter of August 21, 2015, an Evaluation Contractor (“EC”) will be responsible for undertaking various studies which may include “examining the level of persisting natural gas savings from various programs and conducting other evaluation studies as required.” As outlined in the Board’s letter, any such efforts would include input and advice from the Evaluation Advisory Committee (“EAC”).

b) Please refer to the response provided in a). The Utilities are not aware of any recent persistence studies conducted by verifiers, auditors or the Board.

c) Please refer to the response provided in a). The proposed definition reflects a generally accepted understanding of “Measure Life”, as outlined in leading industry publications. For example, the definition of “Measure Life” developed through the National Research Labs’ Uniform Methods Project (2013) includes equipment life and measure persistence, as well as “early retirement or failure of the installed equipment, and any other reason the measure would be removed or discontinued.”

As an industry expert in the development of TRMs, ERS was commissioned by the TEC with the objective of providing best available and substantiated information.

Witnesses: D. Bullock
L. Kulperger

ENERGY PROBE INTERROGATORY #1

INTERROGATORY

Ref: TRM

a) Please indicate in some detail whether the mandate of the TRC requires that the TRM is a Consensus Document and/or whether/how dissents are addressed, either at a measure level, or an overall level.

b) Please indicate which Residential Measures are/are not the result of a Consensus of the TRC

c) Please explain in detail how Union and EGD expect the Board to address any non-consensus matters?

RESPONSE

a) The Technical Reference Manual ("TRM") was a deliverable of the Technical Evaluation Committee ("TEC") as outlined in the Joint Terms of Reference on Stakeholder Engagement for Demand Side Management ("DSM") Activities by Union and Enbridge ("ToR") dated November 4, 2011. At p. 11, the ToR states:

> The TEC will produce an annual Update to the TRM for the two Utilities to file with the Board as per the Guidelines. This submission may be on a consensus or non-consensus basis. [1]

As such, the TRM does not require consensus; it was however, filed with full agreement from the TEC.

A subcommittee of TEC members was established to oversee the TRM work. The TRM-subcommittee worked collaboratively and iteratively with Energy and Resource Solutions Inc. ("ERS") in managing the development of the TRM substantiation documents and the associated TRM supporting documents. The completed documents were brought forward to the full TEC, who were given the opportunity to review and provide feedback at both a measure and an overall level. Beginning in the fall of 2015 and throughout 2016, during the time of the transition of responsibilities of work from the TEC, Board Staff also attended a number of TRM

[1] EB-2011-0237, Settlement Agreement, Attachment A, p.11

Witnesses: D. Bullock
L. Kulperger

sub-committee meetings, as well as TEC meetings which included reviews and discussion regarding the TRM. Members of the TEC, including the TRM sub-committee, approved filing the TRM with the Board.

b) All of the members of the TEC and TRM sub-committee endorsed filing the TRM. Mr. Shepherd (School Energy Coalition) expressed concerns over some specific inputs in the following Residential Measures: Adaptive Thermostat, Low-Flow Showerhead, and Heat Reflector Panel.

c) The utilities' expectations of the Board would align with what is stipulated in the ToR; the Board will determine how to address any non-consensus matters at its discretion. For the purpose of this Application, the TEC ToR established at page 13 that it was the role of the Board

> *where a consensus on the Update to Input Assumptions or the conduct of evaluation work is not achieved, to resolve any such dispute by way of Board Decision at the Board's discretion.*[2]

Going forward, Union and Enbridge will adhere to the evaluation process outlined in Section 7.1 of the Board's Guidelines (EB-2014-0134) and further detailed in the August 21, 2015 Board letter (EB-2015-0245). Part of the newly outlined DSM evaluation governance involves a third party Evaluation Contractor retained by the Board to undertake DSM program evaluations and annual audits of program results. The Evaluation Contractor will also review and propose updates related to data within the TRM on an annual basis.

[2] EB-2011-0327, Settlement Agreement, Attachment A, p. 13.

Witnesses: D. Bullock
L. Kulperger

ENERGY PROBE INTERROGATORY #2

INTERROGATORY

Refs: Exhibit B, Tab 1, Tab 2;

Exhibit B, Page 8: Appendix A, Page 3 - Common Assumptions;
Exhibit B, Tab 1, Schedule 6, Page 6

Preamble:

Where assumptions are shared between multiple technologies, they have been gathered in a Common Assumptions table (Appendix A). 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.
Energy Probe would like to understand the sensitivity and effect of environmental variations in the Common Assumption for Heating Degree Days (HDD) and Cooling Degree Days (CDD) on the estimated savings for the listed Residential Measures in each of the two Union (North/South) and three Enbridge (Niagara, Central and Eastern) Zones, leaving other assumptions as per the TRM.

Building Envelope
Attic Insulation Retrofit
Basement Insulation Retrofit
Draft Proofing Kit Retrofit
Heat Reflector Panels Retrofit
Heating and Cooling
95% High Efficiency Furnace Retrofit
Adaptive Thermostat Direct Install Retrofit

Please Provide in Excel and PDF format:

a) A Table/Tab with the approved Heating and Cooling Degree days for each of the 5 Zones listed in the Preamble.

b) For the Residential Measures listed below, please provide a Table/Tab summarizing the Common Assumptions.

Witnesses: D. Bullock
L. Kulperger

c) For the listed Measures please provide a Table/Tab with the savings estimates using Common Assumptions.

d) For the listed Measures provide the savings for each of the 5 HDD and comparable CDD Zones in the Union/Enbridge Zones. Compare to the results using Common assumptions (London).

e) For each of the Measures apply a weighting to the savings from the installed measures based on the last 3 years DSM programs.

f) Prepare a Summary of the Weighted Difference in savings for each measure.

g) Please provide the claimed savings for each measure using Common Assumptions and the savings using Zone-Based Heating and Cooling DD assumptions.

h) Please provide statistical analysis of the variation/difference in heating/cooling Degree days on savings claimed for each measure in the last three years by Union and Enbridge.

RESPONSE

a) Union's approved 2016 weather normal heating degree days ("HDD") have been calculated based on the Board approved methodology. For Union South, it is 3,780 and for Union North it is 4,930[1]. Union does not have cooling degree day ("CDD") data.

   Enbridge's 2016 weather normal heating degree days have been calculated based on the Board approved methodology in accordance with the Board's EB-2012-0459 Decision with Reasons dated July 17, 2014 as follows: For Enbridge Niagara it is 3,408; Enbridge Central it is 3,617; and Enbridge Eastern it is 4,323[2]. Enbridge does not have CDD data.

b) Attic Insulation Retrofit, Basement Insulation Retrofit, and Draft Proofing Kit Retrofit have not been updated as part of the Technical Evaluation Committee ("TEC") Technical Reference Manual ("TRM") Project and do not form part of this Application. The input assumptions for these measures shown on the Updated

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[1] EB-2016-0245, 2017 Rates–Updated Interrogatory Responses, Exhibit B.Staff.9 p. 2.
[2] As filed at EB-2015-0114, Exhibit C2, Tab 1, Schedule 2.

Summary Table of Measure Assumptions (Exhibit B, Tab 1, Schedule 2) have not been updated or changed from the Board-approved values.

Of the remaining listed Residential Measures included in the TRM, only the High Efficiency Furnace for New Construction / Time of Natural Replacement (there is not a Retrofit measure) relies on a Common Assumption. Specifically, the London climate zone was used in computing the Equivalent Full-Load Hour ("EFLH") value required in the savings algorithm.

c) The savings estimate using the Common Assumptions for the High Efficiency Furnace New Construction / Time of Natural Replacement can be found in the substantiation document (Exhibit B, Tab 1, Schedule 6, p. 98).

$$NG\ savings\ factor = \frac{675\ hours}{35.738\frac{kBtu}{m^3}} \times \left(\frac{95\%}{90\%} - 1\right) = \frac{1.05\ m^3}{\frac{kBtu}{hr}}$$

d) HDD's and CDD's are not direct inputs into the substantiation documents for the listed measures. As noted above, calculating the annual gas savings factor for the High Efficiency Condensing Furnace uses an assumption for the EFLH, derived by Caneta Research Inc. This research provided estimated EFLH values for three cities: London, North Bay, and Toronto. The utilities have used this data for further analysis since EFLH values were derived through energy modeling, which assessed the heating and cooling characteristics of various house archetypes and furnace sizes

e) As outlined above HDD and CDD are not direct inputs for the listed measures; however the High Efficiency Condensing Furnace uses an EFLH assumption by city.

Union: In 2016, Union launched the Low Income Furnace End-of-Life offering and installed 24 residential high efficiency condensing furnaces. All of these units were installed in Union South.

Enbridge: In the previous three years, Enbridge did not include the High Efficiency Condensing Furnace measure in its prescriptive offerings.

f) See response to part (e).

g) Union: The total claimed cumulative natural gas m^3 savings for Union's Low Income Furnace End-of-Life installs is 29,106 m^3 (pre-audit). All of these units are installed in Union South. For illustrative purposes, if using the North Bay EFLH value rather

Witnesses: D. Bullock
L. Kulperger

than the Common Assumptions, this would result in an increase to savings of approximately 32%.

Enbridge: See response to part e)

h) Union: Since Union only has results in the Low Income Furnace End-of-Life offering for one measure, there is no comparative data to use for statistical analysis.

Enbridge: See response to part e)

Witnesses: D. Bullock
L. Kulperger

ENERGY PROBE INTERROGATORY #3

INTERROGATORY

Ref: Exhibit B, Page 8, Appendix A, Page 3, Common Assumptions Table

Preamble:

Energy Probe would like to understand the sensitivity and effect of changed Common Assumptions of environmental temperatures for mains water input supply for the Water Heating DSM Measures listed below.

Water Heating
Tankless Water Heater Condensing EF 0.91 Replacement
High Efficiency Gas Storage Water Heaters EF 0.8 New

Please provide in Excel and PDF formats

-A Table/Tab with the Common Assumption(s).

-The Algorithm calculation(s) for the Measures.

-Estimates for the average mean water supply temperatures for Union North and Union South and for Enbridge Niagara, Central and Eastern Areas.

-Profile/statistics of units installed under Union and Enbridge Programs for last three years.

-Weighted Savings with Common Assumptions.

-Weighted Savings for revised input assumptions.

-Statistical analysis of differences between Common and Zone/Area input assumptions.

RESPONSE

a) Common Assumptions used for these Residential Measures can be found in Table 4 in the substantiation documents.

Witnesses: D. Bullock
L. Kulperger

For Residential Condensing Tankless Gas Water Heater, refer to Exhibit B, Tab 1, Schedule 6, p.109. For Residential High Efficiency Gas Storage Water Heater refer to Exhibit B, Tab 1, Schedule 6, p.191.

b) The algorithm used to calculate the gross annual natural gas m^3 savings is shown in detail in the substantiation documents. For Residential Condensing Tankless Gas Water Heater, refer to Exhibit B, Tab 1, Schedule 6, pp. 108 to109. For Residential High Efficiency Gas Storage Water Heater, refer to Exhibit B, Tab 1, Schedule 6, p.190 to191.

c) The average mean water supply temperature assumptions are based on the average of findings in two studies as noted in the Common Assumptions Table , Exhibit B, Tab 1, Schedule 4, p.2. Inlet water temperature was not elevated as a priority for the development of the Technical Reference Manual ("TRM"). The Utilities do not have substantiated estimates for areas other than the 9.39 degree value included in the Common Assumptions Table, Exhibit B, Tab 1, Schedule 4 p.2.

d) Neither Union nor Enbridge have included Residential Condensing Tankless Gas Water Heater or Residential High Efficiency Gas Storage Water Heater in any offerings in the past three years.

e) through g) Neither Union nor Enbridge have installs for these measures and, consequently, can provide no such analysis.

Witnesses: D. Bullock
L. Kulperger

IGUA INTERROGATORY #1

INTERROGATORY

Reference: Ex. B, Tab 1, Sch. 3, p. 1 of 8 and Ex. B, Tab 1, Sch. 2, p. 1-10 of 15.

Preamble: The TRM Front Section states that the purpose of 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. The Updated Summary Table of Measure Assumptions includes a column titled "free rider (%)", with a value provided for each measure.

Questions:

(a) Please reconcile the statement made in the TRM front section with the inclusion of a free rider percentage for each measure in the Updated Summary Table of Measure Assumptions.

(b) Explain how the values listed in the free rider column in the Updated Summary Table of Measure Assumptions were derived, and the source of the information for the free rider rates listed on p. 10 of 15.

RESPONSE

a) Please see SEC Interrogatory response #3 found at Exhibit I.EGDI.SEC.3 a).

b) Union:

Free rider rates for commercial/industrial custom programs, presented under "Other Free Rider Rates" on p.10 of Exhibit B, Tab 1, Schedule 2, has been derived and provided by the Custom Projects Attribution study performed by Summit Blue Consulting in 2008. Summit Blue calculated the free ridership rate for five segments and recommended Union use the aggregate portfolio-level value of 54%.

Union's Low-Income free rider rate in the Other Free Rider Rates tables remains unchanged and was last included in the New and Updated DSM Measures Joint Submission (EB-2014-0354), which was filed March 27, 2015 and subsequently approved in a Board Decision dated July 23, 2015.

Witnesses: D. Bullock
L. Kulperger

Union notes an error in the 15% free rider rate listed for Residential-Home Reno Rebate. This value was filed and approved in the New and Updated DSM Measures Joint Submission (EB-2013-0430). Union updated this value to 5% as part of its 2015-2020 DSM Plan (EB-2015-0029), approved by the Board in their Decision and Order dated January 20, 2016.

Enbridge:

The Summit Blue study noted above, recommended the following free rider rates for Enbridge:

Custom Projects:

a. Agriculture: 40%
b. Commercial: 12%
c. Industrial: 50%
d. Multifamily: 20%
e. New Construction: 26%

The 15% free rider rate value for Home Energy Conservation was endorsed by the Technical Evaluation Committee (“TEC”) on February 13, 2014 and approved by the Board in EB-2013-0430.

Enbridge’s 0% Low Income free rider rate for Part 9 and Part 3 buildings was derived during the 2013-2014 update to the 2012-2014 Demand Side Management (“DSM”) Plan in EB-2012-0394.

Witnesses: D. Bullock
L. Kulperger

IGUA INTERROGATORY #2

INTERROGATORY

Reference: Ex. B, Tab 1, Sch. 1, p. 1 of 8.

Preamble: Footnote 3 states that the TRM does not include certain inputs to be used in the calculation of cost-effectiveness for projects undertaken and funded by the utility efficiency programs, one of which inputs is net-to-gross ratios. There was to have been a study conducted on the topic of net-to-gross ratios.

Question:

(a) Please advise of the status of the study of net-to-gross ratios.

RESPONSE

a) There is no net-to-gross study currently planned for measures included in the Technical Reference Manual ("TRM"). As discussed at Exhibit I.EGDI.IGUA.1, the Evaluation Contractor, with Evaluation Advisory Committee ("EAC") advice and input, will determine evaluation activities and priorities.

   A Custom Commercial and Industrial Net-to-Gross Study is underway and it will update the current net-to-gross rates used to estimate the impact of Custom Commercial and Industrial projects. This study has been transitioned to the OEB. As stated in the March 4, 2016 letter from the Board on the Transition of Technical Evaluation Committee ("TEC") Activities to the OEB (EB-2015-0245):

   > *Net-to-Gross Study*
   >
   > *Following input from the TEC, this study will be transitioned to OEB. The utilities will continue to manage contractual obligations and payments associated with this project. OEB Staff will assume oversight of the study and will confirm the completion of major milestones for the utilities to process payments of consultant's invoices (p.3).*

Witnesses: D. Bullock
L. Kulperger

OSEA INTERROGATORY #1

INTERROGATORY

Reference: Exhibit B, Tab 1, Schedule 2, Annual Resource Savings

Please provide a column summarizing the cap and trade implications for each measure, including but not limited to the carbon dioxide equivalent of the natural gas savings and associated minimum cost of compliance assuming the auction floor price (monetary savings that can be achieved through implementation of measure). Please provide calculations and assumptions.

RESPONSE

Union:
The customer related carbon dioxide emission conversion factor is 0.001875 tonnes CO_2e/m^3 as filed in Union's 2017 Cap-and-Trade Compliance Plan (EB-2016-0296) at Exhibit 2, Schedule 1, Updated 2017-01-18.

The Calculation of 2017 Estimated Ontario Minimum Auction Price, filed in Union's 2017 Cap-and-Trade Compliance Plan at Exhibit 2, Schedule 2, p.2 is $17.70.

Enbridge:
The customer related carbon dioxide emission conversion factor is 0.001875 tonnes CO_2e/m^3 as filed in Enbridge's 2017 Cap and Trade Compliance Plan (EB-2016-0300) at Exhibit B, Tab 3, Schedule 1, p.5, Table 5, Updated 2017-02-23.

The calculation of the 2017 forecasted Ontario Auction Reserve Price, filed in Enbridge's 2017 Cap and Trade Compliance Plan (EB-2016-0300) at Exhibit B, Tab 4, Schedule , p.7, Table 3 is $17.70.

Witnesses: F. Oliver-Glasford
L. Kulperger

OSEA INTERROGATORY #2

INTERROGATORY

Reference: Exhibit B, Tab 1, Schedule 2, Page 13 of 15

Preamble: Union states "Useful Life estimates are most dependent on the application and quality of maintenance. Any equipment life that was reported higher than 20 years was reduced to 20 years to conform to Union Gas's 20 year limit"

Please explain why Union is reducing the Useful Life estimates to 20 years for equipment with reported higher life estimates. If the direction of the OEB was to use common assumptions, why are the useful lives of the two utilities different?

RESPONSE

Please refer to BOMA Interrogatory response #1 found at Exhibit I.EGDI.BOMA.1.

Further, Union elected to implement a 20 year cap on Commercial/Industrial Custom Effective Useful Life to be conservative. Union's EUL Guide notes "*where site specific information or a relevant prescriptive EUL is available to support an alternate EUL value for a specific custom project, Union Gas will use the alternative value for that custom project*."

Witnesses: D. Bullock
L. Kulperger

OSEA INTERROGATORY #3

INTERROGATORY

Reference: Exhibit B, Tab 1, Schedule 3, Page 8 of 8

Preamble: Where assumptions are shared between multiple technologies, they have been gathered in a Common Assumptions table (Appendix A). 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.

Please explain how local conditions are factored into actual results.

RESPONSE

Measures contained in the Technical Reference Manual ("TRM") are prescriptive or quasi-prescriptive in nature. Energy savings calculations for these measures are based on underlying input assumptions to substantiate the savings claimed. A table of Common Assumption values was determined by Energy and Resource Solutions Inc. ("ERS"), the firm commissioned by the Technical Evaluation Committee ("TEC") to support the development of a TRM common to both Utilities for application province wide. The application of common assumptions in the TRM savings calculations provides a consistent and transparent approach. Local conditions are not specifically factored into results.

Witnesses: D. Bullock
L. Kulperger

OSEA INTERROGATORY #4

INTERROGATORY

Reference: Exhibit B, Tab 1, Schedule 6, Page 6 of 271, Table 2, column B.

Preamble: % Furnace Type from 2008 Residential Survey

The footnote for this table cites the TNS, Residential Market Survey 2013 as the source for the furnace type population distribution data. Please advise what year(s) the data in the table applies.

RESPONSE

The data applies to the 2013 year and correctly references the 2013 Survey. It should be noted that the column heading should more accurately state "% Furnace Type from 2013 Residential Survey"

Witnesses: D. Bullock
L. Kulperger

OSEA INTERROGATORY #5

INTERROGATORY

Reference: Exhibit B, Tab 1, Schedule 6, Page 72 of 271

Please file the report: Nexant, "Questar Gas, DSM Market Characterization Report," August 2006 and indicate if the utilities intend to update this study.

RESPONSE

The Nexant study was commissioned by Questar Gas. The study is available at: http://www.swenergy.org/Data/Sites/1/media/documents/news/news/file/Questar_DSM_Market_Characterization_Report.pdf.

The value referenced in the study was included in the TRM by the third-party consultant (Energy and Resources Solutions Inc.) to support an input assumption contained in the substantiation document. The Utilities cannot speak to the contents of the report.

Regarding future updates to input assumptions, please refer to the response to SEC Interrogatory #3 found at Exhibit I.EGDI.SEC.3.

Witnesses: D. Bullock
L. Kulperger

OSEA INTERROGATORY #6

INTERROGATORY

Reference: Exhibit B, Tab 1, Schedule 6, Page 105 of 271

How many showerheads have each of the utilities distributed since demand side programs were initiated in the natural gas sector?

RESPONSE

Union Gas

Showerheads distributed since 2007 as part of Union's Demand Side Management ("DSM") programs are shown below. As of 2016, only Low Income programs continue to have showerheads included in the offering.

	Residential Programs	Low Income Programs	Commercial Programs
2007	67,919	7,338	40,499
2008	96,690	7,888	22,927
2009	83,054	20,061	44,736
2010	72,000	14,384	28,609
2011	87,214	28,692	28,661
2012	62,641	9,529	9,639
2013	43,078	2,607	1,124
2014	45,967	41	0
2015	19,753	15	0
2016	0	15	0

Enbridge

Showerheads distributed since 2007 as part of Enbridge's DSM offerings are summarized below.

Witnesses: D. Bullock
L. Kulperger

	Residential	Low Income	Multi Res
2007	70,912	4,109	26,678
2008	120,115	2,838	22,312
2009	95,393	1,726	15,147
2010	102,075	972	18,528
2011	105,371	864	25,727
2012	86,991	12,210	8,472
2013	-	3,448	15,777
2014	-	3,137	17,410
2015	-	3,435	15,554
2016	-	660	5,785

Witnesses: D. Bullock
L. Kulperger

OSEA INTERROGATORY #7

INTERROGATORY

Reference: Exhibit B, Tab 1, Schedule 6, Page 134 of 271

Preamble: Commercial – Heat Recovery Ventilation – New Construction/Retrofit. The joint submission states that the HRV measure is not eligible in areas where ERV is required by building code.

Given that the Building Code is provincial, how is this decision rule applied?

RESPONSE

In this case, "area" does not refer to geographical location but rather an area within a building. For example, eligibility is restricted where "Special Requirements for Heating, Ventilation, and Air Conditioning ("HVAC") Systems in Health Care Facilities." are required. (see "Uses and Exclusions" sub-heading, Exhibit B, Tab 1, Schedule 6, p. 140).

Witnesses: D. Bullock
L. Kulperger

OSEA INTERROGATORY #8

INTERROGATORY

Reference: Exhibit B, Tab 1, Schedule 6, Page 139 of 271

Preamble: The data in “Hours of Weekly Operations” tables appear to be solely from the Nexant report: "Evaluation of Natural Gas DSM Measures: ERVs & HRVs," March 12 2010. While the 24/7 operations make sense for hospitals, multi-residential, etc. the 54 hours of operation per year estimate for schools seems low given the recent expansion of the use of schools for day care, community engagement and other uses.

Please file the Nexant report and indicate if the utilities intend to update the study.

RESPONSE

Please see SEC Interrogatory response #15 c) found at Exhibit I.EGDI.SEC.15 c) for discussion of inputs used in measure substantiation documents and SEC Interrogatory response #3 c) found at Exhibit I.EGDI.SEC.3 c) regarding updates to input assumptions.

As requested, the Nexant Evaluation of Natural Gas DSM Measures: ERVs & HRVs Report has been attached to this Exhibit.

Witnesses: D. Bullock
L. Kulperger

Final Report:

Evaluation of Natural Gas DSM Measures: Energy Recovery Ventilators & Heat Recovery Ventilators

Submitted to:

Union Gas Limited
DSM, Research & Evaluation Department

March 12, 2010

Submitted by:

Nexant

Table of Contents

Nomenclature

°F	Degrees Fahrenheit
A	Amps
ACEEE	American Council for an Energy-Efficiency Economy
AFUE	Annual Fuel Utilization Efficiency
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AHRI	Air-Conditioning, Heating and Refrigeration Institute
Btu	British thermal units
CEE	Consortium for Energy Efficiency
CFM	Cubic Feet per Minute
CPUC	California Public Utility Council
DOE	Department of Energy
DSM	Demand Side Management
EPA	U.S. Environmental Protection Agency
ERV	Energy Recovery Ventilator
EUL	Equipment Useful Life
hr	hour
HVAC	Heating, Ventilation and Air-Conditioning
HVI	Home Ventilation Institute
HRV	Heat Recovery Ventilator
kBtu	1 thousand Btu
lba	pound air
lbw	pound water
m^3	cubic meters
MBH	1 thousand Btu per Hour
psia	pounds per square inch (pressure)
RTU	Rooftop Unit
SEER	Seasonal Energy Efficiency Ratio
TRC	Total Resource Cost
wk	week
yr	Years

Section 1 Executive Summary

Union Gas Ltd. retained Nexant, Inc (Nexant), to complete an evaluation study and report the findings of the inputs and assumptions used by Union Gas in the quasi-prescriptive ERV and HRV tool. The primary objective of the evaluation is to develop a Final Report of our conclusions summarizing key findings, providing updated input assumptions and addressing the possible need for unique inputs for new versus existing commercial buildings.

To accomplish the study objectives, Nexant has focused on and completed the following Tasks:

1. Conducted a Project Kick-Off Meeting on December 18, 2009.
2. Generated and delivered a project Work Plan on December 23, 2009.
3. Performed a due diligence review of the existing input assumptions used in Union's quasi-prescriptive tool for HRV and ERV measures (operational parameters, HVAC system type, design and application, equipment specifications, etc.).
4. Conducted a thorough review of secondary literature of HRV / ERV energy saving measures.
5. Investigated New versus Existing HRV/ERV applications.
6. Executed an independent engineering review of new vs. existing building HRV / ERV applications including focus on input assumptions, HVAC design implications, energy saving calculation methods and control strategies to ensure that accurate and relevant numbers will be provided as updated assumptions for use in the quasi-prescriptive tool.
7. Provided the Interim Findings Report and conducted a review meeting to determine if additional investigation is required. As directed by Union Gas, Nexant carried out additional investigation into heating equipment efficiency and the number of hours of operation per week in each market segment.
8. Generated a Final Report of our conclusions summarizing key findings, providing updated input assumptions and addressing the possible need for unique inputs for new versus existing commercial buildings.

Nexant's next steps are the following:

9. Conduct any review conference calls or discussions that may include review of technical analysis and findings from the Final Report.

Nexant's evaluation study of the inputs and assumptions used by Union Gas in the quasi-prescriptive ERV and HRV tool have resulted in several findings and recommendations detailed in the body of the report.

1.1 SUMMARY OF SPECIFIC ANSWERS TO QUESTIONS

Union Gas presented several specific questions from the *Navigant* Audit Report and two (2) Intervenors that this report is to address. Below is a summary of Nexant's responses to specific questions.

1.1.1 AUDIT REPORT – OPERATION HOURS

Question:

> *"The ERV / HRV tabs include assumptions on hours of operation that seem very high for average conditions. They also include degree-day factors that are potentially misapplied to buildings such as schools and offices that are not occupied at night."*

Nexant Response:

The existing tool used weather information from the London area, with original values of 4,800 and 5,800 hours in the heating season for new building construction and existing buildings, respectively. Nexant reviewed Canadian weather files as part of the tool analysis. The results showed that for the London area, the hours in the heating season are 4,846 for new building construction, and 6,306 for existing buildings. This analysis shows that the existing assumptions for hours in the heating season are a conservative estimate and do not overstate savings.

Buildings that are not occupied throughout the entire day are already factored into the existing tool via the user input *1 – Market Segment,* which changes the *Number of Hours of Operation per Week*. Section 5.1.3 describes the calculation, which indicates the existing tool does adjust the operation hours and gas savings for different market segments.

The calculations are not specific to buildings that are unoccupied at night. Depending on the actual building schedule and scheduled hours of HRV/ERV operation, the average temperature within the heating season may change since daytime temperatures are generally higher than nighttime temperatures. Accounting for such variances would require a much more complex tool utilizing hourly weather data and additional information from the applicant regarding HRV/ERV scheduling. Such a calculation is commonplace for custom measures, but it is not typically applicable to prescriptive measure programs.

1.1.2 INTERVENOR – OPERATION HOURS

Question:

> *"Navigant's estimates of savings for new buildings are slightly lower than for existing buildings. Intuitively that makes sense, because one would expect newer buildings to have more efficient heating systems. However, the inputs Navigant presents for computing savings are the same for both building types. While Navigant notes that "New buildings and existing buildings mainly differ in the enthalpy (BTU/LBa) that is used to calculate the Specific Supply Air Conditions Volume in formula (B)," it is not clear why the specific energy content of the supply air would be different for the two situations."*

Nexant Response:

After the review of the existing tool, Nexant found that the inputs for computing savings are different for new construction buildings and existing buildings (Table 1-1). The assumptions changed are the *Number of Hours in Heating Season* and the *Average Outside Air Temperature* based on the assumption that the building balance temperature is lower for a new building.

Table 1-1: Difference in key variables between new building construction and existing buildings

Symbol	Variable Name	Units	New Building Construction - Existing Value	Existing Building - Existing Value
2	Program		New Building Construction	Existing Building
E	Average Outside Air Temperature	°F	31.5	35.5
H	No. of Hours in Heating Season	hrs	4,800	5,800
N	Enthalpy of Inlet Supply Air	Btu/lba	10.38	11.86
O	Enthalpy of Outlet Supply Air	Btu/lba	16.89	17.69
S	Average Hourly Heat Recovery	MBH	27	24
U	Average Annual Gas Reduction	m^3	4,547	4,903

New construction buildings and existing buildings do have different supply air enthalpy (Symbol *O*) in the tool, but the difference is calculated based on the assumptions for the *Number of Hours in Heating Season* and the *Average Outside Air Temperature*. Since new construction buildings are assumed to only require heating below 50°F outdoor temperature, compared to 60°F for existing buildings, new construction buildings therefore have a lower average outside air temperature during the heating season hours (Table 1-1). Consequently, the enthalpy of outside air is lower, and the resulting enthalpy of the outlet supply air is lower since the heat recovery equipment is operating with a greater difference between indoor and outdoor enthalpy. The existing tool calculates the change in supply air enthalpy between the two different building types correctly.

The difference in the tool between the new construction buildings and existing buildings is only slightly impacted by the change in specific volume of supply air in the calculation. A larger contributor to the different values for the two different buildings is the difference between the *Enthalpy of Outlet Supply Air* and the *Enthalpy of Inlet Supply air*. When reviewing the calculations, it can be seen that the average hourly heat recovery actually increases for new building construction (Table 1-1) when the impact of the outside air conditions are factored into the equation.

The main difference between new and existing buildings that causes the difference in gas savings is the *Number of Hours in Heating Season.* The *Average Hourly Heat Recovery* actually decreases by 11% for existing buildings, while the *Average Annual Gas Reduction* increases by 8%. Overall, the calculations in the existing tool are correct for the two building types.

1.1.3 INTERVENOR – INCREMENTAL COST

Question:

> *"The incremental cost assumption is presumably based on the 2000 Jacques Whitford study suggestion that the incremental cost for a 1000 CFM unit is $2500. Given inflation, wouldn't the incremental cost be higher in 2009?"*

Nexant Response:

Given the cost data gathered by Nexant, shown in Appendix B, the cost of ERVs and HRVs has been found to increase by an average of 6.1% annually. Nexant recommends that the current incremental cost is increased by 6.1% to account for the annual increase in cost. In addition, Union Gas should update the incremental cost annually to account for inflation. Nexant's recommendations regarding the *Incremental Cost* is thoroughly discussed in Section 6.1, as is our recommendation that an additional tool input be added to accommodate actual equipment cost to further improve the accuracy of the tool and/or further studies to more accurately consider total costs.

1.2 RECOMMENDATIONS FOR TOOL IMPROVEMENTS

As discussed in Section 6 a few slight modifications to the existing Union Gas tool would greatly improve the accuracy of the final values for the *Average Annual Gas Savings* and *TRC* calculations. These recommendations are shown in Table 1-2 and Table 1-3 for HRVs and ERVs, respectively.

Table 1-2: Summary of HRV tool recommendations

Symbol	Variable Name	Units	Exisitng Value	Recommended Value
4	Equipment Useful Life	yrs	20	14
5	Incremental Cost	$/CFM	3.40	3.61
E	Average Outside Air Temperature (Exist. Bldgs)	**°F**	35.5	Adjust based on district
E	Average Outside Air Temperature (New Bldgs)	**°F**	31.5	Adjust based on district
F	Average Outdoor Relative Humidity	%	70	75
H	No. of Hours in Heating Season (Exist. Bldgs)	hrs	5800	Adjust based on district
H	No. of Hours in Heating Season (New Bldgs)	hrs	4800	Adjust based on district
I1	Demand Controlled Ventilation?	-	no	Remove from analysis
I2	No. of Hours of Operation per Week	hrs/wk	60-168	54-168
J	Make and Model of Heat Recovery Equipment		Eng A HRW-2100	Remove from analysis
K	Effectiveness of Heat Recovery Equipment	%	70	61

Table 1-3: Summary of ERV tool recommendations

Symbol	Variable Name	Units	Exisitng Value	Recommended Value
4	Equipment Useful Life	yrs	20	14
5	Incremental Cost	$/CFM	3.00	3.18
E	Average Outside Air Temperature (Exist. Bldgs)	°F	35.5	Adjust based on district
E	Average Outside Air Temperature (New Bldgs)	°F	31.5	Adjust based on district
F	Average Outdoor Relative Humidity	%	70	75
H	No. of Hours in Heating Season (Exist. Bldgs)	hrs	5800	Adjust based on district
H	No. of Hours in Heating Season (New Bldgs)	hrs	4800	Adjust based on district
I1	Demand Controlled Ventilation?	-	no	Remove from analysis
I2	No. of Hours of Operation per Week	hrs/wk	60-168	54-168
J	Make and Model of Heat Recovery Equipment		Eng A HRW-2100	Remove from analysis
K	Effectiveness of Heat Recovery Equipment	%	60	67

Nexant also recommends that the tool be modified to add additional user inputs and existing variable values be updated accordingly as discussed below.

1.2.1 ADDITIONAL TOOL INPUTS

By adding three (3) additional user inputs to the tool Union Gas can expect to increase the accuracy of the tool calculations, see Table 1-4. While one (1) of the new user inputs will utilize data already acquired by Union Gas on the customer application, the other inputs will require further information from the customer. Nexant believes that the customer will have this data readily available. In the case that the applicant does not supply the additional information, Union Gas could default to Nexant's recommendations discussed in Section 6.

Table 1-4: Recommended additional tool inputs

Symbol	User Input Name	Create New Tool Input?	Collect New Data from Customer?
6	Union Gas District	Yes	No
7	Weekly Operating Hours	Yes	Yes
8	Thermal Effectiveness	Yes	Yes

1.2.2 MODIFICATONS TO EXISTING TOOL VARIABLE VALUES

Several modifications will need to be made to the existing values for variables to properly account for Nexant's recommended values and the additional user inputs described in Section 1.2.1. Table 1-5 below is a summary the recommended values.

Table 1-5: Summary of recommended value modifications

Symbol	Variable Name	Recommendation
5	Incremental Cost	Allow user input of Equipment Cost
E	Average Outside Air Temperature	Make dependent on user input *6*
H	No. of Hours in Heating Season	Make dependent on user input *6*
I2	No. of Hours of Operation per Week	Make dependent on user input *7*
K	Effectiveness of Heat Recovery Equipment	Make dependent on user input *8*

1.3 BASE CASE RESULTS FROM RECOMMENDATIONS

The assumed base case impacts of all of the recommended changes in input assumptions are shown in Table 1-6. Table 1-6 values are based on a 1,000 CFM HRV/ERV, 168-hours per week of operation, and London, Ontario weather location. The results show that gas savings decrease for HRVs, which is primarily a result of Nexant's recommendation to decrease the effectiveness of the HRV. Gas savings increase for ERVs with the recommended changes. TRC decreases for both HRVs and ERVs, which is primarily a result of Nexant's recommendation to the decrease the EUL.

Table 1-6: Results from changing input assumptions for the London, ON weather location

	Existing Gas Savings (m^3)	Recommended Gas Savings (m^3)	% Increase	Existing TRC	Recommended TRC	% Increase
HRV Tool for New Construction Buildings	4,547	4,182	-8%	13,334	9,410	-29%
HRV Tool for Existing Buildings	4,903	4,618	-6%	14,633	10,748	-27%
ERV Tool for New Construction Buildings	4,888	5,621	15%	14,957	14,235	-5%
ERV Tool for Existing Buildings	5,139	5,965	16%	15,871	15,291	-4%

Base Case: 1,000 CFM HRV/ERV Capacity, 168 hrs per week operation, London, ON weather files

If the London, Ontario location also has the operating hours for the warehouse reduced as recommended, the gas savings and TRC greatly decrease, as shown in Table 1-7. The gas savings and TRC decrease by as much as 67% and 91%, respectively, for the HRV tool for new construction buildings. Other cases do not have as much of a decrease in savings and TRC, but are still significant. It should be noted that these impacts are only for warehouses; other market segments that do not have a recommended decrease in hours would not be impacted.

Table 1-7: Results from changing warehouse input assumptions for the London, ON weather location

	Existing Gas Savings (m3)	Recommended Gas Savings (m3)	% Increase	Existing TRC	Recommended TRC	% Increase
HRV Tool for New Construction Buildings	4,547	1,519	-67%	13,334	1,233	-91%
HRV Tool for Existing Buildings	4,903	1,677	-66%	14,633	1,718	-88%
ERV Tool for New Construction Buildings	4,888	2,041	-58%	14,957	3,244	-78%
ERV Tool for Existing Buildings	5,139	2,166	-58%	15,871	3,628	-77%

Base Case: 1,000 CFM HRV/ERV Capacity, Warehouse market segment, London, ON weather files

To show the impact of including multiple weather file locations on the tool, the same analysis was completed for the North Bay, Ontario weather location (Northeast Union Gas district). The results are shown in Table 1-8. For this location, gas savings increases for ERVs and HRVs for both new construction and existing buildings. The increase is very large for ERVs, with a 52%

increase for both new construction and existing buildings, respectively. TRC increases for ERVs, and remains approximately the same for HRVs. Overall, this shows that the selected weather file location has a significant impact on tool savings and the recommended change to include weather from other locations will greatly improve the accuracy of the tool.

Table 1-8: Results from changing input assumptions for the North Bay, ON weather location

	Existing Gas Savings (m^3)	Recommended Gas Savings (m^3)	% Increase	Existing TRC	Recommended TRC	% Increase
HRV Tool for New Construction Buildings	4,547	5,447	20%	13,334	13,292	0%
HRV Tool for Existing Buildings	4,903	5,840	19%	14,633	14,500	-1%
ERV Tool for New Construction Buildings	4,888	7,441	52%	14,957	19,823	33%
ERV Tool for Existing Buildings	5,139	7,826	52%	15,871	21,005	32%

Base Case: 1,000 CFM HRV/ERV Capacity, 168 hrs per week operation, North Bay, ON weather files (Northeast Union Gas district)

All of the recommended weather file locations are north of London, except for the Windsor, Ontario weather location (Windsor/Chatham Union Gas district). Since this is the only gas district with warmer weather and a shorter heating season than London, Ontario, Nexant also reviewed the impact on the Windsor/Chatham district to the determine the impact of the changes (Table 1-9). For this location gas savings decreases for HRVs, and it stays approximately the same for ERVs. TRC decreases for all ERV and HRV projects.

Table 1-9: Results from changing input assumptions for the Windsor, ON weather location

	Existing Gas Savings (m3)	Recommended Gas Savings (m3)	% Increase	Existing TRC	Recommended TRC	% Increase
HRV Tool for New Construction Buildings	4,547	3,602	-21%	13,334	7,628	-43%
HRV Tool for Existing Buildings	4,903	4,017	-18%	14,633	8,902	-39%
ERV Tool for New Construction Buildings	4,888	4,807	-2%	14,957	11,736	-22%
ERV Tool for Existing Buildings	5,139	5,119	0%	15,871	12,695	-20%

Base Case: 1,000 CFM HRV/ERV Capacity, 168 hrs per week operation, Windsor, ON weather files (Windsor/Chatham Union Gas district)

Complete results for each case are shown in Appendix D.

1.4 RECOMMENDATIONS FOR FURTHER REVIEW

End of Useful Life (EUL) has a significant reduction on the TRC results for these projects and programs. While data exists from a DEER study based on empirical data, more data could be collected in the Province of Ontario where different weather conditions may result in a different EUL than the DEER study. If ERV/HRV quasi-prescriptive programs are highly valued, Nexant recommends a long-term empirical study to regionally evaluate the EUL of ERV/HRV equipment.

Incremental costs also have a significant impact on the TRC results for these projects and programs. The current incremental cost approach may not be the most accurate and may also be outdated. The incremental cost accuracy could be improved by using installed cost data, as noted in the report. Nexant recommends the incremental cost be further evaluated with empirical data collected by the program in the next program year or through surveys of the previous three years of installed projects.

Lastly, while the sensitivity analysis provided may be adequate to consider for general program guidance for Union Gas's DSM program goals and targets; Nexant is available to provide additional base-case sensitivity analysis services upon the request of Union Gas. Specifically, sensitivity analysis may be of value to Union Gas for different market segments and ERV/HRV capacities.

2.1 GENERAL APPROACH

The primary objective of Nexant's evaluation of Energy Recovery Ventilators (ERVs) and Heat Recovery Ventilators (HRVs) for Union Gas Distribution Inc. (Union Gas) was to ensure that accurate, relevant numbers are being used in the quasi-prescriptive tool. The tool determines and reports the energy savings and net benefit impacts resulting from installations of these measures in Union's DSM programs. It calculates the impacts of the measure on a "deemed-calculated basis;" i.e. calculated impacts based on standard assumptions (e.g. average indoor air temperature) and algorithms as well as "application-specific" inputs. (e.g. ERV capacity in CFM). This evaluation objectively assessed the assumptions, algorithms and inputs used to determine commercial ERVs and HRVs potential gas energy savings in three (3) steps: review of the existing Union Gas Tool, review of secondary literature, and engineering analysis of input assumptions and algorithms.

2.2 REVIEW OF EXISTING UNION GAS TOOL

Nexant began the evaluation with a thorough review of the existing Union Gas tool. While it was the inputs and not the tool itself being evaluated, understanding of tool function and the mathematical calculations provided insight into the relative significance of each input or assumed value and the downstream effects of their modification. As a result, Nexant was able to focus the secondary literature reviews and the engineering analysis around tool functionality.

2.3 REVIEW OF SECONDARY LITERATURE

Nexant conducted extensive research for the ERV/HRV evaluation, reviewing primary and secondary data sources in order to evaluate the reasonableness of the existing input assumptions in the quasi-prescriptive tool. Primary sources including weather data, Union provided information, vendor specification sheets, etc. were consulted and data was used to evaluate the existing assumptions and recommend modifications. Also, over 30 secondary sources including deemed savings databases, DSM program summaries, AHSRAE Standards, and published reports were reviewed for insight into operating hours, temperature setpoints, and equipment useful lifetime along with the remaining variables.

2.4 ENGINEERING ANALYSIS OF INPUT ASSUMPTIONS

Nexant compiled the research and examined the information gathered in order to address the primary goals outlined in the scope of work: evaluating the reasonableness of the input assumptions used in Union's quasi-prescriptive tool for HRV and ERV equipment and answering the question regarding new versus existing building applications. Union's current input assumptions were evaluated against a rubric of information gathered from secondary literature, industry standard DSM programs, applicable market segments, and climate data, as well as independent calculations defining a realistic range of natural gas savings resulting from HRV and ERV equipment installations. With this data Nexant evaluated the relative sensitivity of each parameter in the quasi-prescriptive tool to calculate impacts of adjustments to the input assumptions of the tool. In addition to the review of HRV and ERV input assumptions, Nexant evaluated the energy content of supply air in new and existing commercial buildings as requested in the RFP. For this task, Nexant's goal was to ultimately determine if the impact of an HRV / ERV installation differs when installed in a new building versus an existing building.

The tables below demonstrate Nexant's review of the provided Existing Union Gas Tool. Nexant tracked the inputs, variables, algorithms and overall tool function and recorded the existing values. The results are ordered using the reference symbols from the existing Union tool. Table 3-1 and Table 3-2 show the review of the HRV and ERV tools respectively including tool functions and variable interactions observations, which are explained in the comments column.

Table 3-1: HRV quasi-prescriptive tool inputs and variables

Symbol	User Input Name	Units	Value	Comments
1	Market Segment		User Selected	Sets building type. Determines value of variable I2.
2	Program		User Selected	New or Existing. Determines values of variables E and H
3	HRV Capacity	CFM	User Entered	HRV Capacity is specified here.
Symbol	**Variable Name**	**Units**	**Value**	**Comments**
4	Equipment Life	yrs	20	Assumption. Value is constant.
5	Incremental Cost	$/CFM	3.40	Assumption. Value is constant.
A	Supply Air Flow	CFM	HRV Capacity	Set by user input 3.
B	Exhaust Air Flow	CFM	HRV Capacity	Set by user input 3.
C	Average Indoor Air Temperature	°F	70	Assumption. Value is constant.
D	Average Indoor Relative Humidity	%	30	Assumption. Value is constant.
E	Average Outside Air Temperature (Exist. Bldgs)	°F	35.5	Assumption. Value set by user input 2.
E	Average Outside Air Temperature (New Bldgs)	°F	31.5	Assumption. Value set by user input 2.
F	Average Outdoor Relative Humidity	%	70	Assumption. Value is constant.
G	Atmospheric Pressure	psia	14.25	Assumption. Value is constant.
H	No. of Hours in Heating Season (Exist. Bldgs)	hrs	5,800	Assumption. Value set by user input 2.
H	No. of Hours in Heating Season (New Bldgs)	hrs	4,800	Assumption. Value set by user input 2.
I1	Demand Controlled Ventilation?	-	no	This value is always no. Variable no longer used.
I2	No. of Hours of Operation per Week	hrs/wk	60-168	Assumption. Value set by user input 1.
J	Make and Model of Heat Recovery Equipment		EngA HRW-2100	Value cannot be changed. Variable no longer used.
K	Effectiveness of Heat Recovery Equipment	%	70	Assumption. Value is constant.
L	Sensible Heat Recovery Only?		Yes	Value is constant.
M	Enthalpy of INLET Exhaust Air	Btu/lba	Calculated	Calculated. Depends on variables C and D.
M	Humidity Ratio of INLET Exhaust Air	lbw/lba	Calculated	Calculated. Depends on variables C and D.
N	Enthalpy of INLET Supply Air	Btu/lba	Calculated	Calculated. Depends on variables E,F, and G.
N	Humidify Ratio of INLET Supply Air	lbw/lba	Calculated	Calculated. Depends on variables E,F, and G.
O	Enthalpy of OUTLET Supply Air	Btu/lba	Calculated	Calculated. Depends on variables C,E,F,G and K.
O	Humidity Ratio of OUTLET Supply Air	lbw/lba	Calculated	Calculated. Depends on variables E,F, and G.
P	Average Temperature of OUTLET Supply Air	°F	Calculated	Calculated. Depends on variables C,E, and K.
Q	Average Hourly Moisture Addition	lbw/hr	0	Value is constant by HRV definition.
R	Defrost Control Derating Factor	%	5	Assumption. Value is constant.
S	Average Hourly Heat Recovery	MBH	Calculated	Calculated. Depends on variables A,C,E,K,M,N,O and R.
T	Seasonal Efficiency of Gas-Fired Equipment	%	82	Assumption. Value is set by user input 2.
U	Average Annual Gas Reduction	m^3	Calculated	Calculated. Depends on variables H,I2,S, and T.
V	Incremental Natural Gas Rate	$\$/m^3$	0.30	Assumption. Value is constant.
W	Average Annual Gas Savings	$	Calculated	Calculated. Depends on variables U and V.

Table 3-2: ERV quasi-prescriptive tool inputs and variables

Symbol	User Input Name	Units	Value	Comments
1	Market Segment		User Selected	Sets building type. Determines value of variable I2.
2	Program		User Selected	New or Existing. Determines values of variables E and H.
3	ERV Capacity	CFM	User Entered	ERV Capacity is specified here.

Symbol	Variable Name	Units	Value	Comments
4	Equipment Useful Life	yrs	20	Assumption. Value is constant.
5	Incremental Cost	$/CFM	3.00	Assumption. Value is constant.
A	Supply Air Flow	CFM	ERV Capacity	Set by user input 3.
B	Exhaust Air Flow	CFM	ERV Capacity	Set by user input 3.
C	Average Indoor Air Temperature	°F	70	Assumption. Value is constant.
D	Average Indoor Relative Humidity	%	30	Assumption. Value is constant.
E	Average Outside Air Temperature (Exist. Bldgs)	°F	35.5	Assumption. Value set by user input 2.
E	Average Outside Air Temperature (New Bldgs)	°F	31.5	Assumption. Value set by user input 2.
F	Average Outdoor Relative Humidity	%	70	Assumption. Value is constant.
G	Atmospheric Pressure	psia	14.25	Assumption. Value is constant.
H	No. of Hours in Heating Season (Exist. Bldgs)	hrs	5,800	Assumption. Value set by user input 2.
H	No. of Hours in Heating Season (New Bldgs)	hrs	4,800	Assumption. Value set by user input 2.
I1	Demand Controlled Ventilation?	-	no	This value is always no. Variable no longer used.
I2	No. of Hours of Operation per Week	hrs/wk	60-168	Assumption. Value set by user input 1.
J	Make and Model of Heat Recovery Equipment		EngA HRW-2100	Value cannot be changed. Variable no longer used.
K	Effectiveness of Heat Recovery Equipment	%	60	Assumption. Value is constant.
L	Sensible Heat Recovery Only?		No	Value is constant.
M	Enthalpy of INLET Exhaust Air	Btu/lba	Calculated	Calculated. Depends on variables C and D.
M	Humidity Ratio of INLET Exhaust Air	lbw/lba	Calculated	Calculated. Depends on variables C and D.
N	Enthalpy of INLET Supply Air	Btu/lba	Calculated	Calculated. Depends on variables E,F, and G.
N	Humidify Ratio of INLET Supply Air	lbw/lba	Calculated	Calculated. Depends on variables E,F, and G.
O	Enthalpy of OUTLET Supply Air	Btu/lba	Calculated	Calculated. Depends on variables C,E,F,G and K.
O	Humidity Ratio of OUTLET Supply Air	lbw/lba	Calculated	Calculated. Depends on variables E,F, and G.
P	Average Temperature of OUTLET Supply Air	°F	Calculated	Calculated. Depends on variables C,E, and K.
Q	Average Hourly Moisture Addition	lbw/hr	Calculated	Calculated. Depends on variables A,C,E,G,K,L,M,N and O.
R	Defrost Control Derating Factor	%	5	Assumption. Value is constant.
S	Average Hourly Heat Recovery	MBH	Calculated	Calculated. Depends on variables A,C,E,K,M,N,O and R.
T	Seasonal Efficiency of Gas-Fired Equipment	%	82	Assumption. Value is set by user input 2.
U	Average Annual Gas Reduction	m^3	Calculated	Calculated. Depends on variables H,I2,S, and T.
V	Incremental Natural Gas Rate	$\$/m^3$	0.30	Assumption. Value is constant.
W	Average Annual Gas Savings	$	Calculated	Calculated. Depends on variables U and V.

4.1 COMPLETE BILIOGRAPHY

Nexant reviewed a variety of reputable and unbiased sources. The list of all sources consulted follows; sources cited in the report are bolded. Sources are categorized by type: Database, Manufacturer Publications, Software and Automated Calculators, and Published Articles:

Database

#	Source
(1)	***Database for Energy Efficiency Resources.* [Online] 2008.2.05, California Public Utilities Commission, December 16, 2008. [Cited: January 12, 2010.] http://www.deeresources.com.**
(2)	Summit Blue Consulting, LLC. *2008 DEER Measure Cost Documentation Revision 3.* California Public Utilities Commission. 2008.
(3)	***2008 DEER Estimated Useful Life (EUL) Summary.* California Public Utilities Commission . October 2008.**
(4)	**Air-Conditioning, Heating and Refrigeration Institute. Commercial Air-to-Air Energy Recovery Ventilators. [Online] [Cited: January 16, 2010.] www.ahridirectorry.org.**
(5)	***HVI Tested/Certified Heat Recovery Ventilators and Energy Recovery Ventilators.* Home Ventilation Institute.**
(6)	***NYSERDA Gas Deemed Savings Database.* New York State Energy Research and Development Authority.**
(7)	**U.S. Department of Energy. *EnergyPlus Energy Simulation Software: Weather Data CANADA.* [Download from Website] September 30, 2009. [Cited: January 2010.] http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data3.cfm/region=4_north_and_central_america_wmo_region_4/country=3_canada/cname=CANADA.**

Manufacturer Specifications

#	Source
(8)	***Fantech Heat Recovery Ventilator VHR Series.* Fantech. May 22, 2006.**
(9)	***GreenHeck Energy Recovery Model ERV.* GreenHeck. February 2000.**
(10)	***Lennox Engineering Data ERV Bulletin No. 210245 Indoor/Outdoor 500 to 10,000 CFM.* Lennox. April 2009.**
(11)	***Whitepaper Obtaining 100% Outside Air with an Integral ERV, mated to a rooftop unit, as opposed to a rooftop unite with an exhaust fan.* MicroMetl.**

Software and Automated Calculators

#	Source
(12)	**Airx Estimator for Central Plant Systems. [Online] Air Xchange. [Cited: January 29, 2010.] www.airxchange.com/Collateral/Documents/English-US/airx_central_plant.htm.**
(13)	**James J. Hirsch. *eQUEST: the QUick Energy Simulation Tool.* [Software] 2006. Version 3.63 build 6510. www.doe2.com/eQuest/.**
(14)	**SC&A. *Indoor Air Quality Tools for New Schools: ERV Financial Assessment Software Tool Version 1.1 Reference Manual.* [Computer Software] s.l. : U.S. Environmental Protection Agency.**
(15)	U.S. EPA and U.S. DOE. Life Cycle Cost Calculator for Energy Star Qualified Monitors. *Energystar.gov.* [Online] April 2009. [Cited: January 28, 2010.]
(16)	U.S. EPA and U.S. DOE. Life Cycle Cost Calculator for Energy Star Qualified Room Air Conditioners. *Energystar.gov.* [Online] April 2009. [Cited: January 18, 2010.] http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls.

Published Articles

#	Source
(17)	**Itron, Inc., JJ Hirsh & Associates, Synergy Consulting and Quantum, Inc. *2004-2005 Database for Energy Efficiency Reseources (DEER).* Southern California Edison. December 2005.**
(18)	***2007 ASHRAE Handbook: HVAC Applications.* I-P Edition. Atlanta, GA : ASHRAE, 2007.**
(19)	***2008 ASHRAE Handbook: HVAC Systems and Equipment.* I-P Edition. Atlanta, GA : ASHRAE, 2008.**
(20)	***2009 ASHRAE Handbook: Fundamentals.* I-P Edition. Atlanta, GA : ASHRAE, 2009.**
(21)	**Mossman, Melville J. PE, et al, [ed.]. *2005,and 2007-2010 RSMeans Mechanical Cost Data.* 31. Kingston :**
(21)	**Reed Construction Data, Inc. , 2010.**
(22)	**ACEEE. Consumer Guide: Condensed Online Version . *Heating System: Furnaces and Boilers.* [Online] August 2007. [Cited: January 16, 2010.] http://www.aceee.org/consumerguide/heating.htm.**
(23)	***Emerging Technologies Report: Commercial Energy Recovery Ventilation Systems.* Washington, D.C. : ACEEE, March 2009.**
(24)	Dieckmann, John, Roth, Kurt W.,Ph. D., and Brodrick, James, Ph.D. Air to Air Energy Recovery Heat Exchangers. *ASHRAE Journal.* August 2003, pp. 57-58. www.ashrae.org.
(25)	**Summit Blue Consulting, Nexant, Inc., A-TEC Energy Corporation and Britt/Makela Group. *Assessment of Energy and Capacity Savings Potential In Iowa.* The Iowa Utility Association. January 23, 2008.**
(26)	Haeri, Hossein, Ph.D., Seiden, Ken, Ph.D., Perussi, Matei and Quantec, LLC. *Assessment of Technical and Achievable Demand-Side Resource Potentials.* Puget Sound Energy. April 20, 2005.
(27)	**KEMA-XENERGY Inc. *Assessment of the Commercial Building Stock in the Pacific Northwest.* Portland, OR : Northwest Energy Efficiency Alliance, March 8, 2004.**
(28)	**KEMA-XENERGY. *California Statewide Commercial Sector Natural Gas Energy Efficiency Potential Study.* Pacific Gas and Electric. May 14, 2003. Study ID #SW061.**
(29)	Itron, Inc. *CPUC Self Generation Incentive Program Sixth-Year Impact Evaluation.* The Self Generation Incentive Program Working Group, Pacific Gas and Electric. August 20, 2007.
(30)	Itron, Inc. *CPUC Self Generation Incentive program Eight-Year Impact Evaluation.* The Self Generation Incentive Program Working Group, Pacific Gas and Electric. June 2009.
(31)	Mumma, Stanley A., Ph.D. P.E. Designing Dedicated Outdoor Air Systems. *ASHRAE Journal.* May 2001, pp. 28-31. www.ashrae.org.
(32)	Besant, Robert W. *Development of a Methodology to Accurated Design and Predict the Part Load Perfomance of an Energy Recover Ventilator/Energy Recovery Device.* Atlanta, GA : ASHRAE, August 1997.
(33)	**Nexant, Inc. *DSM Market Characterization Report.* Questar Gas. August 2006.**
(34)	Stellar Processes and Ecotope. *Energy Efficiency and Conservation Measure Resource Assessment.* Energy Trust of Oregon, Inc. May 4, 2006.
(35)	***Energy Efficiency in the Provincial Building Code.* Alberta Energy Efficiency Alliance. March 2009.**
(36)	**ASHRAE. *Energy Standard for Buildings Except Low-Rise Residential Buildings.* Atlanta, GA : ASHRAE, Inc., 2004. ASHRAE Standard. 90.1-2004.**
(37)	Kushler, Martin Ph.D., York, Dan Ph.D., Witte, Patti M.A. *Examining the Potential for Energy Efficiency To Help Address the Natural Gas Crisis in the Midwes.* Washington, D.C. : ACEEE, January 2005. Report Number U051.
(38)	**Phillips, E.G., Fisher D.R., Chant, R.E. et al. Freeze-control strategy and air-to-air energy recovery performance. *ASHRAE Journal.* December 1992, Vol. 34, 12, pp. 44-49.**
(39)	Krierder, Jan F. *Handbook of Heating, Ventilation and Air Conditioning.* 1. Boca Raton : CRC Press LLC, December 2000.
(40)	Moss, Steven J., Cubed, M. *Market Segmentation and Energy Efficienct Program Design.* Oakland, CA : CIEE, November 2008.
(41)	**Navigant Consulting Inc. *Measure Assumptions for Demand Side Management (DSM) Planning.* Ontario Energy Board. April 16, 2009.**
(42)	**RLW Analytics. *Measurement and Evaluation Study of the 2003 Southern California Gas Company Non-Residential Financial Incentives Program (NRFIP).* San Diego Gas and Electric Company. April 13, 2005.**
(43)	Grondzik, Walter T., Kwok, Alison G., Stein, Benjamin, Reynolds, John S. *Mechanical and Electrical*

Equipment for Buildings. 11. Hoboken : John Wiley & Sons, Inc., 2010.

(44) Kushler, Martin Ph.D., York, Dan Ph.D., Witte, Patti. *Meeting Essential Needs: The results of a National Search for Exemplary Utility Funded Low-Income Energy Efficiency Programs.* Washington, D.C. : ACEEE, September 2005. Report Number U053.

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(47) **Jacques Whitford Environmental Limited, Agviro Inc., and Engineering Interface Ltd. *Prescriptive Incentives for Selected Natural Gas Technologies.* Enbridge Consumers Gas and Union Gas Ltd. September 2000.**

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(51) SERA, Inc. and Quantec, LLC. *Review of Retention and Persistence Studies for the California Public Utilities Commission (CPUC).* California Public Utilities Commision. October 20, 2004.

(52) Summit Blue Consulting, LLC. With RLW Analytics and Energy Insights. *Self Generation Incentive Program Retention Study.* M&E, Pacific Gas and Electric. December 3, 2007.

(53) Turner, Stephen C. P.E. Using ERV to Improve Sensible Heat Ratio. *ASHRAE Journal.* March 2005, pp. 80-84. www.ashrae.org.

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4.2 SOURCES CONSULTED BY VARIABLE

In order to better represent the secondary literature review, a brief discussion of each tool variable and the relevant sources consulted follows.

4.2.1 USER INPUTS

1 – Market Segment

Several sources were consulted in order to evaluate the breakdown of market segments. The current HRV/ERV tool provides a drop down list of nine (9) options for the user: Multi-Family, Hotel, Restaurant, Retail, Office, School, Health Care, Nursing Home, or Warehouse. This list was compared to market segments used by other utility efficiency programs, common HVAC applications and energy modeling software. The main sources consulted for market segment information were a Connecticut Light and Power (CL&P) program report (56), Efficiency Vermont's technical reference manual (57), database information collected for MidAmerican Energy's Nonresidential Energy Analysis (MEC/NEA) program (58), a market characterization report regarding existing buildings in the Pacific Northwest by KEMA-XENERGY, Inc. (27 pp. 3-21, 3-23, A-22), and a 2005 study for the Database of Energy Efficiency Resources (DEER) (17).

2 – Program

No secondary review was conducted. This is a user input from a drop down list: New Building Construction or Existing Building.

3 – HRV/ERV Capacity

No secondary review was conducted. This is a user input. Value is required on the prescriptive application form (provided by applicant).

4.2.2 VARIABLES

4 – Equipment Useful Life

The *Estimated Useful Life* (EUL) of HRV and ERV equipment is fixed at 20-years in the existing tool. This number was derived from various secondary sources, including the Whitford study (47), Navigant report (41) and Nexant's *DSM Market Characterization Report* (33). Additional measure resource databases, engineering handbooks, reports and retention studies were reviewed and many of them conflicted. Table 4-1 shows the variety of results from the secondary review.

Table 4-1: Estimated equipment useful life (EUL)

Source	EUL (years)
Whitford, (47)	15
Nexant (33 pp. E-3)	20*
Navigant (41 pp. C-183)	20*
2008 DEER (3)	14
NYSERDA (55)	20*
KEMA *California* (28 pp. C.1-1)	20*
RLW Analytics (42 p. 5)	20*
KEMA *Retention* (50 pp. E-2)	14
Response N.E. Gas (49 p. 1)	20
2007 ASHRAE (18 p. 36.3)	15

**Study results based on the same CA EE Program Study*

5 – Incremental Cost

Incremental cost data was gathered primarily from RSMeans cost publications between 2005 and 2007-2010 (21). Additionally, a survey of ERV/HRV costs which included vendor quotes and prices published online was assembled, shown in Appendix B. The Whitford study (47), manufacturer sources: *MicroMetl Whitepaper* (11) and *Airx Estimator* (12), SC&A's *ERV Financial Assessment* (14) and an *Emerging Technology Report: Commercial Energy Recovery Ventilation Systems* (23 p. 2) were also considered for cost information.

A – Supply Air Flow

No secondary review was conducted. This value is equal to user input *3 – HRV/ERV Capacity*.

B – Exhaust Air Flow

No secondary review was conducted. This value is equal to user input *3 – HRV/ERV Capacity*.

C – Average Indoor Air Temperature

The *2007 ASHRAE Handbook: HVAC Applications* provides a recommended temperature range for indoor design conditions in several market segments (18 pp. 2.3, 2.5, 3.2, 5.4, 6.1, 6.5, 7.6). Temperature range recommendations were gathered for all market segments used in the tool.

D – Average Indoor Relative Humidity

The *2007 ASHRAE Handbook: HVAC Applications* provides a recommended humidity range for indoor design conditions in several market segments (18 pp. 2.3, 2.5, 3.2, 5.4, 6.1, 6.5, 7.6). Humidity range recommendations were gathered for all market segments used in the tool.

E – Average Outside Air Temperature

In order to assess the existing average outside air temperature, Canadian Weather for Energy Calculation (CWEC) files were obtained for eleven (11) Ontario locations. The CWEC files represent an approximate average year of hourly weather and provide useful information for engineering approximations of energy use (7).

F – Average Outdoor Relative Humidity

CWEC files were used to evaluate the existing value for the average outdoor relative humidity (7).

G – Atmospheric Pressure

CWEC files were used to evaluate the value used for atmospheric pressure (7).

H – No. of Hours in Heating Season

CWEC files were used to evaluate the value used for the number of hours in heating season (7).

I1 – Demand Controlled Ventilation?

No secondary review was conducted. This field is not active in the existing tool.

I2 – No. of Hours of Operation per Week

The weekly operating hours assumed in the existing tool are based on user input *1 – Market Segment* (41 pp. C-182). Other values for operating hours by market segment were obtained from a Connecticut Light and Power (CL&P) program report (56), Efficiency Vermont's technical reference manual (57), database information collected for MidAmerican Energy's Nonresidential Energy Analysis (MEC/NEA) program (58), a market characterization report regarding existing buildings in the Pacific Northwest by KEMA-XENERGY, Inc. (27 pp. 3-21, 3-23, A-22), and a 2005 study for the Database of Energy Efficiency Resources (DEER) (17).

Table 4-2: Operating hours

Typical Hrs of Operation per week						
Market Segment	Existing Value	CL&P Value†	DEER Value†	KEMA Value	MEC/NEA Value	Eff. VT Value
Multi-Family	168	147	NA	NA	NA	NA
Hotel	168	59	168	164	157	52
Restaurant	108	80	93	93	NA	80
Retail	108	78	87	66	73	59
Office	60	72	50	62	69	66
School	84	42	70	56	62	40
Health Care	168	147	168	NA	123	NA
Nursing Home	168	112	168	NA	168	NA
Warehouse	168	50	55	74	81	46

† *Study values based on facility lighting hours.*

J – Make and Model of Heat Recovery Equipment

No secondary review was conducted. This field is not active in the existing tool.

K – Effectiveness of Heat Recovery Equipment

To evaluate the effectiveness of the heat recovery equipment, Nexant consulted manufacturer specification sheets (8) (9) (10), two (2) equipment certification databases (4) (5) , an ACEEE emerging technology report (23), and the DEER database (1). Effectiveness values ranged from 60 to 90% depending on equipment type, brand and rated airflows.

L – Sensible Heat Recovery Only?

No secondary review was conducted. This is a *Yes/No* field in the tool and by definition an HRV technology recovers only sensible heat.

M – Enthalpy and Humidity Ratio of INLET Exhaust Air

ASHRAE psychrometric relations were used to evaluate the enthalpy and humidity ratio of inlet exhaust air (20).

N – Enthalpy and Humidity Ratio of INLET Supply Air

ASHRAE psychrometric relations were used to evaluate the enthalpy and humidity ratio of inlet supply air (20).

O – Enthalpy and Humidity Ratio of OUTLET Supply Air

ASHRAE air-to-air heat recovery equipment relations were used to evaluate the enthalpy and humidity ratio of outlet supply air (19).

P – Average Temperature of OUTLET Supply Air

ASHRAE air-to-air heat recovery equipment relations were used to evaluate the average temperature of outlet supply air (19).

Q – Average Hourly Moisture Addition

ASHRAE air-to-air heat recovery equipment relations were used to evaluate the average hourly moisture edition (19).

As noted in above, HRV technology recovers only sensible heat. Thus this value should be null for HRV applications.

R – Defrost Control Derating Factor

Several types of information were collected in order to evaluate the defrost control derating factor: weather data for the Union Gas service area (7), a sample of manufacturer literature to determine the outside temperature at which frost becomes an issue in commercially available equipment (9) (10), and studies on the subject. An ASHRAE study, *Freeze-control strategy and air-to-air energy recovery performance* (38), was used in Nexant's evaluation.

S – Average Hourly Heat Recovery

Average Hourly Heat Recovery is calculated from numerous other variables using an energy balance of the supply air flow. The calculation was reviewed to ensure proper engineering methods and unit conversions.

T – Seasonal Efficiency of Gas-Fired Equipment

The efficiency of gas-fired equipment refers to the efficiency of the heat source that the HRV/ERV output is impacting. Nexant reviewed secondary literature detailing the appropriate average value for existing buildings only. Values for existing furnace seasonal efficiencies were taken from the *2008 ASHRAE Handbook: HVAC Systems and Equipment* (19 pp. 32.9, Table 1) and ACEEE (22).

U – Average Annual Gas Reduction

Average Annual Gas Reduction is calculated from numerous other variables and assumptions. The calculation was reviewed to ensure proper engineering methods and unit conversions.

V – Incremental Natural Gas Rate

No secondary review was conducted. Nexant assumes that Union Gas would be best able to determine the appropriate *Incremental Natural Gas Rate* for the tool.

W – Average Annual Gas Savings

Average annual gas reduction is calculated from *Average Annual Gas Reduction* and *Incremental Natural Gas Rate*. The calculation was reviewed to ensure proper engineering methods and unit conversions.

An engineering analysis of the Union Gas Quasi-Prescriptive HRV/ERV Tool was completed to determine the calculation methodology and the relative impact of the numerous input assumptions. This section describes the Union Gas tool and Nexant's sensitivity analysis of input assumptions.

5.1 CALCULATION METHODOLOGY OF UNION GAS QUASI-PRESCRIPTIVE TOOL

The Union Gas tool was analyzed to determine the calculation methodology and equations used to determine gas savings. The review of the existing tool ensured that appropriate calculations are used and to better understand how the assumptions are used within the tool. The tool inputs and outputs, assumptions, and calculations are described in this section.

5.1.1 UNION GAS INPUTS AND OUTPUTS

The Quasi-Prescriptive tool has only three (3) inputs required by users: *1 – Market Segment*, *2 – Program*, and *3 – HRV/ERV Capacity*. All other values shown in the tool are either calculated or a constant. The tool then outputs the analysis results in the form of *Average Annual Gas Savings (m^3)* and *Total Resource Cost* (TRC).

5.1.2 ASSUMPTIONS

Sixteen (16) constants and assumptions are used for the analysis of the project. These are Symbols *A-L, R, T*, and *V*. A description of each of these Symbols is given in Section 3, Table 3-1 and Table 3-2. Specific assumptions related to tool inputs and variables are described in this section.

2 – Market Segment Input Determines *I2 – Operating Hours*

The number of operating hours per week (Symbol *I2*) is determined based on user input *1 – Market Segment* input. A lookup table contains the values of operation hours per week, as shown in Table 5-1. The values shown in this table are the existing values in the tool.

Table 5-1: Market Segment operating hours per week

Market Segment	Existing Hours
Multi-Family	168
Hotel	168
Restaurant	108
Retail	108
Office	60
School	84
Health Care	168
Nursing Home	168
Warehouse	168

2 – Program Input Determines *E – Average Outside Air Temperature* & *H – No. of Hours in Heating Season*

The selected *Program* determines the weather conditions used in the analysis. The overall assumption is that a new construction building has a different balance point than an existing building. The building balance point is defined as the outdoor temperature at which the building interior heat gains equal the heat loss to the outdoors through the building envelope. The balance point is less than the conditioned space temperature due to internal loads, such as people, lights, and equipment, which provide heat to the space. A new building is assumed to be built to higher standards with better insulation, and therefore the building has a lower building balance temperature of 50°F. An older building that is not built to modern standards with poor insulation and infiltration leaks result in a higher balance temperature; for the Union Gas analysis, the balance point for an existing building is assumed to be 60°F.

The weather conditions that the selected Program determines are shown in Table 5-2, which are Symbols *E* and *H*. Since a new building has a lower balance point, there are fewer hours in the heating season (Symbol *H*). Consequently, the average outside air temperature (Symbol *E*) is colder during the heating season for new buildings since an average is taken of lower temperatures.

Table 5-2: Program selection assumptions

Program	E - Average Outside Air Temperature (F°)	H - No. of Hours in Heating Season
New Building Construction	31.5	4800
Existing Building	35.5	5800

3 – HRV/ERV Capacity Input Determines *A – Supply Air Flow & B – Exhaust Air Flow*

HRV/ERV Capacity is used as *Supply Air Flow* and *Exhaust Air Flow*. In this analysis, only packaged HRV/ERV tools are analyzed, and for these units, the supply and exhaust air flow should be equal to each other. This tool is not used for more complex custom installations that may have different supply and exhaust air flows.

L – Sensible Heat Recovery Only?

Symbol *L – Sensible Heat Recovery Only?* has a different value between the HRV/ERV tools due to the type of heat recovery. An HRV only recovers sensible heat, and therefore the value is *Yes* for an HRV analysis. In contrast, an ERV recovers sensible and latent heat energy, and therefore the value for Symbol *L* is always *No* for an ERV.

5.1.3 CALCULATIONS

The enthalpy and humidity ratio of inlet exhaust air (Symbol *M*), inlet supply air (Symbol *N*), and outlet supply air (Symbol *O*) are first determined using a psychrometric analysis of the air conditions and air-to-air energy recovery calculations. The HRV/ERV inlet exhaust air conditions are based on the conditioned space dry bulb temperature, relative humidity, and atmospheric pressure. Similarly, HRV/ERV inlet supply air conditions are based on outside air dry bulb temperature, relative humidity, and atmospheric pressure. The outlet conditions of each air stream are based on a heat recovery analysis of the air flow and the assumed effectiveness of heat recovery equipment.

Psychrometrics relations and the calculations used in this calculator can be found in the *2009 ASHRAE Handbook: Fundamentals* Chapter 1 (20). Equation 8 is used to determine humidity ratio, and Equation 32 is used to determine the enthalpy of the air. These calculations are industry standard methods for calculating moist air properties.

All energy recovery calculations used in this analysis can be found in the *2008 ASHRAE Handbook: HVAC Systems and Equipment* Chapter 25 (19). The outlet supply air conditions are based on Equation 3a and 7a and the assumed effectiveness of the energy recovery device. Notice that the humidity ratio of outlet supply air (Symbol *O*) is the same as the humidity ratio of inlet supply (Symbol *N*) for an HRV since no moisture is transferred between the supply and exhaust streams. Similarly, the supply air humidity ratio always increases (during the heating season) as it passes from the inlet to outlet of an ERV since an ERV recovers moisture in the exhaust stream.

Average Hourly Heat Recovery is calculated from the enthalpy of the inlet and outlet supply air streams, which are Symbol *N* and *O*, respectively. The ERV/HRV flow is multiplied by the difference in enthalpy and appropriate conversion factors to give the average hourly heat recovery in MBH (1,000 Btus per hour). *Defrost Control Derating Factor* is also used in this equation to decrease the theoretical recovered energy by 5%.

Average Annual Gas Reduction is calculated from Symbols *H*, *I2*, *S*, and *T*. *Average Hourly Heat Recovery* is multiplied by the hours in the heating season to determine the total heat recovery, which is then multiplied by the fraction of the operating hours per week (Symbol *I2*) divided by the total hours in a week. In this way, the actual heat recovery is adjusted based on the building market segment (Symbol *1*). The total heat recovery is also divided by the *Seasonal Efficiency of Gas-Fired Equipment* to give the actual gas savings for the reduced energy consumption. Appropriate conversion factors are used to calculate the *Average Annual Gas Savings* in units of cubic meters (m^3) of natural gas.

5.2 SENSITIVITY ANALYSIS

The Secondary Literature Review (Section 4) determined that many of the assumptions could potentially be changed to provide more accurate calculations in the HRV/ERV tool. To determine the relative impact of changes on the *Average Annual Gas Savings* and *TRC* outputs, and to provide good recommendations for tool improvements, a single-factor sensitivity analysis was completed for each of the input assumptions. The methodology and results are presented in this section.

5.2.1 METHODOLOGY

The sensitivity analysis required setting baseline inputs that would be held constant while analyzing the impact of other assumptions. The baseline inputs are shown in Table 5-3 for both HRVs and ERVs. Nearly all of the baseline values in the sensitivity analysis are the existing assumptions used in the Union Gas tool. The Union Gas tool outputs of gas savings and TRC were recorded as the baseline value.

Table 5-3: Baseline assumptions for sensitivity analysis

Parameter	Symbol	HRV Base Value	ERV Base Value	Units
Market Segment	1	Warehouse	Warehouse	-
HRV/ERV Capacity	3	1,000	1,000	CFM
Equipment Useful Life	4	20	20	yrs
Incremental Cost	5	3.40	3.00	$/CFM
Average Indoor Air Temperature	C	70	70	°F
Average Indoor Relative Humidity	D	30	30	%
Average Outside Air Temperature (New Bldg)	E	31.5	31.5	°F
Average Outside Air Temperature (Existing Bldg)	E	35.5	35.5	°F
Average Outdoor Relative Humidity	F	70	70	%
Atmospheric Pressure (psia)	G	14.25	14.25	psia
No. of Hours in Heating Season (New Bldg)	H	4,800	4,800	hrs
No. of Hours in Heating Season (Existing Bldg)	H	5,800	5,800	hrs
No. of Hours of Operation Per Week	I2	168	168	hrs
Effectiveness of Heat Recovery Equipment	K	70	60	%
Defrost Control Derating Factor	R	5	5	%
Seasonal Efficiency of Gas-Fired Equipment	T	82	82	%
Incremental Natural Gas Rate	V	0.30	0.30	$/m^3

There are two (2) baseline assumptions that are of particular note: *HRV/ERV Capacity* (Symbol *3*) and *Market Segment* (Symbol 1). The HRV/ERV capacity was set to 1,000 CFM, however, any value could be used as the baseline and the relative impact of the other variables would remain the same. The *Market Segment* was set to "Warehouse" as a baseline assumption, which sets the *Number of Hours of Operation per Week* (Symbol *I2*) to 168 hours per week. Since most of the program applicable market segment buildings currently have 168 hours per week of operation, this was considered a good baseline as a point of comparison. Since the *Number of Hours of Operation per Week* is effectively a fraction of the savings in the equation, using a lower number of hours per week would still provide the relative impact of the other variables; however, the output results would decrease. Also, by using the Warehouse market segment, the impact of potentially changing the hours of operation per week for this market segment could be evaluated.

For each selected assumption of interest, all other assumptions were held constant and the selected assumption was changed. The new *Average Annual Gas Savings* and *TRC* value were then recorded and compared to the baseline value. This step was repeated for the upper and lower bound of each assumption of interest for four different combinations of baseline assumptions:

1. HRV Tool for Existing Buildings
2. HRV Tool for New Buildings

3. ERV Tool for Existing Buildings

4. ERV Tool for New Buildings

The input assumptions, bounds and resulting impact on both gas savings and *TRC* can be found in Table 5-4 to Table 5-7 for existing buildings. Due to the large amount of information, and somewhat redundant information, only results for existing buildings are shown within the text and the results for existing and new buildings can be found in Appendix A.

Table 5-4: Sensitivity analysis of gas savings results of HRV tool for existing buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	Gas Savings (m^3)	Gas Savings Increase (%)	Parameter Value	Gas Savings (m^3)	Gas Savings Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	4,903	0.0%	14 yrs	4,903	0.0%
Incremental Cost	3.40 $/CFM	3.40 $/CFM	4,903	0.0%	3.61 $/CFM	4,903	0.0%
Average Indoor Air Temperature	70 °F	72 °F	5,174	5.5%	70 °F	4,903	0.0%
Average Indoor Relative Humidity	30 %	35 %	4,903	0.0%	30 %	4,903	0.0%
Average Outside Air Temperature (Existing Bldg)	35.5 °F	30.8 °F	5,604	14.3%	37.1 °F	4,672	4.7%
Average Outdoor Relative Humidity	70 %	78 %	4,904	0.0%	73 %	4,903	0.0%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	5,017	2.3%	14.08 psia	4,845	1.2%
No. of Hours in Heating Season (Existing Bldg)	5800 hrs	7330 hrs	6,197	26.4%	5690 hrs	4,810	1.9%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	4,903	0.0%	61 hrs/wk	1,780	63.7%
Effectiveness of Heat Recovery Equipment	70 %	68 %	4,769	-2.7%	55 %	3,891	20.6%
Defrost Control Derating Factor	5 %	0 %	5,161	5.3%	10 %	4,645	5.3%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	5,155	5.1%	85 %	4,730	3.5%

Base Case: Gas Savings = 4,903 m^3. Savings evaluated for existing buildings based on the Warehouse market segment and a 1,000 CFM HRV.

Table 5-5: Sensitivity analysis of TRC results of HRV tool for existing buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	TRC ($)	TRC Increase (%)	Parameter Value	TRC ($)	TRC Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	$14,633	0.0%	14 yrs	$11,823	19.2%
Incremental Cost	3.40 $/CFM	3.40 $/CFM	$14,633	0.0%	3.61 $/CFM	$14,433	1.4%
Average Indoor Air Temperature	70 °F	72 °F	$15,618	6.7%	70 °F	$14,633	0.0%
Average Indoor Relative Humidity	30 %	35 %	$14,633	0.0%	30 %	$14,633	0.0%
Average Outside Air Temperature (Existing Bldg)	35.5 °F	30.8 °F	$17,187	17.5%	37.1 °F	$13,789	5.8%
Average Outdoor Relative Humidity	70 %	78 %	$14,634	0.0%	73 %	$14,633	0.0%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	$15,046	2.8%	14.08 psia	$14,420	1.5%
No. of Hours in Heating Season (Existing Bldg)	5800 hrs	7330 hrs	$19,345	32.2%	5690 hrs	$14,294	2.3%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	$14,633	0.0%	61 hrs/wk	$3,256	77.7%
Effectiveness of Heat Recovery Equipment	70 %	68 %	$14,145	-3.3%	55 %	$10,946	25.2%
Defrost Control Derating Factor	5 %	0 %	$15,573	6.4%	10 %	$13,693	6.4%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	$15,549	6.3%	85 %	$14,002	4.3%

Base Case: TRC = $14,633. Savings evaluated for existing buildings based on the Warehouse market segment and a 1,000 CFM HRV.

Table 5-6: Sensitivity analysis of gas savings results of ERV tool for existing buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	Gas Savings (m^3)	Gas Savings Increase (%)	Parameter Value	Gas Savings (m^3)	Gas Savings Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	5,139	0.0%	14 yrs	5,139	0.0%
Incremental Cost	3.00 $/CFM	3.00 $/CFM	5,139	0.0%	3.18 $/CFM	5,139	0.0%
Average Indoor Air Temperature	70 °F	72 °F	5,557	8.1%	70 °F	5,139	0.0%
Average Indoor Relative Humidity	30 %	35 %	5,577	8.5%	30 %	5,139	0.0%
Average Outside Air Temperature (Existing Bldg)	35.5 °F	30.8 °F	6,041	17.6%	37.1 °F	4,825	6.1%
Average Outdoor Relative Humidity	70 %	73 %	5,065	-1.4%	78 %	4,943	3.8%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	5,237	1.9%	14.08 psia	5,088	1.0%
No. of Hours in Heating Season (Existing Bldg)	5800 hrs	7330 hrs	6,494	26.4%	5690 hrs	5,041	1.9%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	5,139	0.0%	61 hrs/wk	1,962	61.8%
Effectiveness of Heat Recovery Equipment	60 %	78 %	6,598	28.4%	60 %	5,139	0.0%
Defrost Control Derating Factor	5 %	0 %	5,409	5.3%	10 %	4,868	5.3%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	5,402	5.1%	85 %	4,957	3.5%

Base Case: Gas Savings = 5,139 m^3. Savings evaluated for existing buildings based on the Warehouse market segment and a 1,000 CFM ERV.

Table 5-7: Sensitivity analysis of TRC results of ERV tool for existing buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	TRC ($)	TRC Increase (%)	Parameter Value	TRC ($)	TRC Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	$15,871	0.0%	14 yrs	$12,926	18.6%
Incremental Cost	3.00 $/CFM	3.00 $/CFM	$15,871	0.0%	3.18 $/CFM	$15,700	1.1%
Average Indoor Air Temperature	70 °F	72 °F	$17,393	9.6%	70 °F	$15,871	0.0%
Average Indoor Relative Humidity	30 %	35 %	$17,467	10.1%	30 %	$15,871	0.0%
Average Outside Air Temperature (Existing Bldg)	35.5 °F	30.8 °F	$19,160	20.7%	37.1 °F	$14,727	7.2%
Average Outdoor Relative Humidity	70 %	73 %	$15,604	-1.7%	78 %	$15,158	4.5%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	$16,227	2.2%	14.08 psia	$15,687	1.2%
No. of Hours in Heating Season (Existing Bldg)	5800 hrs	7330 hrs	$20,809	31.1%	5690 hrs	$15,516	2.2%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	$15,871	0.0%	61 hrs/wk	$4,296	72.9%
Effectiveness of Heat Recovery Equipment	60 %	78 %	$21,186	33.5%	60 %	$15,871	0.0%
Defrost Control Derating Factor	5 %	0 %	$16,856	6.2%	10 %	$14,886	6.2%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	$16,831	6.0%	85 %	$15,210	4.2%

Base Case: TRC = $15,871. Savings evaluated for existing buildings based on the Warehouse market segment and a 1,000 CFM ERV.

5.2.2 RESULTS

TRC Sensitivity Analysis Results

The gas savings and *TRC* results of the analysis have been plotted in Figure 5-1 through Figure 5-4 for the HRV and ERV tools for existing buildings, respectively, to show the relative impact of each assumed value. Only existing building results are shown here since the new construction buildings have similar results. Additionally, new construction buildings are shown in Appendix A.

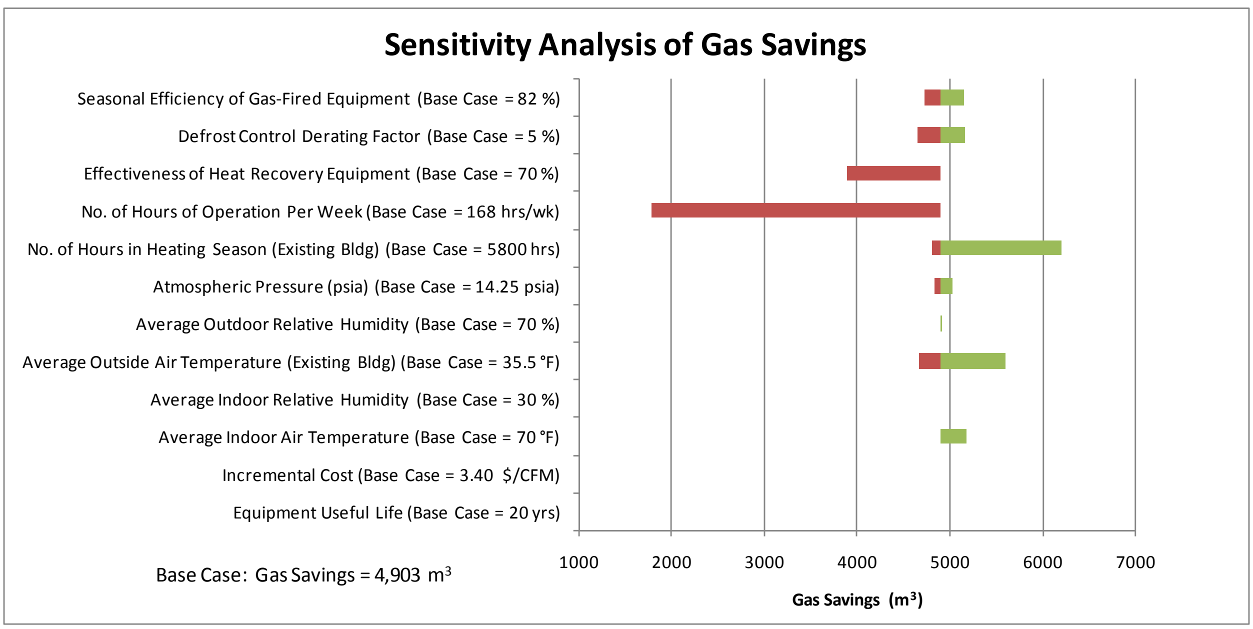

Figure 5-1: Gas Savings sensitivity analysis of HRV tool for existing buildings

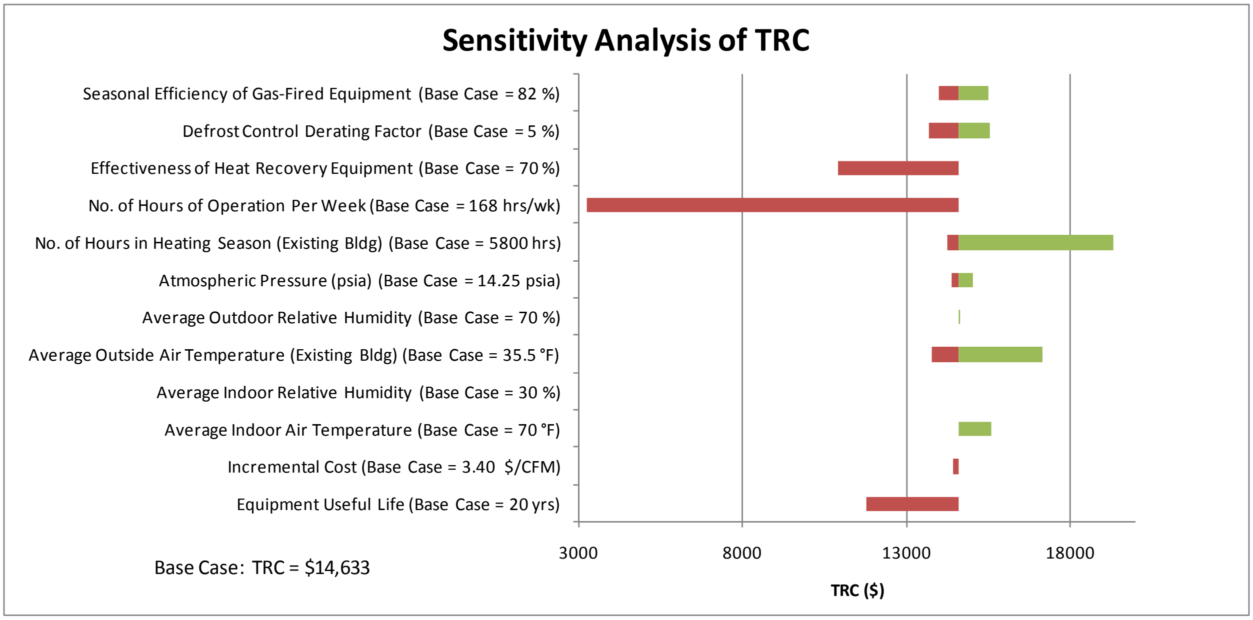

Figure 5-2: TRC sensitivity analysis of HRV tool for existing buildings

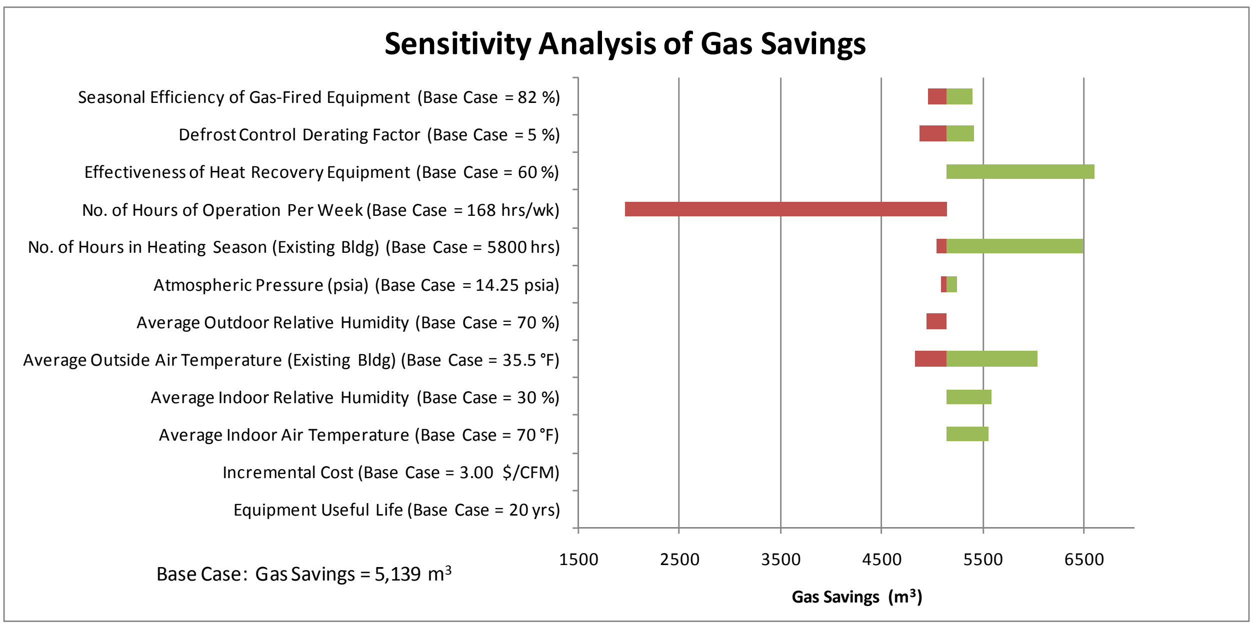

Figure 5-3: Gas Savings sensitivity analysis of ERV tool for existing buildings

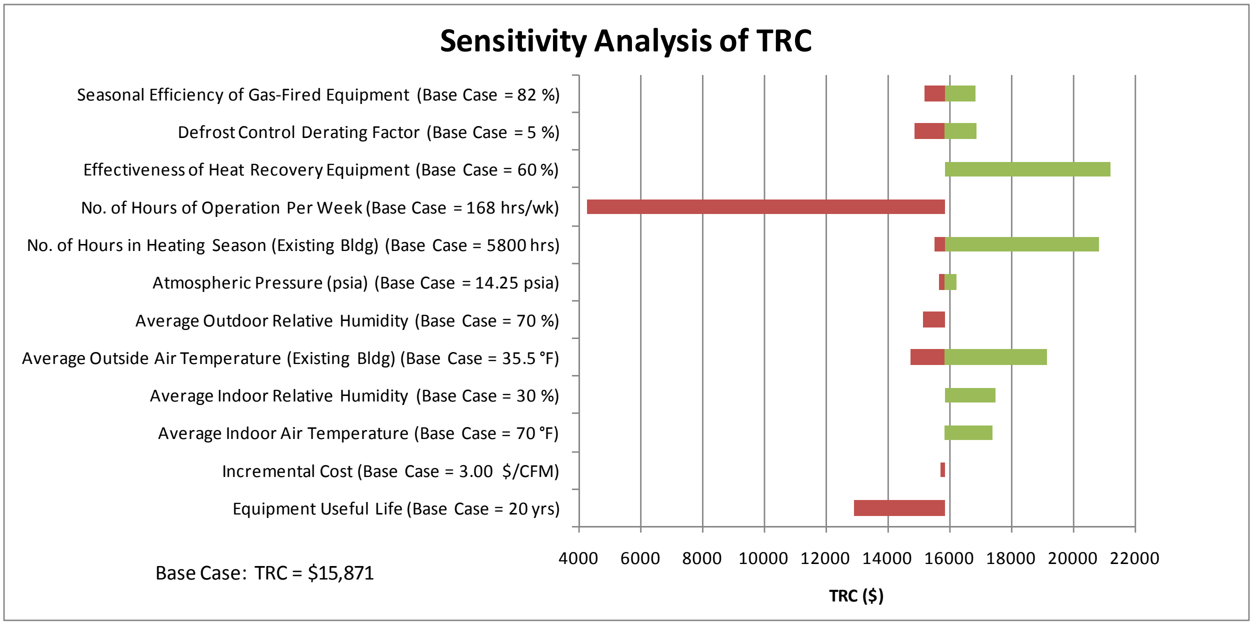

Figure 5-4: TRC sensitivity analysis of ERV tool for existing buildings

The results show several trends between the different baseline assumptions and significant opportunities for improvement for certain assumed values. In addition, the sensitivity analysis also validates that some of the existing assumptions are suitable in the tool.

5.2.3 RELATIVE IMPACTS

W – Average Annual Gas Savings & TRC

In general, both the gas savings and *TRC* results show similar relative impacts for most of the variables. The two variables of interest are *Equipment Useful Life* and *Incremental Cost.* For both of these variables, only *TRC* is affected and gas savings are not changed regardless of the value of each of these two variables. This is expected since *Incremental Cost* and *Equipment Useful Life* variables are only used in the calculation of *TRC* and are not used in any part of the gas savings calculation.

4 – Equipment Useful Life & 5 – Incremental Cost

Both EUL and incremental cost have a significant impact on *TRC*; however, these variables have no impact on gas savings. This result is expected since the *Equipment Useful Life* and *Incremental Cost are* only used in the *TRC* calculation. *Equipment Useful Life* in the tool could be decreased to 14-years and the same gas savings would be calculated while the *TRC* would decrease. The results also show that incremental cost is a value of significance, and accurately estimating HRV/ERV cost is important in determining *TRC*.

D – Average Indoor Relative Humidity & F – Average Outside Relative Humidity

Indoor and outdoor air humidity only have a significant effect on the ERV tool, and no minimal effect on the HRV tool since only sensible heat is recovered with an HRV. It should be noted that 30% is a minimum value that is recommended by ASHRAE (19 p. 21.1), and that greatly increasing indoor humidity will result in much more gas savings for an ERV. The outdoor relative humidity is relatively constant between all Ontario weather file locations and the weather files show that the outdoor humidity could be increased in the tool with a resulting small decrease in gas savings and TRC.

C – Average Indoor Air Temperature & E – Average Outside Air Temperature

Indoor and outdoor air temperatures have an effect on the savings for both the ERV and HRV tools. The outdoor temperature shows significant opportunity for adjustment within the existing tool with potential for significant increases in gas savings based on the weather file location. Also, if the indoor air temperature was slightly increased, there would be additional gas savings with this tool.

G – Atmospheric Pressure

Atmospheric air pressure has a minimal impact on the results of this tool. Even though regions in Ontario have significantly different average atmospheric pressure during the heating season, the impact on gas savings and *TRC* are minimal compared to the other assumptions in the tool.

H – No. of Hours in Heating Season

The *Number of Hours in Heating Season* greatly impacts savings in a similar way as the *Average Outside Air Temperature*. Northern parts of Ontario have significantly more heating hours than the Toronto area and additional gas savings would be realized if weather data from these locations is included in the tool. It should be noted that the Windsor/Chatham Union Gas district is an exception and would result in a decrease in gas savings and TRC with changes in weather file location.

I2 – Number of Hours of Operation per Week

The *Number of Hours of Operation per Week* had the largest impact on the results for both gas savings and TRC. For both tool outputs, the value greatly decreases. Note that the result is shown only for the Warehouse market segment, and other market segment buildings are not evaluated in this sensitivity analysis. This analysis does show that the weekly hours of operation assumption has a larger impact on tool results than all other assumptions and a good estimate is required for accuracy of the tool.

K – Effectiveness of Heat Recovery

Effectiveness of Heat Recovery equipment is another key variable in the tool. For HRVs, gas savings and TRC would decrease if a new value for heat exchanger effectiveness was used in the tool. Conversely, gas savings and TRC would increase if recommendations are implemented to increase the ERV effectiveness.

R – Defrost Control Derating Factor and T – Seasonal Efficiency of Gas-Fired Equipment

The *Defrost Control Derating Factor* and *Seasonal Efficiency of Gas-Fired Equipment* have a much smaller impact on the tool than the weather conditions and the effectiveness of the heat recovery equipment. These factors are dependent on the installed equipment and parameters specific to each installation.

Based on the secondary literature review, the engineering analysis of the tool and results of the sensitivity analysis, several improvements in input assumptions are recommended to further improve the accuracy of the tool. The original values for the variables in the report, and the values recommended by Nexant, are shown Table 6-1 and Table 6-2 for the HRV and ERV tools, respectively. The sensitivity analysis results discussed in Section 5.2.2 indicate potential for modifications to several variables. The variable recommendations are noted in bold text and shaded background in the respective tables. The remainder of this section describes the recommended changes for each individual variable.

Table 6-1: Summary of HRV tool recommendations

Symbol	Variable Name	Units	Exisitng Value	Recommended Value
4	***Equipment Useful Life***	***yrs***	***20***	***14***
5	***Incremental Cost***	***$/CFM***	***3.40***	***3.61***
A	Supply Air Flow	CFM	HRV Capacity	HRV Capacity
B	Exhaust Air Flow	CFM	HRV Capacity	HRV Capacity
C	Average Indoor Air Temperature	°F	70	70
D	Average Indoor Relative Humidity	%	30	30
E	***Average Outside Air Temperature (Exist. Bldgs)***	***°F***	***35.5***	***Adjust based on district***
E	***Average Outside Air Temperature (New Bldgs)***	***°F***	***31.5***	***Adjust based on district***
F	***Average Outdoor Relative Humidity***	***%***	***70***	***75***
G	Atmospheric Pressure	psia	14.25	14.25
H	***No. of Hours in Heating Season (Exist. Bldgs)***	***hrs***	***5,800***	***Adjust based on district***
H	***No. of Hours in Heating Season (New Bldgs)***	***hrs***	***4,800***	***Adjust based on district***
I1	***Demand Controlled Ventilation?***	***-***	***no***	***Remove from analysis***
I2	***No. of Hours of Operation per Week***	***hrs/wk***	***60-168***	***54-168***
J	***Make and Model of Heat Recovery Equipment***		***Eng A HRW-2100***	***Remove from analysis***
K	***Effectiveness of Heat Recovery Equipment***	***%***	***70***	***61***
L	Sensible Heat Recovery Only?		yes	yes
M	Enthalpy of INLET Exhaust Air	Btu/lba	Calculated	Calculated
M	Humidity Ratio of INLET Exhaust Air	lbw/lba	Calculated	Calculated
N	Enthalpy of INLET Supply Air	Btu/lba	Calculated	Calculated
N	Humidify Ratio of INLET Supply Air	lbw/lba	Calculated	Calculated
O	Enthalpy of OUTLET Supply Air	Btu/lba	Calculated	Calculated
O	Humidity Ratio of OUTLET Supply Air	lbw/lba	Calculated	Calculated
P	Average Temperature of OUTLET Supply Air	°F	Calculated	Calculated
Q	Average Hourly Moisture Addition	lbw/hr	Calculated	Calculated
R	Defrost Control Derating Factor	%	5	5
S	Average Hourly Heat Recovery	MBH	Calculated	Calculated
T	Seasonal Efficiency of Gas-Fired Equipment	%	82	82
U	Average Annual Gas Reduction	m^3	Calculated	Calculated
V	Incremental Natural Gas Rate	$\$/m^3$	0.30	0.30
W	Average Annual Gas Savings	$	Calculated	Calculated

Table 6-2: Summary of ERV tool recommendations

Symbol	Variable Name	Units	Existing Value	Recommended Value
4	***Equipment Useful Life***	***yrs***	***20***	***14***
5	***Incremental Cost***	***$/CFM***	***3.00***	***3.18***
A	Supply Air Flow	CFM	ERV Capacity	ERV Capacity
B	Exhaust Air Flow	CFM	ERV Capacity	ERV Capacity
C	Average Indoor Air Temperature	°F	70	70
D	Average Indoor Relative Humidity	%	30	30
E	***Average Outside Air Temperature (Exist. Bldgs)***	***°F***	***35.5***	***Adjust based on district***
E	***Average Outside Air Temperature (New Bldgs)***	***°F***	***31.5***	***Adjust based on district***
F	***Average Outdoor Relative Humidity***	***%***	***70***	***75***
G	Atmospheric Pressure	psia	14.25	14.25
H	***No. of Hours in Heating Season (Exist. Bldgs)***	***hrs***	***5,800***	***Adjust based on district***
H	***No. of Hours in Heating Season (New Bldgs)***	***hrs***	***4,800***	***Adjust based on district***
I1	***Demand Controlled Ventilation?***	***-***	***no***	***Remove from analysis***
I2	***No. of Hours of Operation per Week***	***hrs/wk***	***60-168***	***54-168***
J	***Make and Model of Heat Recovery Equipment***		***Eng A HRW-2100***	***Remove from analysis***
K	***Effectiveness of Heat Recovery Equipment***	***%***	***60***	***67***
L	Sensible Heat Recovery Only?		no	no
M	Enthalpy of INLET Exhaust Air	Btu/lba	Calculated	Calculated
M	Humidity Ratio of INLET Exhaust Air	lbw/lba	Calculated	Calculated
N	Enthalpy of INLET Supply Air	Btu/lba	Calculated	Calculated
N	Humidify Ratio of INLET Supply Air	lbw/lba	Calculated	Calculated
O	Enthalpy of OUTLET Supply Air	Btu/lba	Calculated	Calculated
O	Humidity Ratio of OUTLET Supply Air	lbw/lba	Calculated	Calculated
P	Average Temperature of OUTLET Supply Air	°F	Calculated	Calculated
Q	Average Hourly Moisture Addition	lbw/hr	Calculated	Calculated
R	Defrost Control Derating Factor	%	5	5
S	Average Hourly Heat Recovery	MBH	Calculated	Calculated
T	Seasonal Efficiency of Gas-Fired Equipment	%	82	82
U	Average Annual Gas Reduction	m^3	Calculated	Calculated
V	Incremental Natural Gas Rate	$/$m^3$	0.30	0.30
W	Average Annual Gas Savings	$	Calculated	Calculated

6.1 INDIVIDUAL RECOMMENDATIONS

The following section details individual recommendations for the assumptions and calculations. In addition, the method and sources for each recommendation are identified.

4 – Equipment Useful Life

Recommendation: Modify EUL from 20-years to 14-years for all equipment

Equipment Useful Life for both HRV and ERV equipment is set to 20-years in the existing tool. Nexant's secondary literature review revealed that this number varies from 14-years to 20-years, as shown in Table 6-3.

Table 6-3: Estimated equipment useful life (EUL)

Source	EUL (years)
Whitford, (47)	15
Nexant (33 pp. E-3)	20*
Navigant (41 pp. C-183)	20*
2008 DEER (3)	14
NYSERDA (55)	20*
KEMA *California* (28 pp. C.1-1)	20*
RLW Analytics (42 p. 5)	20*
KEMA *Retention* (50 pp. E-2)	14
Response N.E. Gas (49 p. 1)	20
2007 ASHRAE (18 p. 36.3)	15

**Study results based on the same CA EE Program Study*

Nexant recommends that Union Gas reduce the *Equipment Useful Life* to 14-years based on the 2008 Database for Energy Efficiency Resources (DEER) Estimated Useful Life Summary (3). The 14 year life recommended by DEER is based on KEMA-XENERGY's *Retention Study of PG&Es 1996-1997 Energy Efficiency Incentive Program* (50). This study tracked installed equipment over 6-years and used statistical analysis to calculate EUL. This lifetime also closely aligns with the Whitford Study (47) and ASHRAE's estimates for other packaged HVAC equipment, e.g. roof top units. The remaining sources referenced a 20-year EUL, based on the value used in earlier California-based utility programs. It appears this value was determined from engineering judgment, but it is widely used and accepted in State Utility programs. Since the DEER recommendation is most recent and based on a retention study, Nexant recommends changing *Equipment Useful Life* to 14-years.

5 – Incremental Cost

Recommendation: Adjust current values for both the HRV and ERV tool

In order to evaluate Incremental Cost, Nexant conducted a survey of costs from a variety of sources including: 2005 and 2007-2010 RSMEANS (21), vendor quotes, online retail pricing and an ERV cost database (14). The full survey of relevant cost data can be found in Appendix B.

RSMEANS data indicates an increase in unit price based on equipment capacity each year as shown in

Size (Max CFM)	RS Means 2005	RS Means 2007	RS Means 2008	RS Means 2009	RS Means 2010
1,000	$5,776	$6,498	$6,834	$7,762	$7,788
2,000	$6,782	$7,659	$8,020	$9,103	$9,129
4,000	$7,943	$8,948	$9,387	$10,624	$10,728
6,000	$9,232	$10,418	$10,934	$12,378	$12,378
8,000	$10,186	$11,553	$12,069	$13,616	$13,719
10,000	$12,172	$13,616	$14,338	$16,195	$16,298

Table 6-5. The data also indicates smaller capacity units have greater incremental cost than units with larger capacities as shown in Table 6-5.

Table 6-4: Multi-year RS Means total cost data ($CAD)

Size (Max CFM)	RS Means 2005	RS Means 2007	RS Means 2008	RS Means 2009	RS Means 2010
1,000	$5,776	$6,498	$6,834	$7,762	$7,788
2,000	$6,782	$7,659	$8,020	$9,103	$9,129
4,000	$7,943	$8,948	$9,387	$10,624	$10,728
6,000	$9,232	$10,418	$10,934	$12,378	$12,378
8,000	$10,186	$11,553	$12,069	$13,616	$13,719
10,000	$12,172	$13,616	$14,338	$16,195	$16,298

Table 6-5: Multi-year RS Means incremental cost data ($CAD)

Size (Max CFM)	RS Means 2005	RS Means 2007	RS Means 2008	RS Means 2009	RS Means 2010
1,000	$5.78	$6.50	$6.83	$7.76	$7.79
2,000	$3.39	$3.83	$4.01	$4.55	$4.56
4,000	$1.99	$2.24	$2.35	$2.66	$2.68
6,000	$1.54	$1.74	$1.82	$2.06	$2.06
8,000	$1.27	$1.44	$1.51	$1.70	$1.71
10,000	$1.22	$1.36	$1.43	$1.62	$1.63

The RSMEANS data suggests that an average incremental cost may not fully capture the actual cost of equipment installed. Data provided by Union Gas was analyzed for trends in implementation rates of a range of capacities as shown in Table 6-6. The data indicates that for both HRV and ERV equipment, smaller capacity equipment is installed more frequently than larger capacity equipment.

Table 6-6: 2007-2009 installed projects by capacity range

	HRV		**ERV**	
Range	*# of projects*	*$/CFM*	*# of projects*	*$/CFM*
under 1,000	111	$2.56	102	$2.57
1,000-2,000	38	$2.25	97	$2.10
2,000-5,000	19	$2.32	127	$1.89
5,000-10,000	6	$2.59	54	$1.84
over 10,000	7	$2.19	35	$1.81

As noted earlier, the data indicates that smaller units have a greater incremental cost than larger capacity units. This suggests a minimum capital cost for HRV/ERV equipment in smaller capacities for the technology (i.e. engineering, base materials, controls, and manufacturing costs) and a fairly linear incremental cost associated with the increase in capacity. The base cost equipment and the linear trend of increasing cost with HRV/ERV capacity of the RSMEANS data can be seen graphically in Appendix B. This trend is not entirely unexpected. However with the combination of this cost trend and the installed project data, it suggests the current incremental costs approach used may be low since there have been significantly more smaller-capacity equipment installed. At this time Nexant does not consider that there is enough relevant total cost data to fully examine these circumstances since only one total cost data source was considered reliable. Further study may reveal that increment cost data may be low compared to the total actual cost of the equipment. Potential future studies may show that a fixed base cost with an incremental capacity increase may better approximate the incremental cost of an HRV/ERV.

The RSMEANS data, which was analyzed over 5-years, does indicate an annual inflationary increase in packaged equipment pricing and should be considered. Annual inflation rates did vary between 0.5% and 13.1%; however, the largest increase was in 2009, and the smallest increase was in 2010, indicating that economic concerns may be impacting prices over these years more than steady inflation. Since this ERV and HRV program is a long-term program, a long-term view of inflation is more useful than year to year variations. Given this data, Nexant recommends adjusting the Incremental Cost for both the HRV and ERV tools by 6.1%, which is the average inflation rate over the past five years. Further detail on RSMEANS pricing can be found in Appendix B.

Nexant understands that annual inflationary increases in incremental costs are not currently implemented. Therefore, at a minimum, Nexant recommends the incremental cost account for inflation.

HRV Tool

Currently the HRV tool uses an incremental cost of $3.40/CFM. Nexant recommends increasing the *Incremental Cost* for all HRV projects annually in line with an average inflation rate of 6.1%. For the 2010 program year, the inflated HRV incremental cost from 2009 to 2010 would be $3.61/CFM. If 6.1% inflation was considered for previous years and a $2.50/CFM incremental cost was assume in 2000, the incremental cost may be on the order of $4.52/CFM for 2010. Since Nexant does not fully understand the history of incremental cost within the program, at a minimum Nexant recommends an incremental cost of $3.61/CFM be used.

ERV Tool

The current cost used in the ERV tool is $3.00/CFM. Following the average inflation rate, Nexant also recommends increasing the *Incremental Cost* for all ERV projects annually. For the 2010 program year, the inflated ERV incremental cost from 2009 to 2010 would be $3.18/CFM. If 6.1% inflation was considered for previous years and a $1.76/CFM incremental cost was assume in 2000, the incremental cost may be on the order of $3.86/CFM for 2010. Since Nexant does not fully understand the history of incremental cost within the program, at a minimum Nexant recommends an incremental cost of $3.18/CFM be used.

Opportunity for Additional Improvement

Although the Incremental Cost can be adjusted annually for inflation as discussed above, Nexant would further recommend the tool be modified to allow equipment cost to be input by the user directly, instead of relying on a calculation using the estimated Incremental Cost. Quoted project costs should be readily available to the customer and would greatly improve the accuracy of the tool, especially for very small or large units which have more extreme costs per CFM. By adding a tool input for project cost, Incremental Cost estimates can be bypassed in the tool and the input project cost can be used in TRC calculations directly. In the case that a customer has not yet obtained quotes, or where the analysis cannot wait on quotes, the default Incremental Cost value can be multiplied by user input 3 – HRV/ERV Capacity to obtain equipment cost.

Additionally, inputting the equipment cost would allow for Union to log empirical data for more accurate long-term analysis of incremental cost rather than using assumed rates of inflation or other means of substantiation.

A – Supply Air Flow

Recommendation: No change

Supply Air Flow is currently set to the HRV/ERV capacity. This is a suitable assumption and calculation for the tool and no changes are recommended.

B – Exhaust Air Flow

Recommendation: No change

Exhaust Air Flow is currently set to the HRV/ERV capacity. For packaged HRV/ERV units this is likely a good assumption since each unit should have equal exhaust and supply air flow.

C – Average Indoor Air Temperature

Recommendation: No change

The *Average Indoor Air Temperature* was reviewed based on the existing assumption of 70°F indoor space temperature. To validate this variable, information from ASHRAE was reviewed for all different market segment buildings to determine the range of space temperatures. The results of the ASHRAE literature review can be seen in Table 6-7.

Table 6-7: ASHRAE recommended market segment space temperature

	ASHRAE Recommended Space Temperature	
Market Segment	Winter Low (°F)	Winter High (°F)
Multi-Family	NA	NA
Hotel	68	74
Restaurant	70	74
Retail	70	75
Office	70	74
School	68	75
Health Care	70	75
Nursing Home	75	75
Warehouse	NA	NA

The minimum heating space temperature is typically about 70°F for most of the market segments, as shown in Table 6-7. The maximum heating temperature typical for facilities is 75°F. Based on this range, 70°F is a conservative assumption for energy savings.

D – Average Indoor Relative Humidity

Recommendation: No change

The *Average Indoor Relative Humidity* was reviewed in a similar way as the average indoor air temperature. The existing assumption is a relative humidity of 30% in all buildings. A review of ASHRAE literature was completed for different market segments and the results can be seen in Table 6-8.

Table 6-8: ASHRAE recommended market segment relative humidity

	ASHRAE Recommended Space Relative Humidity	
Market Segment	Winter Low (%rh)	Winter High (%rh)
Multi-Family	NA	NA
Hotel	30	35
Restaurant	20	30
Retail	NA	NA
Office	20	30
School	30	60
Health Care	30	60
Nursing Home	30	50
Warehouse	NA	NA

As shown in Table 6-8, the minimum humidity is either 20% or 30%, with a maximum value of up to 60% for schools and health care, and a maximum as low as 30% for restaurants and offices. The sensitivity analysis showed that for ERVs there is a large impact on gas savings when indoor humidity is changed; however, the current value of 30% is suitable and a conservative estimate for all buildings. In general, ASHRAE recommends humidity levels between 30% and 60% for optimal environmental conditions (19 p. 21.1).

An upper limit of humidity in spaces is generally the point at which condensation forms within the structure. In buildings, the coldest interior surface is generally a window. If the window interior surface temperature is below the dew point of the conditioned indoor air, then condensation will form on the glass. The dew point is a function of the space temperature and relative humidity of air. ASHRAE provides a guideline for the maximum humidity allowed in a space to prevent condensation on windows at various outdoor temperatures, as shown in Table 6-9.

Table 6-9: ASHRAE recommended maximum space humidity to prevent condensation on windows (19)

	Maximum Relative Humidity (%)	
Outdoor Temperature (°F)	Single Glazing	Double Glazing
40	39	59
30	29	50
20	21	43
10	15	36
0	10	30
-10	7	26
-20	5	21
-30	3	17

Source:
(19) 2008 ASHRAE Handbook: HVAC Systems and Equipment. Chapter 21.

The guidelines shown in Table 6-9 are based on an indoor dry bulb temperature of 74°F and natural convection over the window surface. Table 6-9 indicates the upper limit of space humidity when outdoor temperatures are 10°F are 36% and 15% for double and single glazing windows, respectively. This table shows that a value much higher than 30% relative humidity in the Ontario climate is likely not practical due to the regular occurrence of cold winter temperatures. Therefore, due to a low limit of human comfort of 30%, and a high level of about 30% due to cold outdoor temperatures, 30% is considered an acceptable assumption for the *Average Indoor Relative Humidity* used in the HRV/ERV tool.

E – Average Outside Air Temperature

Recommendation: Adjust value based on Union Gas district in which the HRV/ERV is being installed

Note: This will require an additional input to the tool, but Union Gas district is currently tracked by the program and this information should be readily available.

The current assumption for weather data within the tool is a location of London, Ontario. Nexant obtained and evaluated weather data for eleven (11) different locations available in Ontario. For each of these locations, a Canadian Weather for Energy Calculations (CWEC) file was available. The CWEC files represent an approximate average year of hourly weather data and the information is suitable for engineering approximations of energy use. For each of the files, Nexant determined the hours in heating season along with the outside air temperature, average outdoor relative humidity, and atmospheric pressure that occurs during the heating season hours, as shown in Table 6-10.

Table 6-10: Summary of Union Gas service territory weather data

Union Gas District	Recommended Weather File Location	Hours in Heating Season		Avg. Outside Air Temperature (°F)		Average Outdoor Relative Humidity		Avg. Atmospheric Pressure (psia)	
		HDD50	HDD60	HDD50	HDD60	HDD50	HDD60	HDD50	HDD60
Windsor/Chatham	Windsor	4,371	5,690	31.8	37.1	75	75	14.42	14.42
London/Sarnia	London	4,846	6,306	30.2	35.9	78	78	14.27	14.27
Waterloo/Brantford	London	4,846	6,306	30.2	35.9	78	78	14.27	14.27
Hamilton	London	4,846	6,306	30.2	35.9	78	78	14.27	14.27
Halton	London	4,846	6,306	30.2	35.9	78	78	14.27	14.27
Eastern	Kingston	5,031	6,347	29.9	35.1	74	74	14.58	14.58
Northeast	North Bay	5,413	6,903	24.2	30.9	74	74	14.08	14.08
Northwest	Thunder Bay	5,741	7,330	24.3	30.8	72	73	14.38	14.38

Table 6-10 shows that there are numerous differences between the existing Union Gas assumptions and the actual weather at the location where HRV/ERVs are installed. The sensitivity analysis also showed that the hours in the heating season and outside air temperature are assumptions that have a significant impact on HRV/ERV calculations, and more accurate assumptions will provide the best results.

Union Gas provided a service territory map for Nexant to review (Figure 6-1). From the map, Nexant was able to evaluate which weather file location corresponds with the Union Gas district. For districts that have multiple weather files, Nexant reviewed an Ontario population density map (Figure 6-2) to determine the population center and weather file that would best represent the district. For example, the North Bay district contained weather files for both North Bay and Sault Ste. Marie. The North Bay weather file was ultimately selected for this district since North Bay is centrally located within the district and the North Bay area has more of a population than the Sault Ste. Marie area.

The recommendations for which weather file to use can be seen in Table 6-10. While the weather file for London, used in the existing HRV/ERV tool, remains the recommendation for many of the Union Gas districts, other districts to the north of the London area have significantly more hours in the heating season and colder outdoor temperatures. Therefore, more gas savings could be realized with this tool if the weather information was changed to more closely match the actual project location. Similarly, Windsor is located to the south of the London area and has fewer hours in the heating system than London. Consequently, less gas savings would be realized in this district based on weather data.

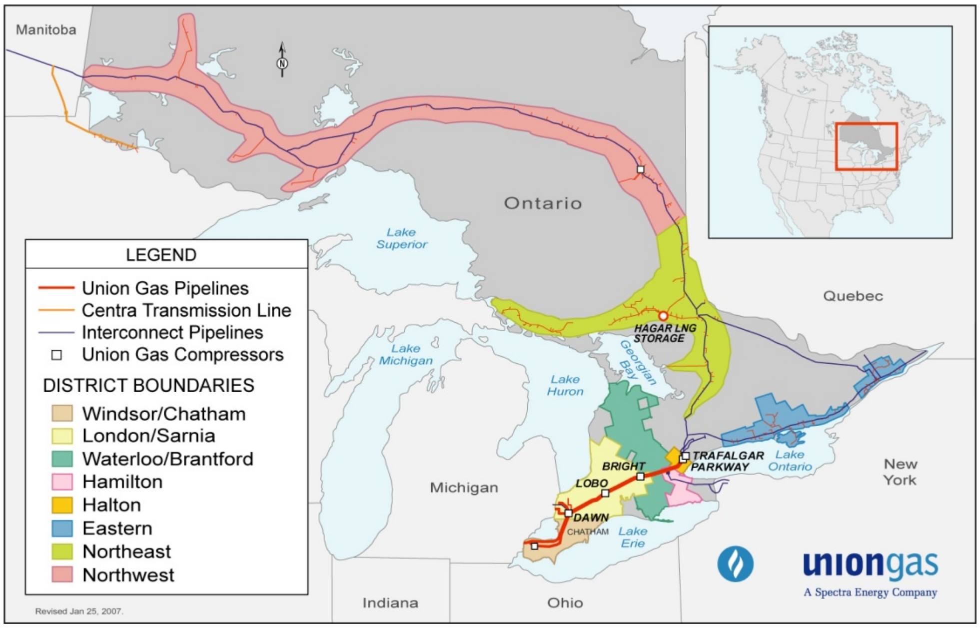

Figure 6-1: Union Gas district boundary map

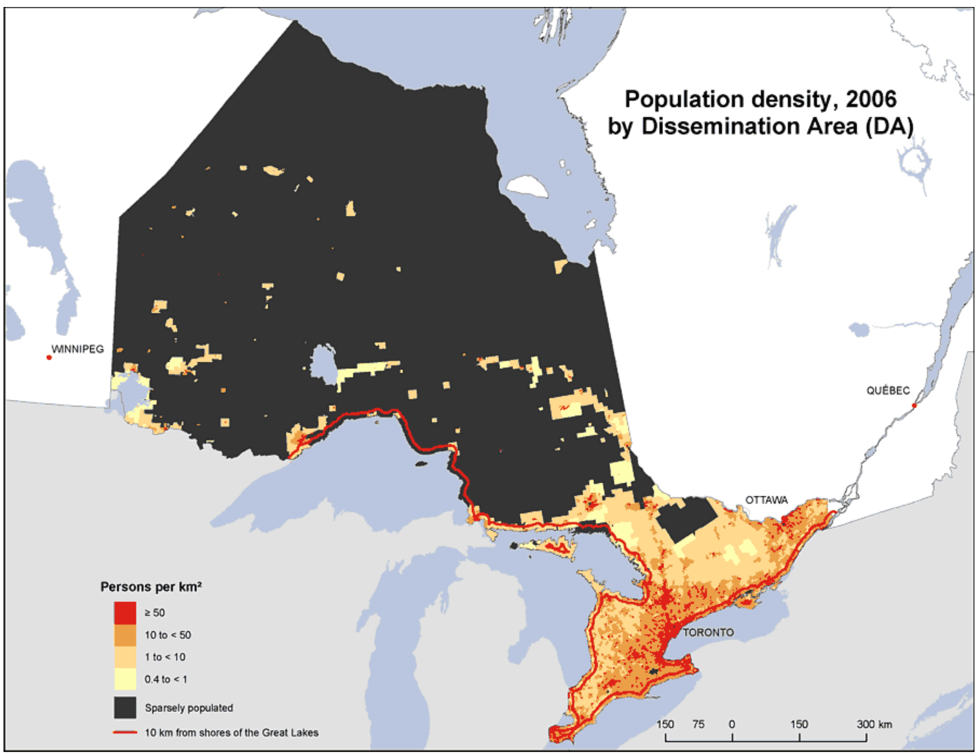

Figure 6-2: Population density of Ontario (46)

For each location, there are two values for each of the affected assumptions: HDD50 and HDD60. These are the values for new versus existing buildings. A new building is assumed to have a building balance temperature of 50°F, and therefore the weather file calculations are based on heating degree days with a 50°F base (HDD50). Similarly, existing buildings are assumed to have a balance point of 60°F, and the heating degree days are therefore based on 60°F (HDD60).

The difference in building balance temperature is an important assumption between new buildings and existing buildings. Historically, heating degree days were reported on a 65°F basis (HDD65) due to poor insulation and low internal gains in a space. As building standards and concerns about energy use have increased, buildings are now built with improved insulation resulting in less heat loss to the environment during the heating season. At the same time, internal gains have increased as more electronic devices that reject heat to the space have become commonplace. Therefore, even an older building has a building balance point of about 60°F. A newer building will have an even lower balance temperature with the current value of 50°F. Based on experience, Nexant considers these values are suitable for this analysis.

It should be noted that actual buildings have widely varying balance temperatures based on quality and tightness of construction, maintenance, type of use, building occupancy schedule, and individual choices made by occupants that influence energy use. An actual calculation of building balance temperature requires significantly more analysis and would be commonplace for custom measures and not applicable to prescriptive measure programs.

The recommended outside air temperature should be changed to match the value shown in Table 6-11 based on the Union Gas district in which the project is installed. Table 6-11 gives the Union Gas district and the relevant weather file data recommended for the district location. Also, the average outside air temperature is given based on HDD50 and HDD60. As previously described in this section, Nexant considers the HDD50 value is appropriate for use for new construction buildings, and the HDD60 value is appropriate for use for existing buildings.

Table 6-11: Recommended *Average Outside Air Temperature* for use in the Union Gas HRV/ERV tool

Union Gas District	Recommended Weather File Location	Avg. Outside Air Temperature (°F) HDD50	HDD60
Windsor/Chatham	Windsor	31.8	37.1
London/Sarnia	London	30.2	35.9
Waterloo/Brantford	London	30.2	35.9
Hamilton	London	30.2	35.9
Halton	London	30.2	35.9
Eastern	Kingston	29.9	35.1
Northeast	North Bay	24.2	30.9
Northwest	Thunder Bay	24.3	30.8

F – Average Outdoor Relative Humidity

Recommendation: Change to 75% relative humidity for all locations

Average Outdoor Relative Humidity is currently 70% in the Union Gas tool. Relative humidity during the heating season was analyzed based on the methods described above for the *Average Indoor Air Temperature*, and the results are summarized in Table 6-12. As can be seen in the table, the average outdoor relative humidity does not vary much between locations and a value of approximately 75% relative humidity characterizes all of the locations more accurately. In addition, the sensitivity analysis showed that outdoor relative humidity is a relatively minor factor (less than 3.8% for ERVs, 0% for HRVs) in the overall results of the HRV/ERV tool, and therefore assuming a constant *Average Outdoor Relative Humidity* of 75% is considered suitable for this tool.

Table 6-12: Summary of Union Gas service territory *Average Outdoor Relative Humidity* during the heating season

Union Gas District	Recommended Weather File Location	Average Outdoor Relative Humidity	
		HDD50	HDD60
Windsor/Chatham	Windsor	75	75
London/Sarnia	London	78	78
Waterloo/Brantford	London	78	78
Hamilton	London	78	78
Halton	London	78	78
Eastern	Kingston	74	74
Northeast	North Bay	74	74
Northwest	Thunder Bay	72	73

G – Atmospheric Pressure

Recommendation: No change

Atmospheric Pressure during the heating season was analyzed based on the methods described above for the *Average Indoor Air Temperature,* and the results are summarized in Table 6-13. The current value of 14.25 psia is shown to be very close to the actual value for all Union Gas districts. In addition, the sensitivity analysis shows that this assumption has a relatively minor impact on the overall results of the HRV/ERV tool. Therefore, assuming a constant average *Atmospheric Pressure* of 14.25 psia is considered suitable for this tool.

Table 6-13: Summary of Union Gas service territory *Average Atmospheric Pressure* during the heating season

Union Gas District	Recommended Weather File Location	Avg. Atmospheric Pressure (psia) HDD50	HDD60
Windsor/Chatham	Windsor	14.42	14.42
London/Sarnia	London	14.27	14.27
Waterloo/Brantford	London	14.27	14.27
Hamilton	London	14.27	14.27
Halton	London	14.27	14.27
Eastern	Kingston	14.58	14.58
Northeast	North Bay	14.08	14.08
Northwest	Thunder Bay	14.38	14.38

H – No. of Hours in Heating Season

Recommendation: Adjust value based on Union Gas district in which the HRV/ERV is being installed

Note: This will require an additional input to the tool, but Union Gas district is currently tracked by the program and this information should be readily available.

The annual *Number of Hours in Heating Season* assumption is currently 4,800 hours for new buildings, and 5,800 hours for existing buildings. The hours in the heating season, which is assumed to be hours below 50°F and 60°F for new and existing buildings, respectively, was calculated based on weather data. The method and source for the weather analysis is described above for the *Average Indoor Air Temperature* and the results are summarized in Table 6-14.

Table 6-14: Recommended hours in the heating season for use in the Union Gas HRV/ERV tool

Union Gas District	Recommended Weather File Location	Hours in Heating Season HDD50	HDD60
Windsor/Chatham	Windsor	4,371	5,690
London/Sarnia	London	4,846	6,306
Waterloo/Brantford	London	4,846	6,306
Hamilton	London	4,846	6,306
Halton	London	4,846	6,306
Eastern	Kingston	5,031	6,347
Northeast	North Bay	5,413	6,903
Northwest	Thunder Bay	5,741	7,330

The sensitivity analysis showed that the assumed annual *Number of Hours in Heating Season* has a significant impact on *Average Annual Gas Savings*. Therefore, to improve accuracy of the tool, Nexant recommends changing the tool to have different annual *Number of Hours in Heating Season* based on the project location within a regional Union Gas district. Table 6-14 shows the recommended hours based on the Union Gas district and the associated weather file location used for the analysis. Also, the annual *Number of Hours in Heating Season* is given based on HDD50 and HDD60. As previously described above for the *Average Indoor Air Temperature*, the HDD50 value should be used for new building construction and the HDD60 value should be used for existing buildings.

I1 – Demand Controlled Ventilation?

Recommendation: Remove from analysis

The current tool always uses the value *No* for *I1 – Demand Controlled Ventilation*. There is no way for users of this tool to change this value in the analysis since this value is protected in the worksheet. Union Gas may want to remove this variable completely from the analysis since its placement in the calculations is unnecessary. Including demand controlled ventilation in this calculation would require significantly more analysis, which would be commonplace for custom measures, but is not applicable to prescriptive measure programs.

I2 – No. of Hours of Operation per Week

Recommendation: Adjust current values based on the market segment

The *Number of Hours of Operation per Week* assumption varied from 60 to 168 hours, depending on the market segment, as shown in Table **6-15**. The *Number of Hours of Operation per Week* has a direct impact on *Average Annual Gas Savings* since the weekly operating hours is divided by 168 (the number of hours in a week) to calculate the faction of the time the HRV/ERV is in operation. A good approximation the *Number of Hours of Operation per Week* is needed to provide accurate savings.

Nexant's secondary review identified several sources for default operating hours by Market Segment to determine the typical hours of operation per week by space type. While the reports contained default hours based on two types of information: the default values for KEMA, MEC/NEA and Eff. VT are based on customer reported operating hours while the defaults used in both CL&P and DEER are derived from recorded facility lighting hours; Nexant expects facility lighting hours are a good approximation facility operating hours and given the correspondence between study values, Nexant used the hours from all reports as shown in Appendix C. Where revised values have been suggested, the average of the sources has been provided as the recommended value, as shown in Table **6-15**.

Table 6-15: Existing and recommended hours of operation per week based on market segment

Typical Hrs of Operation per week							
Market Segment	Existing Value	CL&P Value†	DEER Value†	KEMA Value	MEC/NEA Value	Eff. VT Value	Recommended Value
Multi-Family	168	147	NA	NA	NA	NA	168
Hotel	*168*	*59*	*168*	*164*	*157*	*52*	***120***
Restaurant	*108*	*80*	*93*	*93*	*NA*	*80*	***87***
Retail	*108*	*78*	*87*	*66*	*73*	*59*	***73***
Office	*60*	*72*	*50*	*62*	*69*	*66*	***64***
School	*84*	*42*	*70*	*56*	*62*	*40*	***54***
Health Care	168	147	168	NA	123	NA	168
Nursing Home	168	112	168	NA	168	NA	168
Warehouse	*168*	*50*	*55*	*74*	*81*	*46*	***61***

†Study values based on facility lighting hours.

The recommended default hours have several changes compared to the Union Gas existing value in the HRV/ERV tool. For multi-family, health care, and nursing home *Market Segments*, the existing value of 168-hours per week seems appropriate and reasonable and Nexant recommends maintaining the current values (Table **6-15**). For all other variables, Nexant recommends decreasing the typical *Number of Hours of Operation per Week* to more closely match the average values of the studies.

Opportunity for Additional Improvement

As demonstrated in Section 5, the *Number of Hours of Operation per Week* had the largest impact on the results for both gas savings and *TRC*. Given the impact of the weekly hours of operation, Nexant would recommend the tool be modified to improve accuracy. A simple way to improve the tool accuracy would be to input a requested expected or actual *Number of Hours of Operation per Week* on the application form. The applicant should be familiar with the installed project and be able to easily provide their site specific *Number of Hours of Operation per Week*. If these hours are not provided by the applicant, the default average *Number of Hours of Operation per Week* in Table **6-15** could be used.

J – Make and Model of Heat Recovery Equipment

Recommendation: Remove from analysis

The current tool always uses the value *Eng A HRW-2100* for make and model of heat recovery equipment. There is no way for users of this tool to change this value in the analysis since this value is protected in the worksheet. Union Gas should remove this variable completely from the analysis since its placement in the calculations is unnecessary and the value does not accurately reflect what is being installed for a project.

K – Effectiveness of Heat Recovery Equipment

Recommendation: Adjust current values for both the HRV and ERV technologies

The *Effectiveness of Heat Recovery Equipment* measures the equipment's ability to transfer thermal energy from outlet air to inlet air. This value was set at 70% for the HRV tool and 60%

for the ERV tool. Based on a review of the AHRI Directory for all certified Commercial Air-to Air Energy Recovery Ventilators (4), Nexant recommends the following changes:

HRV Tool

The current average *Effectiveness of Heat Recovery Equipment* value of 70% overestimates the effectiveness of typical heat recovery equipment. The packaged HRV equipment certified by AHRI has an average sensible thermal effectiveness of 61%, with an effectiveness range of 55-68%. Nexant recommends that value of average *Effectiveness of Heat Recovery Equipment* for the HRV tool be changed to match the average value of 61%.

ERV Tool

The current average *Effectiveness of Heat Recovery Equipment* value of 60% underestimates the typical effectiveness of energy recovery ventilators. Packaged ERV equipment certified by AHRI has an average net thermal effectiveness of 67%, with an effectiveness range of 60-78%. Nexant recommends that value for average *Effectiveness of Heat Recovery Equipment* in the ERV tool be changed to match the average value of 67%.

Opportunity for Additional Improvement

Although the average *Effectiveness of Heat Recovery Equipment* value can be used in the tool, Nexant would further recommend the tool be modified to improve accuracy. A simple way to make the calculation more accurate would be to require applicants include the rated effectiveness of their equipment on the application form. The applicant should be familiar with the installed project and be able to easily provide the effectiveness. If the value is not provided by the applicant however, the default average effectiveness could be used.

L – Sensible Heat Recovery Only?

Recommendation: No change

The value for *Sensible Heat Recovery Only* is either *Yes* or *No* depending on whether it is the HRV or ERV tool, respectively. This variable is used in several excel logic statements to adjust outlet supply air conditions (Symbol *O*), average hourly moisture addition (Symbol *Q*), and average hourly heat recovery (Symbol *S*).

HRV Tool

In the HRV tool, the *Sensible Heat Recovery Only* variable is set to *Yes*. This is appropriate since an HRV only recovers sensible heat. No change is recommended for this variable.

ERV Tool

In the ERV tool, the *Sensible Heat Recovery Only* variable is set to *No.* This is appropriate since an ERV recovers both sensible and latent heat. No change is recommended for this variable.

M - Enthalpy and Humidity Ratio of INLET Exhaust Air

Recommendation: No change

The value for *Enthalpy and Humidity Ratio of Inlet Exhaust Air* is calculated based on the average indoor air temperature (Symbol *C*), average indoor relative humidity (Symbol *D*), and atmospheric pressure (Symbol *G*). The calculations are based on moist air properties. The calculation was reviewed and the Union Gas tool calculations accurately determine the enthalpy and humidity ratio. No change is recommended for this variable.

N – Enthalpy and Humidity Ratio of INLET Supply Air

Recommendation: No change

The value for *Enthalpy and Humidity Ratio of Inlet Supply Air* is calculated based on the *Average Outside Air Temperature* (Symbol *E*), *Average Outdoor Relative Humidity* (Symbol *F*), and *Atmospheric Pressure* (Symbol *G*). The calculations are based on moist air properties. The calculation was reviewed and the Union Gas tool calculations accurately determine the *Enthalpy and Humidity Ratio of Inlet Supply Air*. No change is recommended for this variable.

O – Enthalpy and Humidity Ratio of OUTLET Supply Air

Recommendation: No change

The value for *Enthalpy and Humidity Ratio of the Outlet Supply Air* is calculated based on the HRV/ERV *Supply and Exhaust Air Flow* (Symbols *A* and *B*), *Effectiveness of the Heat Recovery Equipment* (Symbol *K*), and inlet conditions of both the exhaust and supply air of the heat recovery equipment (Symbols *M* and *N*). The calculation accounts for whether only sensible heat is recovered (Symbol *L*), which is different between the HRV and ERV tools. The calculation was reviewed and the Union Gas tool calculations accurately determine the *Enthalpy and Humidity Ratio of the Outlet Supply Air*. No change is recommended for this variable.

P – Average Temperature of OUTLET Supply Air

Recommendation: No change

The value for *Average Temperature of Outlet Supply Air* is calculated based on moist air properties and states given for the *Enthalpy and Humidity Ratio of the Outlet Supply Air* (Symbol *O*). The calculation was reviewed and no change is recommended for this variable. In addition, this variable has no dependents, and therefore this variable could be removed from the tool with no impact on overall calculations.

Q – Average Hourly Moisture Addition

Recommendation: No change

The value for *Average Hourly Moisture Addition* to the supply air is calculated based on the *Supply Air Flow* (Symbol *A*) and the difference in humidity ratio between the outlet and inlet supply air (Symbols *O* and *N*). The calculation was reviewed and no change is recommended for this variable. In addition, this variable has no dependents, and therefore this variable could be removed from the tool with no impact on overall calculations.

R – Defrost Control Derating Factor

Recommendation: No change

The *Defrost Control Derating Factor* adjusts the heat recovery to account for frost forming on the energy recovery device and reducing the performance of the equipment. Frost forms when the surface temperature in the heat exchanger is below the frost point of the air stream. There are many individual factors that are related that contribute to whether frost will form. These factors include temperature and humidity levels of indoor and outdoor air, heat exchanger effectiveness, and the design of the heat recovery device in addition to specifics of how the heat recovery device is installed and other site-specific factors. The tool currently uses a value of 5% for the derating factor, which means that heat recovery is assumed to be reduced by 5% throughout the entire heating season due to frost control methods.

There are several ways to control frost on a heat exchanger recommended by ASHRAE (19). One method is simply to preheat the supply inlet air so the air temperature is above the frost point within the heat exchanger. A similar method is to preheat exhaust air such that the surface temperature in the heat exchanger is always above the frost point. Other methods of frost control involve bypassing supply air to maintain the heat exchanger above the frost point or adjusting the sensible effectiveness (e.g. changing energy recovery wheel speed) to prevent frost from forming. All of these methods either require supplementary energy consumption or result in a decreased effectiveness of the energy recovery equipment.

A sample of manufacturer literature was reviewed to determine the outside temperature at which frost becomes an issue in commercially available equipment. For an indoor relative humidity of 30% and indoor temperature of 70°F (these are the assumptions in the Union Gas tool), the frost threshold temperature is -5°F and 5°F for Greenheck and Lennox equipment, respectively. Therefore, the outdoor temperature would have to be below approximately 0°F for frosting to become an issue.

For the London climate, each year averages only 33 hours that are below 0°F, or less than 1% of the heating season based on the 4,846 hours in the HDD50 heating season. For the northernmost regions in the Union Gas service territory, such as Thunder Bay weather data for the Northwest Union Gas district, the weather files show colder temperatures. There are 717 hours each year below 0°F, or about 12% of the total hours in the 5,741 HDD50 heating season hours for the Thunder Bay location.

These weather file and commercial equipment analysis shows that out of each year, less than 12% of the winter heating HRV/ERV hours are below the frost point of commercially available equipment. Furthermore, the majority of the installed HRV/ERVs are in the London area according to Union Gas data. Due to the low number of hours when frost control will be required, the impact of frost control is assumed to be minimal.

This conclusion is further confirmed by an ASHRAE study: *Freeze-control strategy and air-to-air energy recovery performance* (38). This study concluded that for climates with less than 7,500 heating degree days, defrost control strategy has little impact on the performance of energy recovery ventilators. Since the areas in Union Gas territory have less than 7,500 heating degree days (Table 6-10), the effects of defrost derating should be minimal. The study also stated that freeze control strategies only have a significant effect on performance in climates with more than 10,000 heating degree days (38).

From this analysis, Nexant concludes that the current *Defrost Control Derating Factor* of 5% is suitable for this tool. The analysis showed that the factor could possibly be reduced since defrost cycles do not have a significant impact on performance. However, 5% is a conservative assumption for *Defrost Control Derating Factor* in the tool.

S – Average Hourly Heat Recovery

Recommendation: No change

Average Hourly Heat Recovery is the calculated result of numerous assumptions and calculations throughout the tool. The flow of supply air (Symbol *A*) is multiplied by the difference in enthalpy between the inlet and outlet of the supply air, and then converted to MBH using the appropriate conversion factors. The *Defrost Control Derating Factor* (Symbol *R*) is also used in this equation to decrease the recovered heat by 5%. Nexant reviewed the calculations and no changes are recommended for the tool.

T – Seasonal Efficiency of Gas-Fired Equipment

Recommendation: No change

The *Seasonal Efficiency of Gas-Fired Equipment* refers to the seasonal efficiency (i.e. AFUE) of the heat source that the HRV/ERV output is impacting. For both the HRV and ERV tools, the assumed value is 82%. Nexant reviewed this assumption and recommends no changes to the current value.

According to ASHRAE, modern furnaces with fan assisted combustion have an efficiency of 80% to 82% (19). In addition, Ontario adopted ASHRAE Standard 90.1-2004 as part of the building code. This standard requires a minimum efficiency of 78% to 80% for furnaces, and 75% to 80% for boilers, depending on the equipment size (36). Older furnaces may have lower efficiencies, but any new installation will at least meet or exceed the ASHRAE standard. The current efficiency of 82% is therefore considered a conservative estimate of *Seasonal Efficiency of Gas-Fired Equipment*.

U – Average Annual Gas Reduction

Recommendation: No change

Average Annual Gas Reduction is a calculated value based on the assumptions of the *Number of Hours in Heating Season* (Symbol *H*), the *Number of Hours of Operation per Week* (Symbol *I2*), and the *Seasonal Efficiency of Gas-Fired Equipment* (Symbol *T*) along with the calculated *Average Hourly Heat Recovery* (Symbol *S*). Nexant reviewed the calculation and no changes are recommended.

V – Incremental Natural Gas Rate

Recommendation: Regularly update values as appropriate (annually)

The HRV and ERV tools assume an *Incremental Natural Gas Rate* of \$0.30 per m^3. This assumption was not reviewed in this analysis since the incremental cost is an internal Union Gas determined value. Although, Nexant recommends Union Gas should periodically (annually) review the incremental cost of natural gas and adjust the *Incremental Natural Gas Rate* assumption accordingly.

W – Average Annual Gas Savings

Recommendation: No change

The *Average Annual Gas Savings* is the average annual gas reduction multiplied by the *Incremental Natural Gas Rate*. Nexant reviewed the calculation and no changes are recommended.

Section 7 Conclusions

The Union Gas quasi-prescriptive tool for HRVs and ERVs was evaluated in this report. The report fully describes the tool and several recommendations are included in the report to further improve the accuracy of the tool. This section summarizes the report by providing specific answers to questions posed by Union Gas to Nexant along with a summary of recommended changes to the tool and recommendations for further review.

7.1 SPECIFIC ANSWERS TO QUESTIONS

Union Gas presented several specific questions from the Audit Report and two (2) Intervenors that this report is to address. While the report has already detailed how the tool functions and specific recommendations for improvement, this section is meant to directly answer the specific questions for easy reference.

7.1.1 AUDIT REPORT – OPERATION HOURS

Question:

> *"The ERV / HRV tabs include assumptions on hours of operation that seem very high for average conditions. They also include degree-day factors that are potentially misapplied to buildings such as schools and offices that are not occupied at night."*

Nexant Response:

The existing tool used weather information from the London area, with original values of 4,800 and 5,800 hours in the heating season for new building construction and existing buildings, respectively. Nexant reviewed Canadian weather files as part of the tool analysis. The results showed that for the London area, the hours in the heating season are 4,846 for new building construction, and 6,306 for existing buildings. This analysis shows that the existing assumptions for hours in the heating season are a conservative estimate and do not overstate savings.

Buildings that are not occupied throughout the entire day are already factored into the existing tool via the user input *1 – Market Segment*, which changes the *Number of Hours of Operation per Week*. Section 5.1.3 describes the calculation, which indicates the existing tool does adjust the operation hours and gas savings for different market segments.

The calculations are not specific to buildings that are unoccupied at night. Depending on the actual building schedule and scheduled hours of HRV/ERV operation, the average temperature within the heating season may change since daytime temperatures are generally higher than nighttime temperatures. Accounting for such variances would require a much more complex tool utilizing hourly weather data and additional information from the applicant regarding HRV/ERV scheduling. Such a calculation is commonplace for custom measures, but it is not typically applicable to prescriptive measure programs.

7.1.2 INTERVENOR – OPERATION HOURS

Question:

> *"Navigant's estimates of savings for new buildings are slightly lower than for existing buildings. Intuitively that makes sense, because one would expect newer buildings to have more efficient heating systems. However, the inputs Navigant presents for computing savings are the same for both building types. While Navigant notes that "New buildings and existing buildings mainly differ in the enthalpy (BTU/LBa) that is used to calculate the Specific Supply Air Conditions Volume in formula (B)," it is not clear why the specific energy content of the supply air would be different for the two situations."*

Nexant Response:

After the review of the existing tool, Nexant found that the inputs for computing savings are different for new construction buildings and existing buildings (Table 7-1). The assumptions changed are the *Number of Hours in Heating Season* and the *Average Outside Air Temperature* based on the assumption that the building balance temperature is lower for a new building.

Table 7-1: Difference in key variables between new building construction and existing buildings

Symbol	Variable Name	Units	New Building Construction - Existing Value	Existing Building - Existing Value
2	Program		New Building Construction	Existing Building
E	Average Outside Air Temperature	°F	31.5	35.5
H	No. of Hours in Heating Season	hrs	4,800	5,800
N	Enthalpy of Inlet Supply Air	Btu/lba	10.38	11.86
O	Enthalpy of Outlet Supply Air	Btu/lba	16.89	17.69
S	Average Hourly Heat Recovery	MBH	27	24
U	Average Annual Gas Reduction	m^3	4,547	4,903

New construction buildings and existing buildings do have different supply air enthalpy (Symbol *O*) in the tool, but the difference is calculated based on the assumptions for the *Number of Hours in Heating Season* and the *Average Outside Air Temperature*. Since new construction buildings are assumed to only require heating below 50°F outdoor temperature, compared to 60°F for existing buildings, new construction buildings therefore have a lower average outside air temperature during the heating season hours (Table 7-1). Consequently, the enthalpy of outside air is lower, and the resulting enthalpy of the outlet supply air is lower since the heat recovery equipment is operating with a greater difference between indoor and outdoor enthalpy. The existing tool calculates the change in supply air enthalpy between the two different building types correctly.

The difference in the tool between the new construction buildings and existing buildings is only slightly impacted by the change in specific volume of supply air in the calculation. A larger contributor to the different values for the two different buildings is the difference between the *Enthalpy of Outlet Supply Air* and the *Enthalpy of Inlet Supply air*. When reviewing the calculations, it can be seen that the average hourly heat recovery actually increases for new building construction (Table 7-1) when the impact of the outside air conditions are factored into the equation.

The main difference between new and existing buildings that causes the difference in gas savings is the *Number of Hours in Heating Season.* The *Average Hourly Heat Recovery* actually decreases by 11% for existing buildings, while the *Average Annual Gas Reduction* increases by 8%. Overall, the calculations in the existing tool are correct for the two building types.

7.1.3 INTERVENOR – INCREMENTAL COST

Question:

> *"The incremental cost assumption is presumably based on the 2000 Jacques Whitford study suggestion that the incremental cost for a 1000 CFM unit is $2500. Given inflation, wouldn't the incremental cost be higher in 2009?"*

Nexant Response:

Given the cost data gathered by Nexant, shown in Appendix B, the cost of ERVs and HRVs has been found to increase by an average of 6.1% annually. Nexant recommends that the current incremental cost is increased by 6.1% to account for the annual increase in cost. In addition, Union Gas should update the incremental cost annually to account for inflation. Nexant's recommendations regarding the *Incremental Cost* is thoroughly discussed in Section 6.1, as is our recommendation that an additional tool input be added to accommodate actual equipment cost to further improve the accuracy of the tool.

7.2 RECOMMENDATIONS FOR TOOL IMPROVEMENTS

As discussed in Section 6 a few slight modifications to the existing Union Gas tool would greatly improve the accuracy of the final values for the *Average Annual Gas Savings* and *TRC* calculations. These recommendations are shown in Table 7-2 and Table 7-3.

Table 7-2: Summary of HRV tool recommendations

Symbol	Variable Name	Units	Exisitng Value	Recommended Value
4	Equipment Useful Life	yrs	20	14
5	Incremental Cost	$/CFM	3.40	3.61
E	Average Outside Air Temperature (Exist. Bldgs)	**°*F***	35.5	Adjust based on district
E	Average Outside Air Temperature (New Bldgs)	**°*F***	31.5	Adjust based on district
F	Average Outdoor Relative Humidity	%	70	75
H	No. of Hours in Heating Season (Exist. Bldgs)	hrs	5800	Adjust based on district
H	No. of Hours in Heating Season (New Bldgs)	hrs	4800	Adjust based on district
I1	Demand Controlled Ventilation?	-	no	Remove from analysis
I2	No. of Hours of Operation per Week	hrs/wk	60-168	54-168
J	Make and Model of Heat Recovery Equipment		Eng A HRW-2100	Remove from analysis
K	Effectiveness of Heat Recovery Equipment	%	70	61

Table 7-3: Summary of ERV tool recommendations

Symbol	Variable Name	Units	Exisitng Value	Recommended Value
4	Equipment Useful Life	yrs	20	14
5	Incremental Cost	$/CFM	3.00	3.18
E	Average Outside Air Temperature (Exist. Bldgs)	°F	35.5	Adjust based on district
E	Average Outside Air Temperature (New Bldgs)	°F	31.5	Adjust based on district
F	Average Outdoor Relative Humidity	%	70	75
H	No. of Hours in Heating Season (Exist. Bldgs)	hrs	5800	Adjust based on district
H	No. of Hours in Heating Season (New Bldgs)	hrs	4800	Adjust based on district
I1	Demand Controlled Ventilation?	-	no	Remove from analysis
I2	No. of Hours of Operation per Week	hrs/wk	60-168	54-168
J	Make and Model of Heat Recovery Equipment		Eng A HRW-2100	Remove from analysis
K	Effectiveness of Heat Recovery Equipment	%	60	67

Nexant also recommends that the tool be modified to add additional user inputs and existing variable values be updated accordingly as discussed below.

7.2.1 ADDITIONAL TOOL INPUTS

By adding three (3) additional user inputs to the tool Union Gas can expect to increase the accuracy of the tool calculations, see Table 7-4. While one (1) of the new user inputs will utilize data already acquired by Union Gas on the customer application, the other inputs will require further information from the customer. Nexant believes that the customer will have this data readily available. In the case that the applicant does not supply the additional information, Union Gas could default to Nexant's recommendations discussed in Section 6.

Table 7-4: Recommended additional tool inputs

Symbol	User Input Name	Create New Tool Input?	Collect New Data from Customer?
6	Union Gas District	Yes	No
7	Weekly Operating Hours	Yes	Yes
8	Thermal Effectiveness	Yes	Yes

7.2.2 MODIFICATONS TO EXISTING TOOL VARIABLE VALUES

Several modifications will need to be made to the existing values for variables to properly account for Nexant's recommended values and the additional user inputs described in Section 7.2.1. Table 7-5 below is a summary the recommended values.

Table 7-5: Summary of recommended value modifications

Symbol	Variable Name	Recommendation
5	Incremental Cost	Allow user input of Equipment Cost
E	Average Outside Air Temperature	Make dependent on user input *6*
H	No. of Hours in Heating Season	Make dependent on user input *6*
I2	No. of Hours of Operation per Week	Make dependent on user input *7*
K	Effectiveness of Heat Recovery Equipment	Make dependent on user input *8*

7.3 BASE CASE RESULTS FROM RECOMMENDATIONS

The assumed base case impacts of all of the recommended changes in input assumptions are shown in Table 7-6. Table 7-6 values are based on a 1,000 CFM HRV/ERV, 168-hours per week of operation, and London, Ontario weather location. The results show that gas savings decrease for HRVs, which is primarily a result of Nexant's recommendation to decrease the effectiveness of the HRV. Gas savings increase for ERVs with the recommended changes. TRC decreases for both HRVs and ERVs, which is primarily a result of Nexant's recommendation to the decrease the EUL.

Table 7-6: Results from changing input assumptions for the London, ON weather location

	Existing Gas Savings (m^3)	Recommended Gas Savings (m^3)	% Increase	Existing TRC	Recommended TRC	% Increase
HRV Tool for New Construction Buildings	4,547	4,182	-8%	13,334	9,410	-29%
HRV Tool for Existing Buildings	4,903	4,618	-6%	14,633	10,748	-27%
ERV Tool for New Construction Buildings	4,888	5,621	15%	14,957	14,235	-5%
ERV Tool for Existing Buildings	5,139	5,965	16%	15,871	15,291	-4%

Base Case: 1,000 CFM HRV/ERV Capacity, 168 hrs per week operation, London, ON weather files

If the London, Ontario location also has the operating hours for the warehouse reduced as recommended, the gas savings and TRC greatly decrease, as shown in Table 7-7. The gas savings and TRC decrease by as much as 67% and 91%, respectively, for the HRV tool for new construction buildings. Other cases do not have as much of a decrease in savings and TRC, but are still significant. It should be noted that these impacts are only for warehouses; other market segments that do not have a recommended decrease in hours would not be impacted.

Table 7-7: Results from changing warehouse input assumptions for the London, ON weather location

	Existing Gas Savings (m3)	Recommended Gas Savings (m3)	% Increase	Existing TRC	Recommended TRC	% Increase
HRV Tool for New Construction Buildings	4,547	1,519	-67%	13,334	1,233	-91%
HRV Tool for Existing Buildings	4,903	1,677	-66%	14,633	1,718	-88%
ERV Tool for New Construction Buildings	4,888	2,041	-58%	14,957	3,244	-78%
ERV Tool for Existing Buildings	5,139	2,166	-58%	15,871	3,628	-77%

Base Case: 1,000 CFM HRV/ERV Capacity, Warehouse market segment, London, ON weather files

To show the impact of including multiple weather file locations on the tool, the same analysis was completed for the North Bay, Ontario weather location (Northeast Union Gas district). The results are shown in Table 7-8. For this location, gas savings increases for ERVs and HRVs for both new construction and existing buildings. The increase is very large for ERVs, with a 52%

increase for both new construction and existing buildings, respectively. TRC increases for ERVs, and remains approximately the same for HRVs. Overall, this shows that the selected weather file location has a significant impact on tool savings and the recommended change to include weather from other locations will greatly improve the accuracy of the tool.

Table 7-8: Results from changing input assumptions for the North Bay, ON weather location

	Existing Gas Savings (m^3)	Recommended Gas Savings (m^3)	% Increase	Existing TRC	Recommended TRC	% Increase
HRV Tool for New Construction Buildings	4,547	5,447	20%	13,334	13,292	0%
HRV Tool for Existing Buildings	4,903	5,840	19%	14,633	14,500	-1%
ERV Tool for New Construction Buildings	4,888	7,441	52%	14,957	19,823	33%
ERV Tool for Existing Buildings	5,139	7,826	52%	15,871	21,005	32%

Base Case: 1,000 CFM HRV/ERV Capacity, 168 hrs per week operation, North Bay, ON weather files (Northeast Union Gas district)

All of the recommended weather file locations are north of London, except for the Windsor, Ontario weather location (Windsor/Chatham Union Gas district). Since this is the only gas district with warmer weather and a shorter heating season than London, Ontario, Nexant also reviewed the impact on the Windsor/Chatham district to the determine the impact of the changes (Table 7-9). For this location gas savings decreases for HRVs, and it stays approximately the same for ERVs. TRC decreases for all ERV and HRV projects.

Table 7-9: Results from changing input assumptions for the Windsor, ON weather location

	Existing Gas Savings (m3)	Recommended Gas Savings (m3)	% Increase	Existing TRC	Recommended TRC	% Increase
HRV Tool for New Construction Buildings	4,547	3,602	-21%	13,334	7,628	-43%
HRV Tool for Existing Buildings	4,903	4,017	-18%	14,633	8,902	-39%
ERV Tool for New Construction Buildings	4,888	4,807	-2%	14,957	11,736	-22%
ERV Tool for Existing Buildings	5,139	5,119	0%	15,871	12,695	-20%

Base Case: 1,000 CFM HRV/ERV Capacity, 168 hrs per week operation, Windsor, ON weather files (Windsor/Chatham Union Gas district)

Complete results for each case are shown in Appendix D.

7.4 RECOMMENDATIONS FOR FURTHER REVIEW

End of Useful Life (EUL) has a significant reduction on the TRC results for these projects and programs. While data exists from a DEER study based on empirical data, more data could be collected in the Province of Ontario where different weather conditions may result in a different EUL than the DEER study location. If ERV/HRV quasi-prescriptive programs are highly valued, Nexant recommends a long-term empirical study to regionally evaluate the EUL of ERV/HRV equipment.

Incremental costs also have a significant impact on the TRC results for these projects and programs. The current incremental cost approach may not be the most accurate and may also be outdated. The incremental cost accuracy could be improved by using installed cost data, as noted in the report. Nexant recommends the incremental cost be further evaluated with empirical data collected by the program in the next program year or through surveys of the previous three years of installed projects.

Lastly, while the sensitivity analysis provided may be adequate to consider for general program guidance for Union Gas's DSM program goals and targets; Nexant is available to provide additional base-case sensitivity analysis services upon the request of Union Gas. Specifically, sensitivity analysis may be of value to Union Gas for different market segments and ERV/HRV capacities.

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Table 1: Sensitivity analysis of gas savings results of HRV tool for existing buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	Gas Savings (m^3)	Gas Savings Increase (%)	Parameter Value	Gas Savings (m^3)	Gas Savings Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	4,903	0.0%	14 yrs	4,903	0.0%
Incremental Cost	3.40 $/CFM	3.40 $/CFM	4,903	0.0%	3.61 $/CFM	4,903	0.0%
Average Indoor Air Temperature	70 °F	72 °F	5,174	5.5%	70 °F	4,903	0.0%
Average Indoor Relative Humidity	30 %	35 %	4,903	0.0%	30 %	4,903	0.0%
Average Outside Air Temperature (Existing Bldg)	35.5 °F	30.8 °F	5,604	14.3%	37.1 °F	4,672	4.7%
Average Outdoor Relative Humidity	70 %	78 %	4,904	0.0%	73 %	4,903	0.0%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	5,017	2.3%	14.08 psia	4,845	1.2%
No. of Hours in Heating Season (Existing Bldg)	5800 hrs	7330 hrs	6,197	26.4%	5690 hrs	4,810	1.9%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	4,903	0.0%	61 hrs/wk	1,780	63.7%
Effectiveness of Heat Recovery Equipment	70 %	68 %	4,769	-2.7%	55 %	3,891	20.6%
Defrost Control Derating Factor	5 %	0 %	5,161	5.3%	10 %	4,645	5.3%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	5,155	5.1%	85 %	4,730	3.5%

Base Case: Gas Savings = 4,903 m^3. Savings evaluated for existing buildings based on the Warehouse market segment and a 1,000 CFM HRV.

Table 2: Sensitivity analysis of gas savings results of HRV tool for new construction buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	Gas Savings (m^3)	Gas Savings Increase (%)	Parameter Value	Gas Savings (m^3)	Gas Savings Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	4,547	0.0%	14 yrs	4,547	0.0%
Incremental Cost	3.40 $/CFM	3.40 $/CFM	4,547	0.0%	3.61 $/CFM	4,547	0.0%
Average Indoor Air Temperature	70 °F	72 °F	4,770	4.9%	70 °F	4,547	0.0%
Average Indoor Relative Humidity	30 %	35 %	4,547	0.0%	30 %	4,547	0.0%
Average Outside Air Temperature (New Bldg)	31.5 °F	24.2 °F	5,484	20.6%	31.8 °F	4,507	0.9%
Average Outdoor Relative Humidity	70 %	78 %	4,548	0.0%	72 %	4,547	0.0%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	4,652	2.3%	14.08 psia	4,493	1.2%
No. of Hours in Heating Season (New Bldg)	4800 hrs	5741 hrs	5,438	19.6%	4371 hrs	4,140	9.0%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	4,547	0.0%	61 hrs/wk	1,651	63.7%
Effectiveness of Heat Recovery Equipment	70 %	68 %	4,424	-2.7%	55 %	3,614	20.5%
Defrost Control Derating Factor	5 %	0 %	4,786	5.3%	10 %	4,307	5.3%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	4,780	5.1%	85 %	4,386	3.5%

Base Case: Gas Savings = 4,547 m^3. Savings evaluated for new construction buildings based on the Warehouse market segment and a 1,000 CFM HRV.

Table 3: Sensitivity analysis of TRC results of HRV tool for existing buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	TRC ($)	TRC Increase (%)	Parameter Value	TRC ($)	TRC Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	$14,633	0.0%	14 yrs	$11,823	19.2%
Incremental Cost	3.40 $/CFM	3.40 $/CFM	$14,633	0.0%	3.61 $/CFM	$14,433	1.4%
Average Indoor Air Temperature	70 °F	72 °F	$15,618	6.7%	70 °F	$14,633	0.0%
Average Indoor Relative Humidity	30 %	35 %	$14,633	0.0%	30 %	$14,633	0.0%
Average Outside Air Temperature (Existing Bldg)	35.5 °F	30.8 °F	$17,187	17.5%	37.1 °F	$13,789	5.8%
Average Outdoor Relative Humidity	70 %	78 %	$14,634	0.0%	73 %	$14,633	0.0%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	$15,046	2.8%	14.08 psia	$14,420	1.5%
No. of Hours in Heating Season (Existing Bldg)	5800 hrs	7330 hrs	$19,345	32.2%	5690 hrs	$14,294	2.3%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	$14,633	0.0%	61 hrs/wk	$3,256	77.7%
Effectiveness of Heat Recovery Equipment	70 %	68 %	$14,145	-3.3%	55 %	$10,946	25.2%
Defrost Control Derating Factor	5 %	0 %	$15,573	6.4%	10 %	$13,693	6.4%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	$15,549	6.3%	85 %	$14,002	4.3%

Base Case: TRC = $14,633. Savings evaluated for existing buildings based on the Warehouse market segment and a 1,000 CFM HRV.

Table 4: Sensitivity analysis of TRC results of HRV tool for new construction buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	TRC ($)	TRC Increase (%)	Parameter Value	TRC ($)	TRC Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	$13,334	0.0%	14 yrs	$10,728	19.5%
Incremental Cost	3.40 $/CFM	3.40 $/CFM	$13,334	0.0%	3.61 $/CFM	$13,135	1.5%
Average Indoor Air Temperature	70 °F	72 °F	$14,146	6.1%	70 °F	$13,334	0.0%
Average Indoor Relative Humidity	30 %	35 %	$13,334	0.0%	30 %	$13,334	0.0%
Average Outside Air Temperature (New Bldg)	31.5 °F	24.2 °F	$16,748	25.6%	31.8 °F	$13,191	1.1%
Average Outdoor Relative Humidity	70 %	78 %	$13,339	0.0%	72 %	$13,335	0.0%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	$13,717	2.9%	14.08 psia	$13,137	1.5%
No. of Hours in Heating Season (New Bldg)	4800 hrs	5741 hrs	$16,581	24.4%	4371 hrs	$11,854	11.1%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	$13,334	0.0%	61 hrs/wk	$2,784	79.1%
Effectiveness of Heat Recovery Equipment	70 %	68 %	$12,886	-3.4%	55 %	$9,938	25.5%
Defrost Control Derating Factor	5 %	0 %	$14,206	6.5%	10 %	$12,462	6.5%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	$14,183	6.4%	85 %	$12,749	4.4%

Base Case: TRC = $13,334. Savings evaluated for new construction buildings based on the Warehouse market segment and 1,000 CFM HRV.

Table 5: Sensitivity analysis of gas savings results of ERV tool for existing buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	Gas Savings (m^3)	Gas Savings Increase (%)	Parameter Value	Gas Savings (m^3)	Gas Savings Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	5,139	0.0%	14 yrs	5,139	0.0%
Incremental Cost	3.00 $/CFM	3.00 $/CFM	5,139	0.0%	3.18 $/CFM	5,139	0.0%
Average Indoor Air Temperature	70 °F	72 °F	5,557	8.1%	70 °F	5,139	0.0%
Average Indoor Relative Humidity	30 %	35 %	5,577	8.5%	30 %	5,139	0.0%
Average Outside Air Temperature (Existing Bldg)	35.5 °F	30.8 °F	6,041	17.6%	37.1 °F	4,825	6.1%
Average Outdoor Relative Humidity	70 %	73 %	5,065	-1.4%	78 %	4,943	3.8%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	5,237	1.9%	14.08 psia	5,088	1.0%
No. of Hours in Heating Season (Existing Bldg)	5800 hrs	7330 hrs	6,494	26.4%	5690 hrs	5,041	1.9%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	5,139	0.0%	61 hrs/wk	1,962	61.8%
Effectiveness of Heat Recovery Equipment	60 %	78 %	6,598	28.4%	60 %	5,139	0.0%
Defrost Control Derating Factor	5 %	0 %	5,409	5.3%	10 %	4,868	5.3%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	5,402	5.1%	85 %	4,957	3.5%

Base Case: Gas Savings = 5,139 m^3. Savings evaluated for existing buildings based on the Warehouse market segment and a 1,000 CFM ERV.

Table 6: Sensitivity analysis of gas savings results of ERV tool for new construction buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	Gas Savings (m^3)	Gas Savings Increase (%)	Parameter Value	Gas Savings (m^3)	Gas Savings Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	4,888	0.0%	14 yrs	4,888	0.0%
Incremental Cost	3.00 $/CFM	3.00 $/CFM	4,888	0.0%	3.18 $/CFM	4,888	0.0%
Average Indoor Air Temperature	70 °F	72 °F	5,233	7.1%	70 °F	4,888	0.0%
Average Indoor Relative Humidity	30 %	35 %	5,251	7.4%	30 %	4,888	0.0%
Average Outside Air Temperature (New Bldg)	31.5 °F	24.2 °F	6,009	22.9%	31.8 °F	4,840	1.0%
Average Outdoor Relative Humidity	70 %	72 %	4,854	-0.7%	78 %	4,751	2.8%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	4,979	1.9%	14.08 psia	4,841	1.0%
No. of Hours in Heating Season (New Bldg)	4800 hrs	5741 hrs	5,846	19.6%	4371 hrs	4,451	8.9%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	4,888	0.0%	61 hrs/wk	1,775	63.7%
Effectiveness of Heat Recovery Equipment	60 %	78 %	6,266	28.2%	60 %	4,888	0.0%
Defrost Control Derating Factor	5 %	0 %	5,145	5.3%	10 %	4,631	5.3%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	5,139	5.1%	85 %	4,715	3.5%

Base Case: Gas Savings = 4,888 m^3. Savings evaluated for new construction buildings based on the Warehouse market segment and a 1,000 CFM ERV.

Table 7: Sensitivity analysis of TRC results of ERV tool for existing buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	TRC ($)	TRC Increase (%)	Parameter Value	TRC ($)	TRC Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	$15,871	0.0%	14 yrs	$12,926	18.6%
Incremental Cost	3.00 $/CFM	3.00 $/CFM	$15,871	0.0%	3.18 $/CFM	$15,700	1.1%
Average Indoor Air Temperature	70 °F	72 °F	$17,393	9.6%	70 °F	$15,871	0.0%
Average Indoor Relative Humidity	30 %	35 %	$17,467	10.1%	30 %	$15,871	0.0%
Average Outside Air Temperature (Existing Bldg)	35.5 °F	30.8 °F	$19,160	20.7%	37.1 °F	$14,727	7.2%
Average Outdoor Relative Humidity	70 %	73 %	$15,604	-1.7%	78 %	$15,158	4.5%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	$16,227	2.2%	14.08 psia	$15,687	1.2%
No. of Hours in Heating Season (Existing Bldg)	5800 hrs	7330 hrs	$20,809	31.1%	5690 hrs	$15,516	2.2%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	$15,871	0.0%	61 hrs/wk	$4,296	72.9%
Effectiveness of Heat Recovery Equipment	60 %	78 %	$21,186	33.5%	60 %	$15,871	0.0%
Defrost Control Derating Factor	5 %	0 %	$16,856	6.2%	10 %	$14,886	6.2%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	$16,831	6.0%	85 %	$15,210	4.2%

Base Case: TRC = $15,871. Savings evaluated for existing buildings based on the Warehouse market segment and a 1,000 CFM ERV.

Table 8: Sensitivity analysis of TRC results of ERV tool for new construction buildings

		Upper Bound			Lower Bound		
Parameter	Base Case	Parameter Value	TRC ($)	TRC Increase (%)	Parameter Value	TRC ($)	TRC Decrease (%)
Equipment Useful Life	20 yrs	20 yrs	$14,957	0.0%	14 yrs	$12,156	18.7%
Incremental Cost	3.00 $/CFM	3.00 $/CFM	$14,957	0.0%	3.18 $/CFM	$14,786	1.1%
Average Indoor Air Temperature	70 °F	72 °F	$16,215	8.4%	70 °F	$14,957	0.0%
Average Indoor Relative Humidity	30 %	35 %	$16,281	8.9%	30 %	$14,957	0.0%
Average Outside Air Temperature (New Bldg)	31.5 °F	24.2 °F	$19,042	27.3%	31.8 °F	$14,781	1.2%
Average Outdoor Relative Humidity	70 %	72 %	$14,832	-0.8%	78 %	$14,457	3.3%
Atmospheric Pressure (psia)	14.25 psia	14.58 psia	$15,287	2.2%	14.08 psia	$14,787	1.1%
No. of Hours in Heating Season (New Bldg)	4800 hrs	5741 hrs	$18,448	23.3%	4371 hrs	$13,366	10.6%
No. of Hours of Operation Per Week	168 hrs/wk	168 hrs/wk	$14,957	0.0%	61 hrs/wk	$3,616	75.8%
Effectiveness of Heat Recovery Equipment	60 %	78 %	$19,978	33.6%	60 %	$14,957	0.0%
Defrost Control Derating Factor	5 %	0 %	$15,894	6.3%	10 %	$14,020	6.3%
Seasonal Efficiency of Gas-Fired Equipment	82 %	78 %	$15,870	6.1%	85 %	$14,329	4.2%

Base Case: TRC = $14,957. Savings evaluated for new construction buildings based on the Warehouse market segment and a 1,000 CFM ERV.

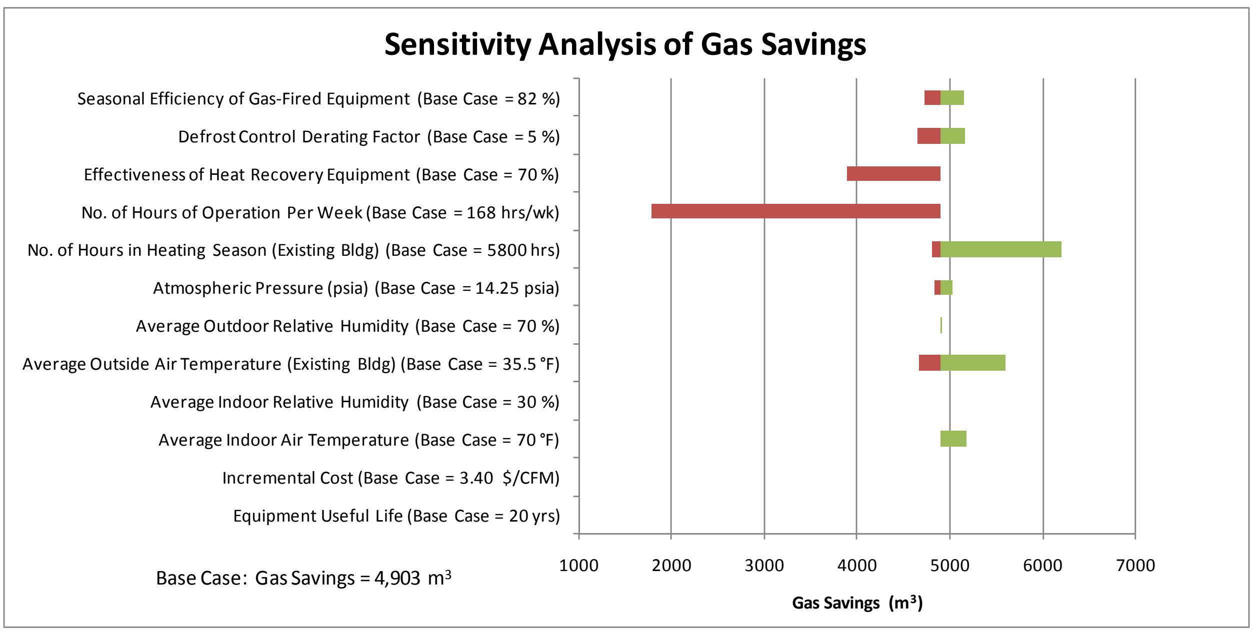

Figure 9-1: Gas savings sensitivity analysis of HRV tool for existing buildings

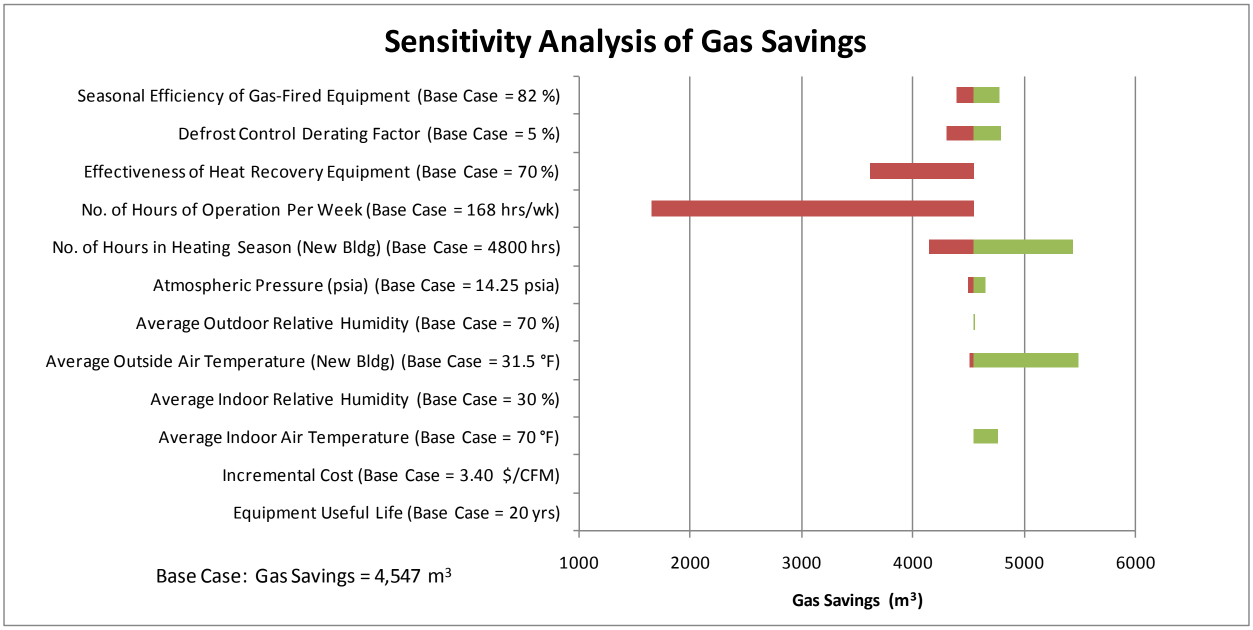

Figure 9-2: Gas savings sensitivity analysis of HRV tool for new construction buildings

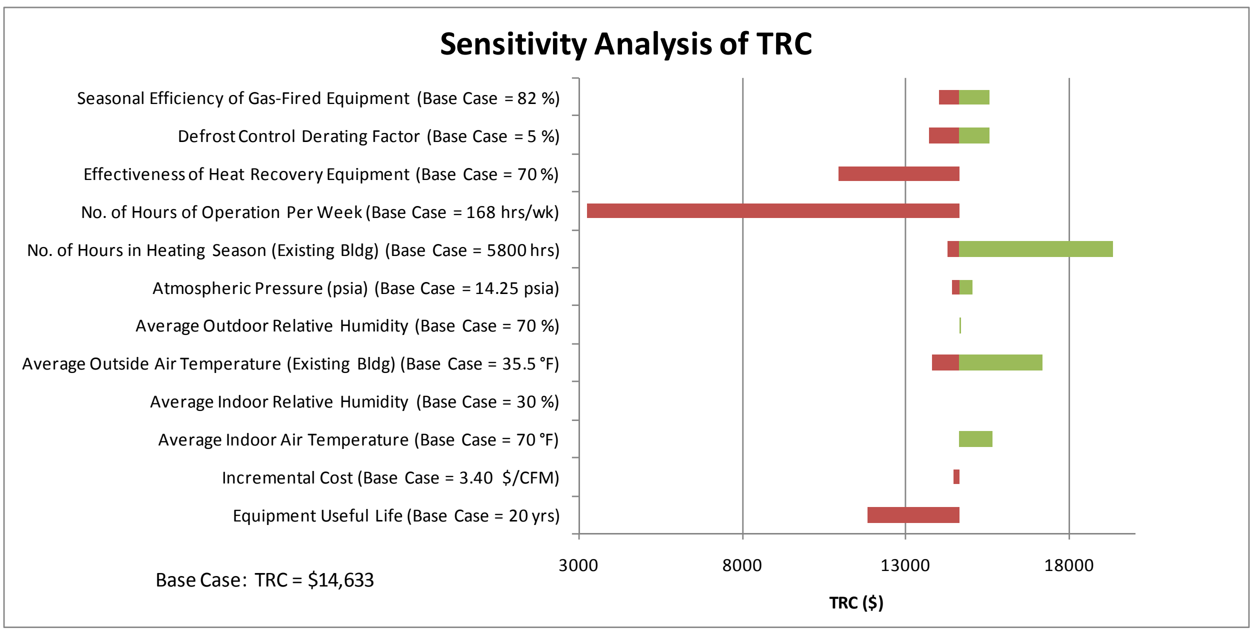

Figure 9-3: TRC sensitivity analysis of HRV tool for existing buildings

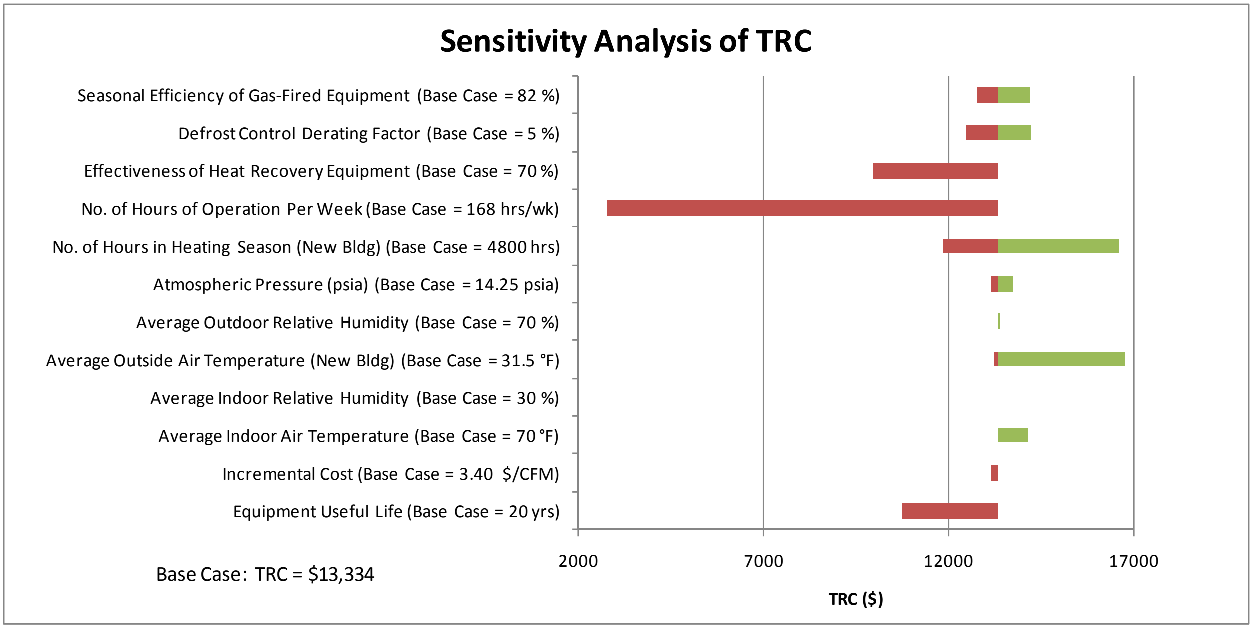

Figure 9-4: TRC sensitivity analysis of HRV tool for new construction buildings

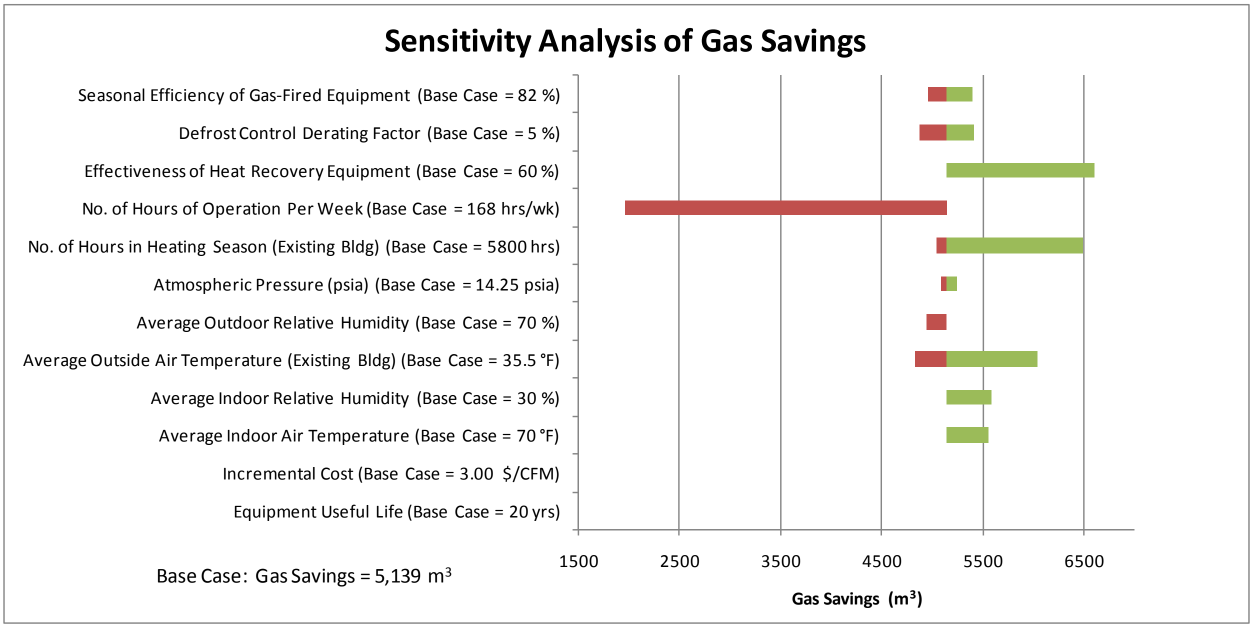

Figure 9-5: Gas savings sensitivity analysis of ERV tool for existing buildings

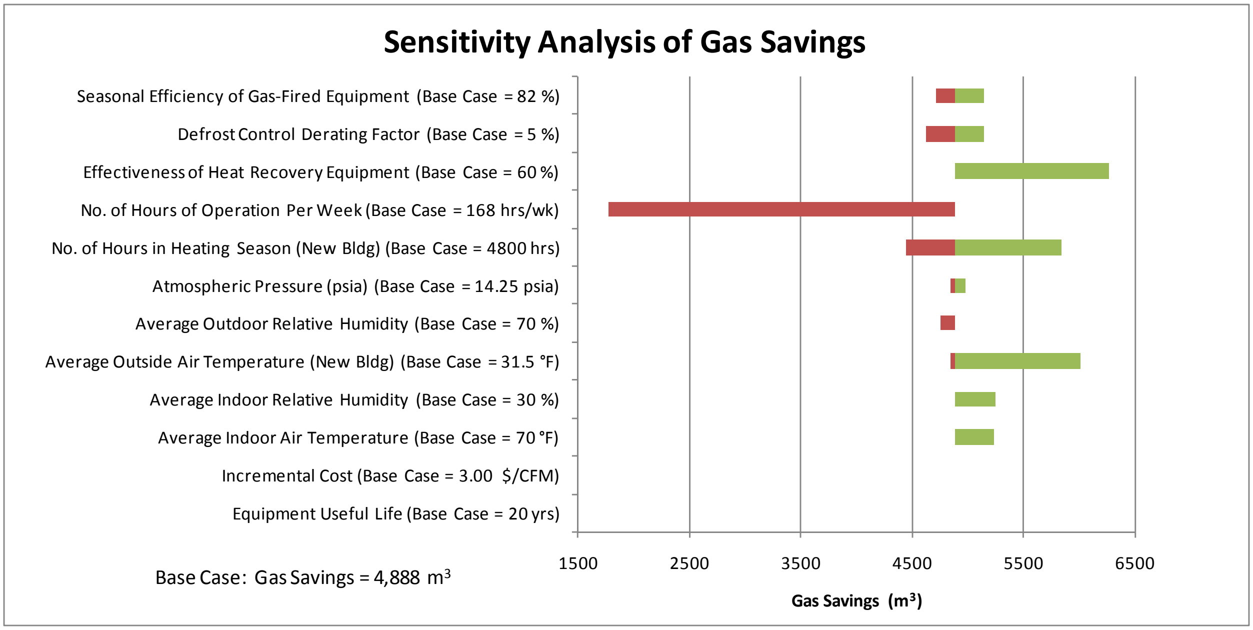

Figure 9-6: Gas savings sensitivity analysis of ERV tool for new construction buildings

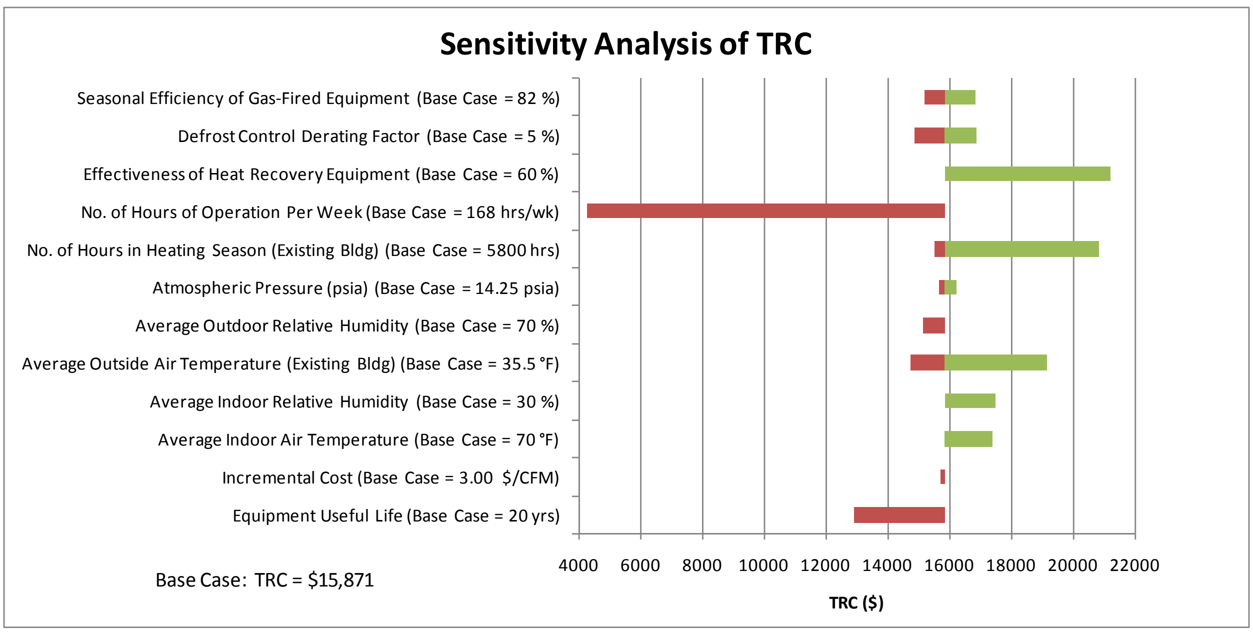

Figure 9-7: TRC sensitivity analysis of ERV tool for existing buildings

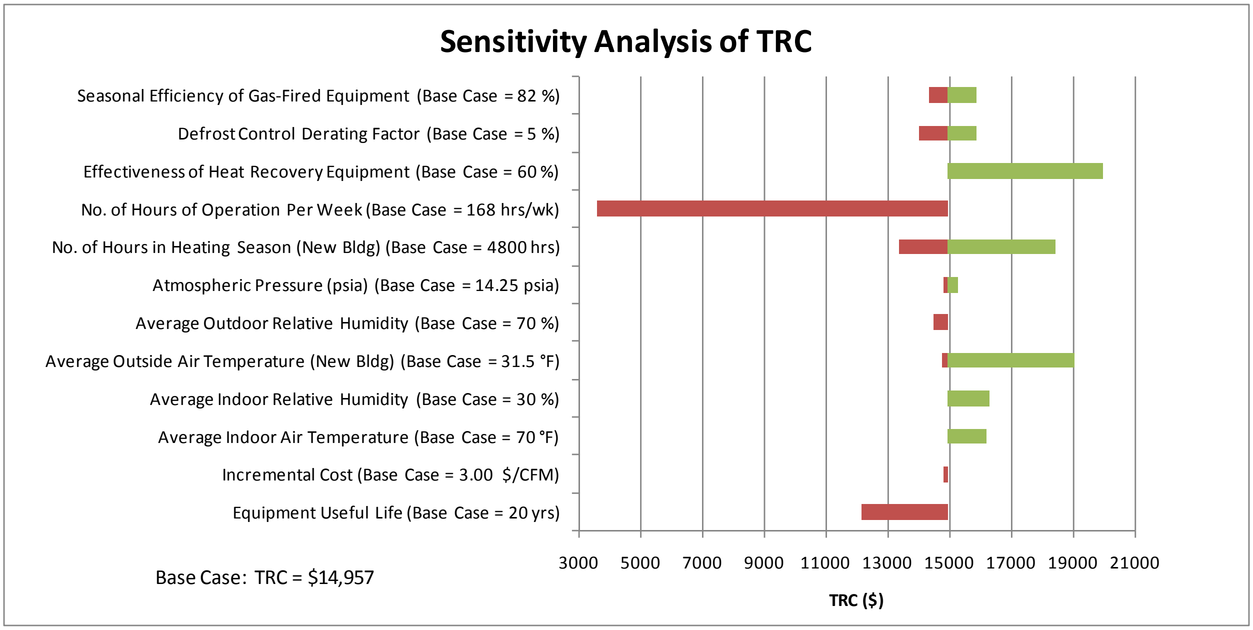

Figure 9-8: TRC sensitivity analysis of ERV tool for new construction buildings

Table 9: RSMEANS air-to-air enthalpy recovery wheel total cost ($CAD)

Size (Max CFM)	RS Means 2005	RS Means 2007	RS Means 2008	RS Means 2009	RS Means 2010
1,000	$5,776	$6,498	$6,834	$7,762	$7,788
2,000	$6,782	$7,659	$8,020	$9,103	$9,129
4,000	$7,943	$8,948	$9,387	$10,624	$10,728
6,000	$9,232	$10,418	$10,934	$12,378	$12,378
8,000	$10,186	$11,553	$12,069	$13,616	$13,719
10,000	$12,172	$13,616	$14,338	$16,195	$16,298

Table 10: Calculated $/CFM by ERV size from RSMEANS cost data

Size (Max CFM)	RS Means 2005	RS Means 2007	RS Means 2008	RS Means 2009	RS Means 2010
1,000	$5.78	$6.50	$6.83	$7.76	$7.79
2,000	$3.39	$3.83	$4.01	$4.55	$4.56
4,000	$1.99	$2.24	$2.35	$2.66	$2.68
6,000	$1.54	$1.74	$1.82	$2.06	$2.06
8,000	$1.27	$1.44	$1.51	$1.70	$1.71
10,000	$1.22	$1.36	$1.43	$1.62	$1.63

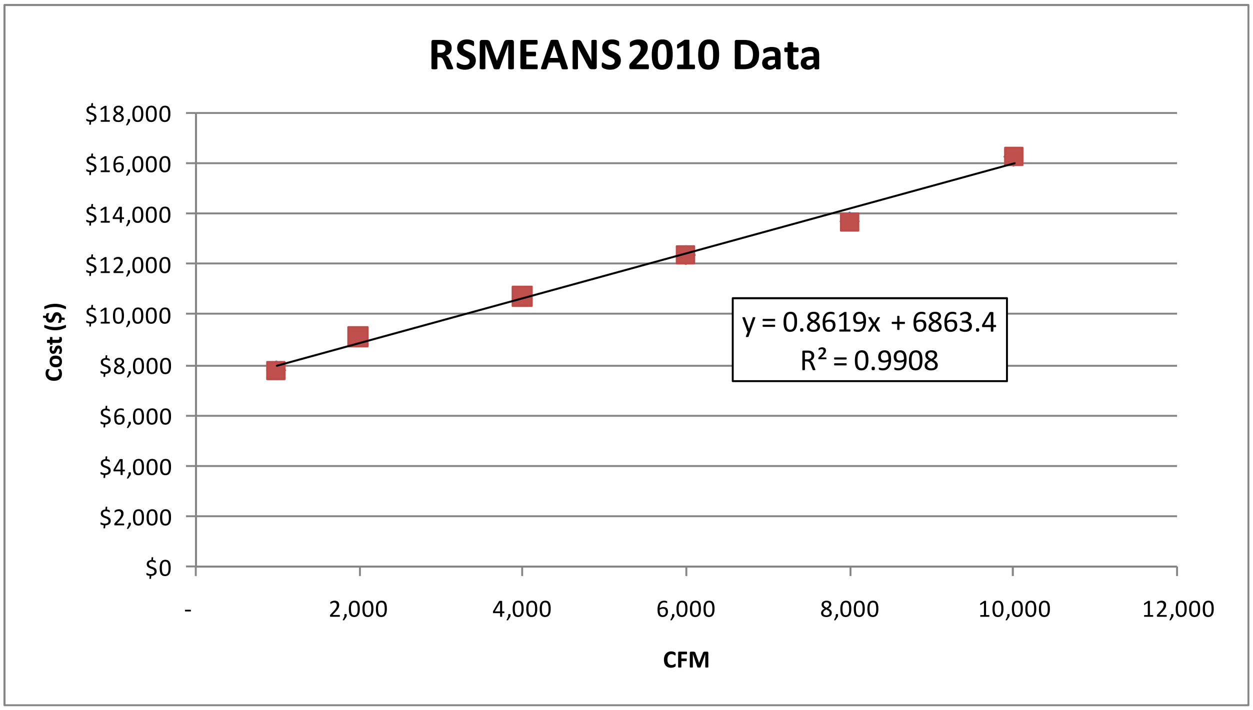

Figure 9: RS Means 2010 Cost Data

Table 11: Equipment Cost Survey ($CAD)

HRV		ERV	
Source: Vendor Quote		Source: Vendor Quote	
SIZE(CFM)	*$/CFM**	*SIZE(CFM)*	*$/CFM**
2000	$5.05	500	$9.49
5000	$5.65	1500	$5.50
8000	$4.31	2000	$5.00
		3000	$3.82
Source: Retailer		4000	$3.04
SIZE(CFM)	*$/CFM**	4000	$3.97
181	$5.72	6000	$4.13
210	$6.18	6500	$4.65
243	$5.21	Source: Retailer	
440	$5.81	*SIZE(CFM)*	*$/CFM**
650	$5.55	192	$5.90
650	$3.56	218	$6.98
792	$3.79	302	$8.31
873	$4.33	400	$6.40
873	$4.41	542	$4.25
1150	$3.57	612	$6.02
1150	$2.30	865	$3.67
1201	$2.62	1022	$5.18
1201	$2.62	1250	$4.45
1410	$2.37	Source: RSMeans	
1601	$2.97	*SIZE(CFM)*	*$/CFM**
1601	$2.58	1000	$5.42
2590	$3.01	2000	$3.17
2590	$3.43	4000	$1.84
3790	$2.57	6000	$1.43
3790	$2.94	8000	$1.19
5250	$2.12	10000	$1.13
**all costs converted to Canadian Dollars using $1 USD = $1.031 CAD*			

HRV Summary		ERV Summary	
Range	*Avg. $/CFM*	*Range*	*Avg. $/CFM*
Overall	$3.86	Overall	$4.56
under 1,000	$4.95	under 1,000	$6.38
1,000-2,000	$3.01	1,000-2,000	$4.79
2,000-5,000	$3.52	2,000-5,000	$3.17
5,000-10,000	$4.03	5,000-10,000	$2.51

Table 12: **Existing and recommended hours of operation per week based on market segment**

	Typical Hrs of Operation per week							
Market Segment	Existing Value	CL&P Value†	DEER Value†	KEMA Value	MEC/NEA Value	Eff. VT Value	Avg. of Lighting Hours†	Avg. of Reported Operating Hours	Recommended Value
Multi-Family	168	147	NA	NA	NA	NA	147	NA	168
Hotel	*168*	*59*	*168*	*164*	*157*	*52*	*114*	*124*	***120***
Restaurant	*108*	*80*	*93*	*93*	*NA*	*80*	*87*	*87*	***87***
Retail	*108*	*78*	*87*	*66*	*73*	*59*	*83*	*66*	***73***
Office	*60*	*72*	*50*	*62*	*69*	*66*	*61*	*66*	***64***
School	*84*	*42*	*70*	*56*	*62*	*40*	*56*	*53*	***54***
Health Care	168	147	168	NA	123	NA	158	123	168
Nursing Home	168	112	168	NA	168	NA	140	168	168
Warehouse	*168*	*50*	*55*	*74*	*81*	*46*	*53*	*67*	***61***

†Study values based on facility lighting hours.

Table 13: Results from changing input assumptions for the HRV tool for existing buildings

Parameter	Symbol	Existing Value	Nexant Recommended Value (London, ON)	Nexant Recommended Value (North Bay, ON)	Nexant Recommended Value (Windsor, ON)	Units
Equipment Useful Life	4	20	14	14	14	yrs
Incremental Cost	5	3.40	3.61	3.61	3.61	$/CFM
Average Outside Air Temperature	E	31.5	30.2	24.2	31.8	°F
Average Outdoor Relative Humidity	F	70	75	75	75	%
No. of Hours in Heating Season	H	4,800	4,846	5,413	4371	hrs
Effectiveness of Heat Recovery Equipment	K	70	61	61	61	%
Gas Savings	-	4,547	4,182	5,447	3602	m^3
TRC	-	13,334	9,410	13,292	7628	$

HRV - New Construction Tool. Base Case: 1,000 CFM HRV Capacity, 168 hrs per week operation

Table 14: Results from changing input assumptions for the HRV tool for new construction buildings

Parameter	Symbol	Existing Value	Nexant Recommended Value (London, ON)	Nexant Recommended Value (North Bay, ON)	Nexant Recommended Value (Windsor, ON)	Units
Equipment Useful Life	4	20	14	14	14	yrs
Incremental Cost	5	3.40	3.61	3.61	3.61	$/CFM
Average Outside Air Temperature	E	31.5	35.9	30.9	37.1	°F
Average Outdoor Relative Humidity	F	70	75	75	75	%
No. of Hours in Heating Season	H	4,800	6,306	6,903	5690	hrs
Effectiveness of Heat Recovery Equipment	K	70	61	61	61	%
Gas Savings	-	4,547	4,618	5,840	4017	m^3
TRC	-	13,334	10,748	14,500	8902	$

HRV - Existing Building Tool. Base Case: 1,000 CFM HRV Capacity, 168 hrs per week operation

Table 15: Results from changing input assumptions for the ERV tool for existing buildings

Parameter	Symbol	Existing Value	Nexant Recommended Value (London, ON)	Nexant Recommended Value (North Bay, ON)	Nexant Recommended Value (Windsor, ON)	Units
Equipment Useful Life	4	20	14	14	14	yrs
Incremental Cost	5	3.40	3.18	3.18	3.18	$/CFM
Average Outside Air Temperature	E	31.5	30.2	24.2	31.8	°F
Average Outdoor Relative Humidity	F	70	75	75	75	%
No. of Hours in Heating Season	H	4,800	4,846	5,413	4371	hrs
Effectiveness of Heat Recovery Equipment	K	70	67	67	67	%
Gas Savings	-	4,547	5,621	7,441	4807	m^3
TRC	-	13,334	14,235	19,823	11736	$

ERV - New Construction Tool. Base Case: 1,000 CFM ERV Capacity, 168 hrs per week operation

Table 16: Results from changing input assumptions for the ERV tool for new construction buildings

Parameter	Symbol	Existing Value	Nexant Recommended Value (London, ON)	Nexant Recommended Value (North Bay, ON)	Nexant Recommended Value (Windsor, ON)	Units
Equipment Useful Life	4	20	14	14	14	yrs
Incremental Cost	5	3.40	3.18	3.18	3.18	$/CFM
Average Outside Air Temperature	E	31.5	35.9	30.9	37.1	°F
Average Outdoor Relative Humidity	F	70	75	75	75	%
No. of Hours in Heating Season	H	4,800	6,306	6,903	5690	hrs
Effectiveness of Heat Recovery Equipment	K	70	67	67	67	%
Gas Savings	-	4,547	5,965	7,826	5119	m^3
TRC	-	13,334	15,291	21,005	12695	$

ERV - Existing Building Tool. Base Case: 1,000 CFM ERV Capacity, 168 hrs per week operation

Table 17: Results from changing input assumptions for the HRV tool for existing buildings – Warehouse Market Segment

Parameter	Symbol	Existing Value	Nexant Recommended Value (London, ON)	Nexant Recommended Value (North Bay, ON)	Nexant Recommended Value (Windsor, ON)	Units
Equipment Useful Life	4	20	14	14	14	yrs
Incremental Cost	5	3.40	3.61	3.61	3.61	$/CFM
Average Outside Air Temperature	E	31.5	30.2	24.2	31.8	°F
Average Outdoor Relative Humidity	F	70	75	75	75	%
No. of Hours in Heating Season	H	4,800	4,846	5,413	4371	hrs
No. of Hours of Operation Per Week (Warehouse)	I2	168	61	61	61	hrs/wk
Effectiveness of Heat Recovery Equipment	K	70	61	61	61	%
Gas Savings	-	4,547	1,519	1,978	1308	m^3
TRC	-	13,334	1,233	2,642	585	$

HRV - New Construction Tool. Base Case: 1,000 CFM HRV Capacity, Warehouse market segment

Table 18: Results from changing input assumptions for the HRV tool for new construction buildings – Warehouse Market Segment

Parameter	Symbol	Existing Value	Nexant Recommended Value (London, ON)	Nexant Recommended Value (North Bay, ON)	Nexant Recommended Value (Windsor, ON)	Units
Equipment Useful Life	4	20	14	14	14	yrs
Incremental Cost	5	3.40	3.61	3.61	3.61	$/CFM
Average Outside Air Temperature	E	31.5	35.9	30.9	37.1	°F
Average Outdoor Relative Humidity	F	70	75	75	75	%
No. of Hours in Heating Season	H	4,800	6,306	6,903	5690	hrs
No. of Hours of Operation Per Week (Warehouse)	I2	168	61	61	61	hrs/wk
Effectiveness of Heat Recovery Equipment	K	70	61	61	61	%
Gas Savings	-	4,547	1,677	2,121	1459	m^3
TRC	-	13,334	1,718	3,080	1048	$

HRV - Existing Building Tool. Base Case: 1,000 CFM HRV Capacity, Warehouse market segment

Table 19: Results from changing input assumptions for the ERV tool for existing buildings – Warehouse Market Segment

Parameter	Symbol	Existing Value	Nexant Recommended Value (London, ON)	Nexant Recommended Value (North Bay, ON)	Nexant Recommended Value (Windsor, ON)	Units
Equipment Useful Life	4	20	14	14	14	yrs
Incremental Cost	5	3.40	3.18	3.18	3.18	$/CFM
Average Outside Air Temperature	E	31.5	30.2	24.2	31.8	°F
Average Outdoor Relative Humidity	F	70	75	75	75	%
No. of Hours in Heating Season	H	4,800	4,846	5,413	4371	hrs
No. of Hours of Operation Per Week (Warehouse)	I2	168	61	61	61	hrs/wk
Effectiveness of Heat Recovery Equipment	K	70	67	67	67	%
Gas Savings	-	4,547	2,041	2,702	1745	m^3
TRC	-	13,334	3,244	5,274	2337	$

ERV - New Construction Tool. Base Case: 1,000 CFM ERV Capacity, Warehouse market segment

Table 20: Results from changing input assumptions for the ERV tool for new construction buildings – Warehouse Market Segment

Parameter	Symbol	Existing Value	Nexant Recommended Value (London, ON)	Nexant Recommended Value (North Bay, ON)	Nexant Recommended Value (Windsor, ON)	Units
Equipment Useful Life	4	20	14	14	14	yrs
Incremental Cost	5	3.40	3.18	3.18	3.18	$/CFM
Average Outside Air Temperature	E	31.5	35.9	30.9	37.1	°F
Average Outdoor Relative Humidity	F	70	75	75	75	%
No. of Hours in Heating Season	H	4,800	6,306	6,903	5690	hrs
No. of Hours of Operation Per Week (Warehouse)	I2	168	61	61	61	hrs/wk
Effectiveness of Heat Recovery Equipment	K	70	67	67	67	%
Gas Savings	-	4,547	2,166	2,842	1859	m^3
TRC	-	13,334	3,628	5,703	2686	$

ERV - Existing Building Tool. Base Case: 1,000 CFM ERV Capacity, Warehouse market segment

Nexant

Nexant, Inc.
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SEC INTERROGATORY #1

INTERROGATORY

[Ex. B/1/1, p. 2]

Each year the assumptions filed by the Utilities includes a cover communication explaining limitations on the approval of the filing by the TEC. Please file the most recent such communication provided to the Board by the Utilities.

RESPONSE

The cover letter included in this Technical Reference Manual ("TRM") Application (EB-2016-0246) has been included per SEC's request and found as an Attachment to this Exhibit.

Witnesses: D. Bullock
L. Kulperger

Kevin Culbert
Manager, Regulatory Policy, & Strategy
Regulatory Affairs

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kevin.culbert@enbridge.com

Enbridge Gas Distribution
500 Consumers Road
North York, Ontario M2J 1P8
Canada

December 21, 2016

VIA RESS, EMAIL and COURIER

Ms. Kirsten Walli
Board Secretary
Ontario Energy Board
2300 Yonge Street, Suite 2700
Toronto, Ontario, M4P 1E4

Dear Ms. Walli:

Re: Enbridge Gas Distribution Inc. ("Enbridge")
Ontario Energy Board ("Board") File Number EB-2016-0246
Joint Submission by Enbridge Gas Distribution Inc. and Union Gas Limited

Enbridge Gas Distribution Inc. ("Enbridge") and Union Gas Limited ("Union"), (collectively the "Utilities") jointly bring the attached application seeking the approval of the Ontario Energy Board (the "Board") for new and updated DSM measures and the Technical Reference Manual ("TRM") (together the "Application").

In the DSM Guidelines for Natural Gas Utilities (EB-2008-0346), the Board directed the Utilities to make an annual application to update input assumptions and encouraged the Utilities to file a joint application. Pursuant to the Joint Terms of Reference on Stakeholder Engagement for DSM Activities by Union and Enbridge ("ToR") dated November 4, 2011, one of the Technical Evaluation Committee's ("TEC") primary task was the development of a TRM for natural gas DSM activities.

Under cover of a letter dated December 16, 2015 the Utilities jointly filed an application for approval of new and updated DSM input assumptions (EB-2015-0344) (the "2015 Update"). In response to the 2015 Update, the Board issued a letter dated April 26, 2016 which stated that a preliminary review of the 2015 Update application determined that it was not required at the time and therefore would not be processed. The Board referenced the ongoing work on the TRM and stated its expectation that when the TRM is finalized, the Utilities would file an update to the 2015 Update application. Consistent with the Board's directive, this Application therefore seeks approval for both new and updated DSM measures and the TRM.

The TRM is the culmination of several years of effort with the Utilities working with the joint TEC and the TRM sub-committee which was struck for the purposes of ultimately finalizing the TRM. In consultation with the TEC, a determination was made as to those measures which should undergo a review for the purposes of the TRM. This resulted in the generation of a prioritized list of measures which were provided to the third party consultant, Energy & Resource Solutions ("ERS"), retained by the TEC to assist with the development of the TRM. The TEC included representatives from each of the Utilities, Mr. Chris Neme, Ms. Julie Girvan and Mr. Jay Shepherd. It also included two independent members, Mr. Bob Wirtshafter and Mr. Ted Kesik. The TRM sub-committee included Mr. Chris Neme and Mr. Ted Kesik.

Since the 2015 Update was filed, ERS has completed its work and the first version of the TRM is included in this Application. The TRM includes all new and updated measures and related substantiation documentation. In addition, an Ontario TRM glossary, TRM Common Assumptions Table and a TRM Front Section (which provides an overview of the TRM) have been developed and are included.

After much effort, the TRM is now in a form where each of the members of the TEC and TRM sub-committee agree that the TRM should be filed with the Board. All of these members with one exception endorse the TRM as filed. While Mr. Shepherd has expressed concerns about several specific matters, he is not opposed to the filing of the TRM as it is believed that these issues can be addressed as part of this Application.

While it is an objective of the ToR that a consensus be reached where possible, the ToR specifically note at page 10 that: "The Committee will endeavour to reach consensus on its recommendations. Where consensus is not reached, the Committee members will outline their respective positions in the appropriate Board processes (…annual submission to Update Input Assumptions…)". Accordingly, the Utilities are of the view that it is appropriate at this time to file the TRM for review by the Board.

Consistent with section 8 of the 2015-2020 Multi-Year DSM Framework (EB-2014-0134) and the Boards stated intent of coordinating the process to annually update input assumptions, Board Staff were involved in various TEC and TRM sub-committee meetings and received copies of communications over the course of the year leading to the completion of the TRM.

This Application seeks approval for an update to the Summary Table of Measure Assumptions and Substantiation Documents, and the TRM.

This Application includes:

- Current approved Summary Table of Measure Assumptions and Substantiation Documentation as updated by the 2015 Update and the subsequent work of ERS and the TEC;
- TRM Front Section
- TRM Glossary
- TRM Common Assumptions Table
- Union's Custom EUL Table
- Enbridge's Measure Life Guide

- Measure Assumptions previously included as part of the 2015 Update:
    - Residential Adaptive Thermostat (New Construction/Retrofit)
    - Commercial Condensing Tankless Gas Water Heater (New Construction/ Time of Natural Replacement)
    - Commercial Kitchen Demand Controlled Ventilation (Retrofit)
    - Commercial Kitchen Demand Controlled Ventilation (New Construction/Time of Natural Replacement)
    - Commercial Condensing Make Up Air Unit (New Construction/Time of Natural Replacement)
    - Commercial Condensing Storage Gas Water Heater (New Construction/Time of Natural Replacement)
    - Commercial Condensing Unit Heater (New Construction/Time of Natural Replacement)
    - Commercial Infrared Heater (New Construction)
    - Commercial Infrared Heater (Retrofit)

- Commercial Pre-rinse Spray Nozzle (New Construction/Time of Natural Replacement/Retrofit)
- Residential Programmable Thermostat (Retrofit)
- Residential High Efficiency Condensing Furnace (New Construction/Time of Natural Replacement)
- Residential Low-Flow Showerheads
- Residential Tankless Water Heater (New Construction/Time of Natural Replacement)
- Commercial Air Curtains (New Construction/Retrofit)
- Commercial Destratification Fans (New Construction/Retrofit)
- Commercial High Efficiency Condensing Furnace (New Construction/ Time of Natural Replacement
- Commercial Heat Recovery Ventilator (New Construction/Retrofit)
- Commercial Energy Recovery Ventilator (New Construction/Retrofit)
- Commercial Heat Recovery Ventilator (50% effectiveness baseline)
- Commercial Energy Recovery Ventilator (50% effectiveness baseline)
- Residential Heat Reflector Panels
- Commercial Multi-Residential Showerhead

- Measure Assumptions reviewed and endorsed subsequent to the 2015 Update:
  - Residential High Efficiency Water Heaters (New Construction)
  - Residential Pipe Wrap (Retrofit)
  - Residential Low Flow Faucet Aerators (Retrofit)
  - Commercial Ozone Laundry (New Construction/Retrofit)
  - Commercial High Efficiency Under-Fired Broiler (New Construction/Time of Natural Replacement)
  - Commercial ENERGY STAR Convection Oven (New Construction/Time of Natural Replacement)
  - Commercial ENERGY STAR Dishwasher (New Construction/Time of Natural Replacement)
  - Commercial ENERGY STAR Fryer (New Construction/Time of Natural Replacement)
  - Commercial ENERGY STAR Steam Cooker (New Construction/Time of Natural Replacement)
  - Commercial Demand Control Ventilation New Construction/Time of Natural Replacement)
  - Commercial Demand Control Ventilation (Retrofit)

The application contains the following exhibits:

Exhibit A, Tab 1, Schedule 1 Table of Contents
Exhibit B, Tab 1, Schedule 1 Background and Introduction
Exhibit B, Tab 1, Schedule 2 Updated Summary Table of Measure Assumptions
Exhibit B, Tab 1, Schedule 3 TRM Front Section
Exhibit B, Tab 1, Schedule 4 TRM Common Assumptions Table
Exhibit B, Tab 1, Schedule 5 TRM Glossary
Exhibit B, Tab 1, Schedule 6 New and Updated Substantiation Documents

As this Application has been filed jointly, please direct correspondence to the following representatives of the Utilities:

Vanessa Innis
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vinnis@uniongas.com
(519) 436-5334

Crawford Smith
Torys LLP
asmith@torys.com
416-865-8209

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EGDRegulatoryProceedings@enbridge.com
416- 495-5499

Dennis M. O'Leary
Aird & Berlis LLP
doleary@airdberlis.com
416-865-4711

Enbridge and Union respectfully request the Board's approval of the new and updated DSM measures and the TRM.

Sincerely,

(Original Signed)

Kevin Culbert
Manager, Regulatory & Policy Strategy

c.c: Dennis M. O'Leary (Aird & Berlis)
Crawford Smith (Torys)
Vanessa Innis (Union Gas)
EB-2015-0029/EB-2015-0049 Intervenors

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

SEC INTERROGATORY #2

INTERROGATORY

[B/1/1, p. 4]

Please confirm that the Union Custom EUL Table and the Enbridge Measure Life Guide for Custom Offers have not been approved by the TEC or by the Board. Please describe in detail any approvals that have been given by any person other than the Utilities to these documents. Please confirm that, in seeking approval from the Board for these documents, the Utilities are asking the Board to look at these documents, and the information within them, with a view to approving them for the first time.

RESPONSE

Not confirmed.

The Utilities have included measure life assumptions for commercial and industrial Custom Offers in input assumption filings for at least ten years. Over that period, measure lives contained therein have been employed by the Utilities for the purpose of forecasting savings to support defining targets, determining cost-effectiveness, calculating lifetime natural gas savings and have been subject to review and update by multiple independent auditors and audit committees through the annual audit process and through Custom Project Savings Verification. The values contained in the Utilities' respective guides recommend a measure life for particular technologies.

Per the 2014 program year, the Utilities further note that prior years' Demand Side Management ("DSM") variance and deferral accounts clearance applications were based upon, at least in part, measure lives taken from these tables, and have been the subject of a complete settlement. It is therefore inaccurate to suggest that this is the first time that many of the measure lives have been before the Board.

Union's custom Effective Useful Life ("EUL") table shown in Exhibit B, Tab 1, Schedule 2 was approved as part of Union's 2015-2020 DSM Plan Board filing (EB-2015-0029, Exhibit A, Tab 3, Appendix D).

In Enbridge's case, the table below summarizes updates made to the Enbridge Measure Life Guide shown in Exhibit B, Tab 1, Schedule 2, p. 15, since those detailed

Witnesses: D. Bullock
L. Kulperger

in the March 27th, 2015 New & Updated DSM Measures filing (EB-2014-0354) approved by the Board on July 23, 2015:

Updates to Enbridge's Measure Life Guide

Measure	**Nature of Update**	**Supporting Reference**	**Notes**
Infrared Heaters	Increase from 10 to 17 years	Technical Reference Manual substantiation document, endorsed by TEC May 28, 2015	Previously noted in the Dec 16, 2015 New & Updated DSM Measures filing (EB-2015-0344)
Heat Reflector Panels	Increase from 15 to 25 years	Technical Reference Manual substantiation document, endorsed by TEC May 28, 2015	Previously noted in the Dec 16, 2015 New & Updated DSM Measures filing (EB-2015-0344)
Steam Pipe/ Tank Insulation	Increase from 15 to 20 years	2011 ASHRAE Handbook – HVAC Applications, Chapter 37, Table 4	Previously noted in the Dec 16, 2015 New & Updated DSM Measures filing (EB-2015-0344)
Steam Trap	Increase from 5 to 6 years	Massachusetts 2013 Prescriptive Gas Impact Evaluation, Steam Trap Evaluation, June 17, 2015	Previously noted in the Dec 16, 2015 New & Updated DSM Measures filing (EB-2015-0344)
Home Energy Conservation	25 years for all projects	Union's 2015-2020 DSM Plan Board filing (EB-2015-0029) approved by the Board January 16, 2016.	Please also see response to Exhibit I.EGDI.SEC.5 a).

As previously noted in the December 16, 2015 New & Updated DSM Measures filing (EB-2015-0344), Exhibit B, Tab 1, Schedule 1, p. 5, in reference to Enbridge's Measure Life Guide, the supporting reference/source was updated in a few cases to reflect updated/best available information with no resulting change to the measure life assumption.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #3

INTERROGATORY

[B/1/2, p 1-10] With respect to the TRM Summary table:

a. Please confirm that the Utilities are not seeking direct or indirect approval of any of the free rider rates in these pages. If the free rider rates are up for approval, please provide the evidentiary basis of each of those rates.

b. Please confirm that the Utilities are seeking approval for the assumptions provided in the subdocs, and not the summary table. Please confirm that, in the event of any disparity in any given situation between the relevant subdoc, and the summary table, the subdoc will apply.

c. For each measure for which the Utility does not either arrange or verify installation of the measure (e.g. showerheads, thermostats, aerators, etc.), please describe how savings assumptions are adjusted to account for the probability of installation of the measure.

RESPONSE

a) The Free Rider rates for existing measures included in the Technical Reference Manual ("TRM") filing are considered by the Utilities to be best available information and reflect previously Board approved input assumptions as filed (EB-2015-0029 and EB-2014-0354).

Reassessment of free rider rates was determined by the Technical Evaluation Committee ("TEC") to be out of the scope of the TRM. The Utilities are not seeking direct or indirect approval of Net to Gross values in the current application, with the exception of Adaptive Thermostats, a new measure first brought forward in the December 16, 2015 New and Updated DSM Measures joint application EB-2015-0344.

For Adaptive Thermostats, a Free Ridership rate of 4% is proposed for Residential based on best available information (EB-2015-0344, Exhibit B, Tab 1, Schedule 1, p.4). A Free Ridership rate of 0% is submitted for Low Income (Enbridge) and 1% (Union) as per EB-2012-0394 (Enbridge) and EB 2012-0441 (Union).

Witnesses: D. Bullock
L. Kulperger

b) Confirmed.

c) As outlined in Section 7.1 of the Filing Guidelines to the DSM Framework for Natural Gas Distributors (EB-2014-0134) and further detailed in the August 21, 2015 2015-2020 DSM Evaluation Process of Program Results (EB-2015-0245) letter from the Board, the new DSM evaluation governance involves a third party Evaluation Contractor ("EC") retained by the Board. The EC will carry out the evaluation and audit processes of all DSM programs, including an annual update of input assumptions and assessing any potential adjustment factors needed.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #4

INTERROGATORY

[B/1/2, p. 11-14] With respect to the Union Gas EUL table:

a. Where no source is listed for any EUL, please explain the evidentiary basis on which Union Gas is seeking the Board's approval for these assumptions.

b. Please provide references 1, 5, 9, 10, and 11. For each of the references that is Audited Results, please provide both the Audit Report and the Report of the Audit Committee.

c. Please provide a reference for the Board's approval of the values under the column "2016-2020".

d. [also reference B/1/5, p. 6] Please advise which of the EULs is Equipment Life only, and which are adjusted for Measure Persistence. In the latter case, please advise the limitations presented by persistence, including business turnover forecasts, forecast early replacement, and any other limits.

RESPONSE

a) Union's Custom Measure Effective Useful Life ("EUL") table was approved by the Board as part of the 2015-2020 Plan filing (Decision and Order, EB-2015-0029).[1] No changes to EULs have been made since that filing.

b) Reference 1 – **Union Gas Limited – 2011 Opportunity Screening Commercial Market Segment (Redacted)**. (Attached to this Exhibit)

   Reference 5 – **Union Gas Limited – 2010 DSM Audit and Results**
   http://www.ontarioenergyboard.ca/oeb/_Documents/RRR/RRR_Union_DSM_Reports_2-1-12_2010.pdf

[1] Union filed its custom EUL table in its 2015-2020 DSM Plan, Exhibit A, Tab 3, Appendix D.

Reference 9 – **Union Gas Limited – 2011 DSM Audit and Results**
http://www.ontarioenergyboard.ca/oeb/_Documents/RRR/RRR_Union_DSM_Reports_2-1-12_2011.pdf

Reference 10 – **Union Gas Limited – 2012 DSM Audit and Results**
http://www.ontarioenergyboard.ca/documents/2012_UGL_DSM_Audit_Documents.pdf

Reference 11 – **Union Gas Limited – 2013 DSM Audit and Results**
http://www.rds.ontarioenergyboard.ca/webdrawer/webdrawer.dll/webdrawer/rec/457797/view/UNION_APPL_2013%20DSM%20Deferrals_redacted_20141201.PDF

c) This table was included in Union's 2015-2020 DSM Plan (EB-2015-0029) evidence at Exhibit A, Tab 3, Appendix D. The Board approved the plan in its Decision and Order EB-2015-0029/EB-2015-0049 on January 20, 2016.

d) Exhibit B, Tab 1, Schedule 5, p. 6 provides the Technical Reference Manual ("TRM") glossary. The TRM Glossary addresses the prescriptive and quasi-prescriptive substantiation documents contained in the TRM. The TRM Glossary does not provide definitions for custom projects and/or the Custom EUL Table. The Custom EUL table provides a guideline for the measure life only.

As per the Board's letter of August 21, 2015 (EB-2015-0245), an Evaluation Contractor ("EC") will be responsible for undertaking various studies which may include "examining the level of persisting natural gas savings from various programs and conducting other evaluation studies as required."

Witnesses: L. Kulperger

DRAFT report for:

2011 OPPORTUNITY SCREENING

COMMERCIAL MARKET SEGMENT

Presented to

Union Gas Limited
777 Bay Street, Suite 2801
PO Box 153
Toronto, ON M5G 2C8
Attention: [redacted]

MAY 2, 2011

NAVIGANT
Navigant
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TABLE OF CONTENTS

NAVIGANT

EXECUTIVE SUMMARY

Union Gas (UG) has identified several potential commercial market DSM opportunities that it wishes to investigate for potential for inclusion in the 2011 DSM program. UG engaged Navigant to perform a screening test of these ideas before investing the time and resources required to fully assess the DSM potential of individual measures.

The focus of this project was to apply information that is readily and publically available to determine the measure inputs for each idea and to assess if the idea is likely to be TRC positive. Given the nature of the screening and timeline of UG's needs; estimates or single reference data were used where multiple, authoritative references would be required in regular DSM research.

Table ES-1 summarizes the results of Navigant's measure research. Measures are ordered from highest market TRC potential (net benefits) to lowest. Considerations for each of the top seven measures (based on market TRC potential) are listed below:

Thermodynamic Process Controls (TPC) for Boilers:

This technology is applicable to almost any boiler system and can save up to 33% based on manufacturer provided case studies. No third part evaluations exist; however, demonstrations in Union Gas territory could help verify savings. The manufacturer has expressed interest in assisting Union Gas by providing additional information needed regarding this technology.

Commercial Weatherization - Air Sealing

The data available that documents energy savings from air sealing shows a large range of possible savings (from 3-36%). Programs from other utilities often combine air sealing with added insulation or some other HVAC retrofits in the commercial sector making it difficult to attribute cost and savings specifically to air sealing. Nonetheless, it is a cross cutting cost effective measure with significant potential. Local case studies and demonstrations may be needed to better understand savings.

Shipping Dock Opportunities

The technology examined reduces air leaks at loading docks when trucks are unloading. Leakages can be reduced by up to 84%. A large uncertainty is this analysis is the number of docks that currently utilize this technology. The manufacturer did not have an estimate they were willing to be quoted on. Additional research is needed to understand the current market penetration. The manufacturer indicated they are willing to provide any information needed to Union Gas for further assessments of this technology.

DART Constant Air Volume Controls for Existing Buildings

This measure can save up to 16% of a building's space heating energy use and up to 22% of its cooling energy use. It is most applicable to large facilities. However, the data used to estimate savings is limited. Navigant does not believe that there is sufficient information available at this time for this technology to be promoted with prescriptive or even quasi-prescriptive savings. Navigant has used the best publically available information to attempt to estimate such savings but notes that the assumptions required to make such estimates are such that savings (and cost) numbers should be regarded more as directionally accurate than numerically precise.

Low Flow Hair Washing Nozzle

Like many other low flow devices, this measure appears to be extremely cost effective. Limited data was available to estimate the baseline water use (and to subsequently estimate energy savings). Manufacturer estimates of savings were used as no case studies or third party reports are available. A large uncertainty is the current market penetration of low flow spray nozzles in the market. Given the extreme cost effectiveness of this measure, it is possible there is some natural market uptake. However no data exists on market penetration.

Boiler Outdoor Reset Controls

This is a well understood measure that is rebated under prescriptive programs by multiple utilities in the US and Canada. Boiler baseline energy use is well understood as are the energy savings from boiler reset controls. Many contractors are capable of installing this "off the shelf" technology. Based on research Navigant believes the naturally occurring market acceptance of this technology is relatively high even in retrofit applications. Any prescriptive program will likely have a high degree of free-ridership.

Greenhouse Heat Curtains

This is a well understood measure that is rebated under prescriptive programs by multiple utilities in the US and Canada. Navigant research revealed that up to 80% of greenhouses in Union Gas territory already use this measure or something very similar. However, the remaining market still provides a significant potential to target. It is possible that this technology is cost prohibitive under current circumstances to the customers that have not already adopted the technology. Therefore Union Gas rebates could still influence these customers. However, it is also possible this measure will have a significant degree of free-ridership.

Table ES-1: Measure Summary

					Resource Savings (per unit)			Cost (C$)				
Technology	**Unit basis**	**Lifetime (years)**	**Market Size (Number of Customers)**	**Units per customer**	**Gas (m^3)**	**Electricity (kWh)**	**Water (m^3)**	**Baseline Cost**	**High Efficiency Cost**	**Installat ion Cost**	**TRC Ratio**	**Total Market TRC Net Benefits ($Million)**
Thermodynamic Process Controls (TPC) for boilers	Per boiler	20	3,159	1	28,167	0	0	$0	$12,849	$9,042	3.7	$187.1
Commercial Weatherization - Air Sealing	per sqft of building	15	8,759	24,726	0.21	0.3	0	$0	$0.23	$0	3.3	$116.7
Shipping Dock Opportunities	Per Dock	7	3,562	5	2,739	0	0	$0	$775	$475	3.3	$51.7
DART Constant Air Volume Controls for existing buildings	per building	20	1,220	1	24,050	101,176	0	$0	$134,381	$0	1.2	$35.0
Low flow hair washing nozzle	Per Nozzle	10	2,682	2	676	0	170	$14	$27	$0	134.2	$19.1
Boiler Outdoor Reset Controls	Per boiler	20	798	1	4,130	0	0	$0	$1,000	$1,500	4.8	$7.5
Greenhouse Heat Curtains	per acre	5	60	2.14	61,788	0	0	$0	$34,000	$15,000	1.5	$2.9

					Resource Savings (per unit)			Cost (C$)				
Technology	Unit basis	Lifetime (years)	Market Size (Number of Customers)	Units per customer	Gas (m^3)	Electricity (kWh)	Water (m^3)	Baseline Cost	High Efficiency Cost	Installa tion Cost	TRC Ratio	Total Market TRC Net Benefits ($Million)
HT Dishwasher Arm Early Replacement	Per Dishwasher	2	2,960	1	896	3,626	4	$0	$320	$0	3.3	$2.2
Restaurant Water Heater Tune Up	per restaurant	7	5,148	1	291	0	0	$0	$38	$111	2.9	$1.5
Ice Rink Fill valves	Per Valve	10	200	1	1,281	0	191	$0	$116	$0	43.4	$1.0
Infrared Controls	per controller	20	220	1	1,563	14.9	0	$0	$206	$0	21.9	$0.9
Programmable Thermostats - New Build	per T-stat	15	48	1	206	481	0	$178	$482	$0	1.9	$0.03
Descaling effects on energy efficiency	per water heater	1	6,302	1	391	0	-1	$0	$200	$129	0.3	($1.4)
Food Service Exhaust Hood Heat Recovery	per restaurant	10	5,920	1	3,679	0	0	$360	$13,250	$0	0.5	($34.1)
VSD boiler circulating pump	per boiler	12	116	1	N/A	0	0	$0	$18,400	$0	N/A	N/A

NAVIGANT

Approach

General Approach

Navigant researched multiple sources of data to obtain the information necessary to characterize these technologies. Typical data sources included:

- Third party case studies of the efficient technologies
- Manufacturer case studies and savings claims
- Measure data from other energy utilities in Canada and the United States
- Interviews with manufacturers, distributors, and contractors
- Interviews with Union Gas staff knowledgeable on these technologies
- Information from NRCan databases to assist market sizing
- Data from Union Gas regarding commercial customer counts to assist market sizing

With the information collected, Navigant drafted technology characterization sheets that document the following information where possible.

- A product description that documents:
  - Base Case & Upgrade Criteria
  - Competing Technologies
  - Efficiency Values
  - Equipment Costs
  - Installation Costs
  - Maintenance Requirements
  - Equipment/Measure life
- A market size assessment that identify market segments most appropriate for each idea, and estimates the approximate number of potential customers who could use the technology
- A savings assessment that documents consumption and savings of gas, electricity and water.
- Measure cost effectiveness was evaluated calculating:
  - Customer Payback
  - The Total Resource Cost per unit
  - The total maximum TRC potential per year

The detailed information collected on each technology can be found in the next section.

Market Sizing

Navigant used various estimates and data sources to determine the market size for each technology. In general the following approach was used:

1. Identify and quantify the number of buildings the target building segment(s) (N_B)
2. Determine the fraction of those buildings with the end use of concern (F_{EU})
3. Determine the fraction of those buildings which would be excluded from installing the measure due to building vintage (F_V)
4. Determine the fraction of buildings that have already installed the efficient technology (F_I)
5. Determine the number of units of the efficient technology that each building could install (N_T)

The total number of measures that could be installed can then be quantified by the following equation:

$$Total\ Market = N_B * F_{EU} * (1 - F_V) * (1 - F_I) * N_T$$

The number of buildings (N_B) was obtained using one of two methods based on the applicability of the measure.

1. For measures that were "whole building" technologies such as boiler-related measures, air sealing, and some water heating measures, data from NRCan was used. NRCan data indicated the number of buildings by market segment in Ontario. Under the instruction of Union Gas, Navigant assumed 40% of these buildings were in Union Gas territory.
2. For measures that are mostly widget based, the total number of customers was obtained from customer count data provided by Union Gas. This data indicated the total number of customer (not buildings) that Union Gas served by customer type. It should be noted that multiple office customers, for example, share the same building as many customers are sub-metered.

In some cases, the number of potential installations could not be obtained from any Union Gas or NRCan data. However, Union Gas staff members were able to provide their insight an estimate as to the total market. Absent any additional information, Navigant assumed Union Gas staff estimates were correct.

Some measures required Navigant to examine the new construction building market. This data was not available from Union Gas and not directly available from NRCan data either. As a proxy Navigant calculated an annual 1.2% growth rate using data from the US DOE on projected new construction. This growth rate was multiplied by the existing stock of buildings to estimate the number of new buildings that would be constructed.

Considerations for the market sizing of each measure are contained below in Table 1. This table is merely a summary of considerations, full information on market sizing for each measure can be found within each measure's technology characterization.

Table 1: Summary of Market Sizing Approach

Technology	Notes on Market Sizing
Thermodynamic Process Controls (TPC) for boilers	NRCan data used to estimate total number of buildings that would have boilers.
Commercial Weatherization - Air Sealing	NRCan data used to estimate total number of buildings that use gas for space heating
Shipping Dock Opportunities	Union Gas customer count data used to estimate number of warehouses, Navigant assumed 5 docks per warehouse
DART Constant Air Volume Controls for existing buildings	NRCan data used to estimate the number of large buildings that have gas space heating in three building classes that this is most applicable to
Low flow hair washing nozzle	Union Gas customer count data used to estimate number of salons, Navigant assumed 2 wash stations per salon
Boiler Outdoor Reset Controls	NRCan data used to estimate total number of buildings that would have boilers
Greenhouse Heat Curtains	Union Gas customer count data used to estimate number of greenhouses, Navigant research reveals the majority of customers already have this measure installed
HT Dishwasher Arm Early Replacement	Union Gas staff informed Navigant of their estimate of the number of dishwashers in Union Gas territory
Restaurant Water Heater Tune Up	Union Gas customer count data used to estimate number of restaurants.
Ice Rink Fill valves	Union Gas staff informed Navigant of their estimate of the number of ice rinks in Union Gas territory
Infrared Controls	Union Gas customer count data for applicable sectors was combined with data as to the percent of floorspace served by infrared heating
Programmable Thermostats - New Build	NRCan data was used to estimate number of existing buildings, Navigant applied a growth factor to estimate new construction

Technology	Notes on Market Sizing
Descaling effects on energy efficiency	NRCan data used to estimate total number of buildings by segment that would have gas water heating
Food Service Exhaust Hood Heat Recovery	Union Gas customer count data used to estimate number of restaurants
VSD boiler circulating pump	Union Gas staff informed Navigant of their estimate of the number of large, high pressure steam boilers Union Gas territory

Thermodynamic Process Controls for Boilers

Union Gas ID: 312

Efficient Technology & Equipment Description
Thermodynamic process control (TPC) is a boiler system controller designed around a wireless communication platform. The control has the ability to accurately read the amount of energy a building is using for heat in real time, and then modulate hot water boilers to supply only that energy. The unit also has the ability to control every piece of equipment in the commercial hydronic heating mechanical room. With the TPC, all the pieces of the system show up in a plug-and-play wireless network. The manufacturer claims this technology can: - Eliminate short-cycling. - Calculate real-time building loads. - Extend equipment life. - Split load between different sizes and types of hot water boilers. - Eliminate over-shooting and under-shooting. - Maximize the amount of time spent in the condensing range. The standard equipment package includes: 1 system administrator, 1 to 64 field devices (24/7 data loggers), 1 flow meter with hot tap, 2 thermistors with wells, and 1 outdoor air thermistor. The system can control a maximum of 64 devices (boilers, boilers pumps, system pumps, dampers, combustion air make-up/exhaust devices, and automatic isolation valves)[1].
Qualifier/Restriction
The manufacturer recommends this technology should be used on larger boilers; systems that use at least 25,000 therms per year or more. This same manufacturer offers an alternative set-up to control systems that consume less than 25,000 therms per year. The concept is similar with the exception that it doesn't include a flow meter, is limited to 3 devices and includes the use of a buffer tank. That system reduces fuel usage by 10% to 15% according to manufacturer claims.
Base Technology & Equipment Description

[1] Manufacturer website: http://www.flowintel.com/products.htm

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We assume the average boiler installed in Ontario. Baseline energy use is based on NRCan data for average space heating energy intensity of various commercial buildings.
Competing Technologies
No competing technologies were identified.

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y)	16,602 – 105,350 varies per segment (see Table 2)	11,123 – 70,584 varies per segment (see Table 2)	5,479 – 34,765 (see Table 2)

The manufacturer[2] indicates that this technology saves between 20% and 50% of energy. We assumed 33% gas savings as showed in a case study provided by the manufacturer[3]

To determine baseline energy use savings, Navigant has estimated the natural gas space-heating energy intensities of buildings in six commercial segments based on data published by NRCan[4]. Unfortunately although NRCan provides the percentage of total space-heating energy consumption in Ontario that is gas and provides an estimate of the total Ontario floor space occupied by each segment, no indication is made as to what percentage of that floor space is heated by natural gas.

Navigant has therefore assumed that the distribution of floor space by heating fuel exactly matches the distribution of energy consumption by fuel.

Energy Intensity data is combined with Commercial and Institutional Building Energy Use Survey (CIBEUS) survey data which contains information on the average floorspace of commercial buildings by type in Ontario.[5] Reliable data was only available for six commercial building types that match those found in Comprehensive Energy Use Database. Combining this data reveals the baseline energy use for various building types. Energy savings are estimated to be 33% of these baseline uses.

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[2] Interview with [redacted] April 20th, 2011.

[3] An U.S. university located in the Mid-West installed this technology to an existing system of two high-efficiency, high-turn down condensing 2,000 MBH boilers and obtained savings of 25,592 therms (70,122 m^3) per year equivalent to a 33% reduction in gas usage. This case study was obtained via e-mail from [redacted].

[4] NRCan, Comprehensive Energy Use Database,

Hhttp://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/index.cfm

[5] NRCan, *Commercial and Institutional Building Energy Use Survey*
Hhttp://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/Cibeus/section_03.cfm?attr=0

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Table 2 – Estimated Savings by Segment

Segment	Base Energy Intensity (m3/m2)	Average Area of Building Type (m2)	Base Energy Use (m3/yr)	% Savings	Efficient Energy Use (m3)	Annual Savings (m^3)
Retail Trade	22.4	743	16,602	33%	11,123	5,479
Transportation and Warehouseing	22.9	3,083	70,542	33%	47,263	23,279
Offices	19.5	4,724	92,044	33%	61,670	30,375
Educational Services	21.3	4,938	105,350	33%	70,584	34,765
Health Care and Social Assistance	32.1	2,012	64,531	30%	45,172	19,359
Accommodation and Food Services	31.6	2,919	92,151	33%	61,741	30,410

Electricity Use (kWh/y)	0	0	0
No electricity savings is expected from this measure.			
Water use (L)	0	0	0
No water savings is expected from this measure.			
Equipment Cost, $	N/A	CAD$ 12,849	CAD$ 12,849
Installation Cost, $	N/A	CAD$ 9,042	CAD$ 9,042
Total Installed Cost $	N/A	CAD$ 21,891	CAD$ 21,891
Annual Maintenance Costs $	N/A	No annual maintenance cost is expected	
From conversations with the manufacturer[6] we gathered the following cost information: Equipment cost = CAD$ 9,994 (includes 24/7 data logger, flow meter and temperature			

[6] Interview with [redacted]. April 2011.

sensor) plus CAD$ 2,855 per boiler controlled. Therefore controlling one boiler would cost CAD$ 12,849; controlling two boilers would cost CAD$ 15,704. We assume the TPC controls one boiler for our analysis.

The manufacturer indicated that installation cost varies from CAD$ 22,843 to CAD$ 33,313 depending on the size of the system. The manufacturer provided two examples from case studies. A recent installation with 4 boilers in the system had an installation cost of CAD$ 26,651. Another installation with 2 boilers in the system had an installation cost of CAD$ 22,843. From these two examples, installation cost can vary from CAD$ 6,663 to CAD$ 11,422 per boiler. We are assuming an average installation cost per boiler of CAD$ 9,042.

OTHER INPUT ASSUMPTIONS

Equipment Life	20 years

The manufacturer[7] indicated the technology has a lifetime of 20 years.

Customer Payback

Customer payback (in years) is presented below for average building sizes assuming a retail gas cost of $\$0.21/m^3$.

As this is an add-on technology, both the equipment and installation costs are included calculations, there is no distinction between the costs associated with retrofit and new construction.

Table 3 – Customer Payback (Years)

[7] Interview with [redacted]. April 2011.

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Segment	CIBEUS Segment	Annual Savings (m3)	Average Area of Building Type (m^2)	Average Area of Building Type (ft^2)	Payback (years)
Retail Trade	Non food retails	5,479	743	7,994	19.0
Transportation and Warehouseing	Warehouse/wholesale	23,279	3,083	33,182	4.5
Offices	Office	30,375	4,724	50,851	3.4
Educational Services	Education	34,765	4,938	53,148	3.0
Health Care and Social Assistance	Health care	19,359	2,012	21,662	5.4
Accommodation and Food Services	Commercial and institutional accommodation	30,410	2,919	31,421	3.4

Average floor area for "Commercial and institutional accomodation" unavailable in CIBEUS - Quebec value used as proxy.

Market Size

Navigant is using the same approach used to calculate the market size of Outdoor Boiler Reset Controls (another technology analyzed as part of this report). From conversations with the manufacturer of TPC, Navigant knows this technology is very new in the market and we are assuming (conservatively) that only 1% of all applicable buildings had this technology installed with the boiler.

The applicable market is commercial buildings that:

- Have natural gas fired boilers
- Are more than five years old
- Are not so old that controls cannot be retrofitted (assumed to be 1% of all natural gas boilers more than five years old).
- Are not amongst the assumed 1% of such buildings which already have this technology

To calculate the applicable market, all of the factors above must be multiplied by the number of buildings of each type in Union Gas' service territory. Although Union Gas maintains customer counts, at the time of writing no count of building types was available. Navigant has therefore, under guidance from Union Gas staff, assumed that 40% of all buildings counted in the NRCan CIBEUS database reside in Union Gas territory. The NRCan, Marbek and CIBEUS segments are mapped to one another in the table below. Navigant has endeavoured to match segments as best possible across the different sources but professional judgment was applied for some of the mapping.

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Table 4 – Applicable Market by Segment

			A	B	C	D = C x 99%	E	F = B x D x (1 - E)	G = F x A
NRCan Segment	Marbek Segment	CIBEUS Segment	Number of Buildings	% With NG Boiler (Marbek)	% Five Years Older or More (NRCan)	% New Enough For Controls (Assumption)	% Penetration of Applicable Buildings	% Applicable Population	Number Applicable Population
Retail Trade	Medium Non-Food Retail	Non food retails	2,552	8%	87%	86%	1%	7%	173
Transportation and Warehouseing	Warehouse	Warehouse/wholesale	567	3%	100%	99%	1%	3%	17
Offices	Medium Office	Office	2,734	25%	91%	90%	1%	22%	611
Educational Services	Medium School	Education	1,906	70%	92%	91%	1%	63%	1,205
Health Care and Social Assistance	Hospital	Health care	933	85%	92%	91%	1%	76%	713
Accommodation and Food Services	Medium Hotel/Motel	Commercial and institutional accommodation	781	62%	93%	92%	1%	56%	440

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. TRC is calculated for two scenarios using thus baseload avoided costs and using weather sensitive avoided costs.

Total net TRC is calculated as follows:

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

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Table 5 – Standard Total Resource Cost Test (TRC)

Segment	TRC Unit Benefits	TRC Unit Costs	Net TRC Benefit Per Building	TRC Benefit/Cost Ratio	Total Net TRC Benefit Potential
Retail Trade	$15,608	$21,891	-$6,284	0.7	-$1,087,676
Transportation and Warehouseing	$66,319	$21,891	$44,428	3.0	$740,940
Offices	$86,534	$21,891	$64,643	4.0	$39,525,512
Educational Services	$99,043	$21,891	$77,152	4.5	$92,984,850
Health Care and Social Assistance	$55,152	$21,891	$33,261	2.5	$23,710,323
Accommodation and Food Services	$86,635	$21,891	$64,743	4.0	$28,483,400
Avg. TRC Weighted By Appliable Building Population:				**3.7**	
Total Net TRC Potential:					**$184,357,348**

Table 6 – Weather Sensitive Total Resource Cost (TRC)

Segment	TRC Unit Benefits	TRC Unit Costs	Net TRC Benefit Per Building	TRC Benefit/Cost Ratio	Total Net TRC Benefit Potential
Retail Trade	$15,778	$21,891	-$6,113	0.7	-$1,058,205
Transportation and Warehouseing	$67,043	$21,891	$45,151	3.1	$753,005
Offices	$87,478	$21,891	$65,587	4.0	$40,102,683
Educational Services	$100,123	$21,891	$78,232	4.6	$94,286,965
Health Care and Social Assistance	$55,754	$21,891	$33,863	2.5	$24,139,193
Accommodation and Food Services	$87,580	$21,891	$65,688	4.0	$28,899,164
Avg. TRC Weighted By Appliable Building Population:				**3.7**	
Total Net TRC Potential:					**$187,122,804**

Comments on Likelihood of Data being Available for Fund Study

The manufacturer has expressed interest in assisting Union Gas with providing additional information needed regarding this technology.

Ice Rink Fill Valves

Union Gas ID: 239

Efficient Technology & Equipment Description
Ice rinks consume significant amounts of hot water in the process of resurfacing the ice. Ice resurfacing machines (commonly referred to by the brand name "Zamboni") work by dispersing hot water over the ice where it melts the surface, smoothes, and then re-freezes. Significant amounts of energy are needed to heat the water required for daily operations. It is expected that the tank capacity of the ice resurfacer is greater than what is required to *flood* the ice rink during a resurfacing operation. However, it is expected that operators fill the tank to capacity. As a result, hot water is wasted during each fill resulting in wasted energy. Resurfacer tanks can take more than 15 minutes to fill. Often operators place a hose in the tank, turn on the water and then leave to return later and check on progress. This often causes tank overflow while they are not being monitored. This wastes hot water and energy and also serves as a source of frustration to the ice rink and staff. Volumetric flow shutoff valve automatically delivers a preset quantity of water and then stops flow. The unique design saves water by actually metering the flow rather than timing it. The valve is Dial/Impeller controlled, hydraulically operated and Dial/Plunger actuated.
Qualifier/Restriction
This technology could be used in any water tank filling application. It has been targeted towards resurfacing vehicles in ice-rinks, although could also be used in firetrucks, for example.
Base Technology & Equipment Description
This is an add-on technology. The baseline assumes operators place a hose in the tank, turn on the hot water, and fill to a level that is not closely monitored.
Competing Technologies
More advanced electronic flow meters are available. One such product is the Aquamatic, a battery operated, wall-mounted computerized receiver control unit, with a computerized radio transmitter unit, overflow water sensor, and a low voltage solenoid water valve. This technology is specifically marketed to ice-rinks for ice resurfacers. The cost is significantly greater than the standard flow metering valve described above, in the range of $895-$1295 USD.

Resource Savings Assumptions

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Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings/Incremental Cost
Gas use (m^3/y)	6,724	5,444	1,281

Gas savings are achieved via reducing hot water use. Gas savings are calculated based on the energy savings at the water heater.

Assumptions and inputs:

- Average water inlet temperature: 54.4 °F[8]
- Average water heater set point temperature: 140 °F
- Water heater thermal efficiency: 0.78[9]

Annual gas use is calculated as follows:

$$GasUse = W_{use} * 8.33 * (T_{out} - T_{in}) * \frac{1}{Eff} * 10^{-6} * 27.8$$

Where:

W_{use} = Water Use (US gallons)
T_{out} = Water heater set point temperature (°F)
T_{in} = Water inlet temperature (°F)
Eff = Water heater efficiency
8.33 = Energy content of water (Btu/gallon/°F)
10^{-6} = Factor to convert Btu to MMBtu
27.8 = Factor to convert MMBtu to m^3

Baseline gas use, high efficiency gas use, and gas savings are calculated as:

G_{eff} = Annual natural gas use with efficient equipment, 5,444 m^3
G_{base} = Annual natural gas use with base equipment 6,724 m^3
Gas Savings = 1,281 m^3

Electricity Use (kWh/y)	0	0	0

This measure is not expected to save any electricity.

[8] Water main temperature for Buffalo, NY obtained from: National Renewable Energy Laboratory. *Building America Benchmark Analysis*. 2010

[9] Minimum thermal efficiency for compliance with ASHRAE 90.1 standard.

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Water use (L)	1,001,511 Litres/year	810,747 Litres/year	190,764 Litres/year

Water use is calculated with a bottom up analysis. Considerations are given to the size of the ice resurfacing tank, the number of times that it is filled with hot water each day, and the total days per year that this occurs. Estimates were intentionally kept conservative.

*Baseline Annual Water use = (Floods per day) * (days per year) * (water use per fill)*

*Annual Water Savings = (Floods per day) * (days per year) * (gallons saved per fill)*

Assumptions and inputs:

- Research into the standard capacity of ice resurfacers ranged from 120 – 195 US Gallons. An average of 157.5 Gallons[10]. Under the baseline water use scenario, we assume the tank is filled to capacity for each flood.
- Estimates for the number of times a rink is resurfaced (flooded) ranged from 6 to 10 times per day (including weekends)[11]. Each time the ice is flooded, the ice resurfacer is refilled. We used an average of 8 times per day to estimate annual water savings.
- Ice rink is operational 210 days per year (30 weeks)[11]
- Estimates of water saved per fill using the shut-off valve ranged from 0 to 64 US gallons. Use of the automatic shut-off valve is assumed to save 30 gallons, or 20% per fill[11]

Baseline water use, high efficiency water use, and water savings are calculated as:

W_{base} = Annual natural gas use with base equipment = 1,001,511 Litres

Water Savings = 190,764 Litres

W_{eff} = Annual natural gas use with efficient equipment = 810,747 Litres

Units of gallons are converted to Litres using 1 Gal = 3.785

Equipment Cost, C$ [12]	C$0	C$115.64	C$115.64
Installation	C$0	C$0[12]	C$0

[10] Average based on interview with [redacted] and interview with [redacted] of [redacted], both conducted on 4-18-11.

[11] Based on interview with [redacted] of [redacted], conducted on 4-18-11

[12] Cost figures and model recommendation based on interview with [redacted], [redacted] buygpi.com, conducted on 4-18-11.

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Cost, $			
Total Installed Cost $	C$0	C$115.64	C$115.64
Annual Maintenance Costs $	$0	None known	$0

Equipment cost[12]:

- The product costs $121.50 USD. This value was converted to Canadian Dollars for the analysis.
- Assumes model MT0011GANP00550, purchased online from distributor.
- This model has a 550 Gallon dial capacity with 10 gallon increments.

No external labour is required for installation. Based on discussion with the product distributor and a review of the information pamphlet, the shut-off valve appears easy to self install such that ice rink maintenance staff could do the job. Therefore no install cost is included in this analysis.[12]

Conversion of US Dollars to Canadian dollars at exchange rate 1 USD = 0.9518 Canadian.

OTHER INPUT ASSUMPTIONS

Equipment Life	10 years

No data exists on the lifetime of this measure and the manufacture did not have any insight into the matter. Navigant estimates a conservative lifetime of 10 years.

This estimate is based off of plumbing-related energy efficiency measures in the 2008 DEER Database.[13]

- “Low-Flow Showerhead” – 10 years
- “Water Loop Pumps” – 15 years

Customer Payback

[13] California Public Utilities Commission. *2008 Database for Energy-Efficient Resources: EUL/RUL Values*. Available online at: Hhttp://www.deeresources.com/index.php?option=com_content&view=article&id=65&Itemid=57

Customer payback is calculated two ways:

- Including gas savings only
- Including gas, electric, and water savings

Customer payback is calculated assuming the following retail rates:

- Gas: $0.21/m^3$
- Electricity: $0.0871/kWh
- Water: $1.829/m^3$

Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right)$$

Payback including gas, electricity, and water is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings + 0.0871 * Electric\ Savings + 1.829 * Water\ Savings}\right)$$

	Valuing Gas Only	**Valuing Gas, Electricity and Water**
Payback Period (Years)	0.4	0.2

Market Size

Union Gas staff estimate there are approximately 500 ice rinks in Ontario and that 40% of then are in Union Gas' territory. Therefore we assume 200 ice rinks in Union's service territory.[14]

[14] Union Gas Staff Estimate. 2011

Each one could purchase one of these devices. The estimates in this review are based on a 1:1 use of a shut-off valve to ice rink facility; although it is noteworthy that each rink may have more than one pad or own more than one ice resurfacer increasing possible savings.

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. This measure is considered to be non-weather sensitive, thus baseload avoided costs are used.

Total market TRC is calculated as follows:

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

Where:

Customers = Maximum number of units that could be installed

	TRC Unit Benefits	TRC Unit Costs	TRC Benefit/ Cost Ratio	Total Market TRC
Early Retirement	$5,013	$116	43.4	$979,554

Comments on Likelihood of Data being Available for Fund Study

Based on initial research, it appears data would be readily available should Union Gas decide to pursue a more in-depth study.
The largest uncertainty is the use of amount of water wasted during tank fills. The values used in this analysis were all based on anecdotal information from multiple parties. However, no data is available on this matter. Interviews of ice-resurfacing machine operators would improve estimates of water usage as would metering the current water used for tank filling.

Additional information regarding behavior of resurfacer operators and their willingness to use this technology would be beneficial It should be noted that it is possible that operators could easily adjust the flow amount set this valve. If they were to turn it to the maximum amount and simply continue previous behavior, savings could be nullified.

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Food Service Exhaust Hood Heat Recovery

Union Gas ID: 313

Efficient Technology & Equipment Description
Standard restaurant fume hood filters are outfitted with a copper heat exchanger which pre-heats inlet water using hot kitchen exhaust air. These filters are located in the kitchen directly above cooking equipment. Exhaust air can be at hot at 140°F depending on the cooking equipment being used and the type of food being cooked. The preheated water can be sent to the restaurant's water heater or can be used to heat kitchen makeup air (fresh air from outside the building) reducing HVAC energy use.
Qualifier/Restriction
This technology must be installed in kitchens that receive hot water from a gas powered water heater. The only manufacturer of this technology could only provide case studies in which heat recovery was used for domestic water heating. Therefore this analysis only focuses on using recovered heat for water heating. The only manufacturer of this technology indicated they currently do not distribute this product in Canada. There are no near term plans to start distribution either.[15] However, the product is ULC (Underwriters Laboratory Canada) approved.
Base Technology & Equipment Description
Standard range hood aluminium filters (20 inches x 20 inches x 2 inches)
Competing Technologies
Rooftop heat recovery units are also available and could be used to pre-heat either water or ventilation air. One such product is manufactured by Halton.[16]

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings or Incremental Cost
Gas use (m^3/y)	6,689	3,010	3,679
Field tests performed by the manufacture and distributor show the units provide 55% of the water heating needs for a typical day. Thus, we assume this product will reduce hot water energy use by 55%.[17]			

[15] Interview with [redacted], Blissfield Mfg. Co. April 11th, 2011.

[16] More information available at: Hhttp://www.halton.com/halton/usa/cms.nsf/www/HRU

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<table>
<tr><td colspan="4">A top down approach is used to estimate the volume of gas savings. Navigant calculated the average energy use by hot water heaters in restaurants and applied the percent savings claimed by the manufacture to calculate energy savings.

$Restaurant\ WH_{EUC} = EI_{WH} * SQFT_{Rest}$
$Energy\ Savings = (Percent\ Savings) * Restaurant\ WH_{EUC}$

Where:
$Restaurant\ WH_{EUC}$ = Water heating energy use in a typical restaurant
EI_{WH} = Natural Gas Intensity of Water Heating in a typical restaurant (m^3/sqft)
$SQFT_{Rest}$ = Average restaurant floorspace (sqft) = 5,600 [18]
$Percent\ Savings$ = 0.55

Natural Gas Intensity of Water Heating in a typical restaurant is calculated as follows:

$EI_{WH} = EI_{Rest} * WH_{share} * 0.0283$

Where:
EI_{Rest} = total gas energy intensity of a restaurant (cubic feet/sqft) = 152.9 [19]
WH_{share} = share of a restaurants natural gas use dedicated to water heating = 28% [20]
0.0283 = conversion factor from cubic feet to cubic meters

Calculation Results:

EI_{WH} = 1.211 m^3/sqft
$Restaurant\ WH_{EUC}$ = 6,689 m^3 (baseline energy use)
$Energy\ Savings$ = 3,679 m^3</td></tr>
<tr><td>Electricity Use (kWh/y)</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="4">No electricity savings is expected from this measure.</td></tr>
</table>

[17] National Hot Water. *An Emerging Technology in Energy Savings for Restaurant Applications: Dragon Fire Thermo Recovery Filter.* December 2010. Obtained via e-mail from [redacted].

[18] US DOE. Commercial Buildings Energy Consumption Survey. Table A1. 2003

[19] US DOE. Commercial Buildings Energy Consumption Survey. Table C27. 2003

[20] Calculated from: US DOE. Commercial Buildings Energy Consumption Survey. Table E7. 2003

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Water use (L)	0	0	0
No water savings is expected from this measure.			
Equipment Cost, $	$360	N/A	N/A
Installation Cost, $	$0 (self install)	N/A	N/A
Total Installed Cost $	$360	$13,250 [21]	$12,890
Annual Maintenance Costs $	Regular cleaning and washing is needed depending on how often the kitchen is used.	Maintenance is similar to standard fume hood filters. No additional cost is assumed.[22]	
Baseline Costs: Baseline assumes standard grease traps installed in restaurant fume hoods. We assume 10 filters are used in a typical restaurant. Each filter costs $36 (for a 20 inch by 20 inch filter.)[23] **High Efficiency Costs:** The manufacturer (Blissfield) provided a typical installed cost of $13,250 which includes all parts and labour. The distributor (National Hot Water) would not provide any further details on the breakdown of costs or number of components as the technology is still pending patents.[24]			

OTHER INPUT ASSUMPTIONS

Equipment Life	10 years
The manufacturer has not tested the lifetime of the product and offers only a limited 1 year	

[21] [redacted], April 2011

[22] [redacted], April 2011

[23] Obtained from: Hhttp://www.hoodfilters.com/aluminumfilter.aspxH. Accessed April 25th, 2011.

[24] [redacted]. [redacted]. National Hot Water. H[redacted]H. April 25th, 2011.

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warranty. Navigant estimates a conservative lifetime of 10 years.

This estimate is based off of data for heat exchange and heat recovery measures documented in the 2008 DEER Database.[25]

- "Compressor Heat Recovery (w/electric water heating)" – 14 years
- "Rotary Heat Recovery" – 14 years
- "Heat Recovery from Central Refrigeration System" – 10 years
- "Air To Air Heat Exchanger" – 14 years

Customer Payback

Customer payback is calculated two ways:

- Including gas savings only assuming early retirement scenario (where the cost used is the full installed cost of the measure)
- Including gas savings only assuming a new construction or replace on burnout scenario (where the cost used is the incremental installed cost).

Customer payback is calculated assuming the following retail rates:

- Gas: $0.21/m[3]

Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right)$$

Payback Period (Years)	Valuing Gas Only
Early Retirement	17.2
New Construction or Replace on Burnout	16.7

Market Size

[25] California Public Utilities Commission. *2008 Database for Energy-Efficient Resources: EUL/RUL Values*. Available online at: Hhttp://www.deeresources.com/index.php?option=com_content&view=article&id=65&Itemid=57

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There are 6,962 customers in Union Gas territory that are classified as either "Foodservice-Fastfood & Limited Serv" or "Foodservice-Full Service Rest". Data obtained on cost and savings is that assumed for a "typical restaurant." Navigant assumes each restaurant could have one of these systems installed.

Navigant assumes 85% of water heating in the Ontario commercial sector fuelled by natural gas.[26]

We estimate the maximum market size to be:
5,920 fume hood heat recovery systems

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. TRC is calculated for two scenarios: 1) early retirement scenario and 2) new construction or replace on burnout.

This measure is considered to be non-weather sensitive, thus baseload avoided costs are used.

Total market TRC is calculated as follows:

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

Where:

Customers = Maximum number of restaurants that could adopt the technology

	TRC Unit Benefits	TRC Unit Costs	TRC Benefit/ Cost Ratio	Total Market TRC
Early Retirement	$7,123	$13,250	0.5	($36,270,276)
New Construction/ Replace On Burnout	$7,123	$12,890	0.6	($34,139,076)

Comments on Likelihood of Data being Available for Fund Study

[26] NRCan, *Comprehensive Energy Use Database*
*H*http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/index.cfm

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The manufacturer and distributor have only conducted one case study with data collection. Additional sites are currently being installed and monitored in Texas.[27] Data may become available later this year.

No third part measurement and verification studies (M&V) studies have been conducted. As this is an emerging technology manufactured by one provider, third party M&V studies are essential to accurately understanding the savings.

The manufacturer and distributor were hesitant to release additional cost information. A better understanding of the cost is needed for further evaluation.

[27] [redacted]. April 2011.

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DART Constant Air Volume Controls for Existing Buildings

Union Gas ID: 314

Efficient Technology & Equipment Description
Federspiel Controls' Discharge Air Regulation Technique (DART) control system is a building controls retrofit. The DART makes use of wireless remote thermometers deployed throughout the building, building supply fan VFDs, sophisticated proprietary software and extensive data-collection to more efficiently condition indoor building spaces. Unless otherwise noted, assumptions and details regarding the savings, technology and implementation of DART have been drawn from Pacific Gas and Electric (PG&E)'s 2009 evaluation of the technology[28]. Navigant interviewed the PG&E [redacted], [redacted], responsible for the PG&E report who in turn arranged for Navigant to interview the analyst that drafted that report. This analyst generously shared his opinion, based on his previous work on this technology, with Navigant. The results of this discussion inform much of the savings analysis which follows, below. Navigant has also spoken with [redacted], a Federspiel Controls [redacted] who provided cost estimates and additional information regarding the DART system's deployment in the U.S. [redacted] indicated that the two principal building types to which the DART system has been applied are large data centres (principally controlling server cooling load) and large office buildings (>25,000 ft^2) with constant air volume HVAC systems. Since application of the DART system to data centres results principally in electricity (from space-cooling) rather than gas savings and since a brief search indicates that most data centres in Ontario are located around Toronto and Ottawa (i.e., not in Union Gas territory) Navigant has calculated savings for this measure only as it applies to large office buildings and educational institutions. Although [redacted] would not share with Navigant how many installations Federspiel Controls had completed, he did note that the system has been used successfully in Chicago and Boston (i.e., in cold climate regions) and achieved savings comparable to those noted in the California and Iowa case studies (citations follow, below). He also noted that they have a publically announced partnership with Nippon Telegraph and Telephone (NTT) to improve distribution of the DART system to data centres worldwide[29].

[28] Pacific Gas and Electric and Energy Solutions, *Field Evaluation of Wireless HVAC Air Distribution Controls – Jordan Hall Annex, Stanford University*, 12 April 2009.

Hhttp://www.federspielcontrols.com/downloads/case_studies/case_study_stanford.pdf

[29] Federspiel Controls and NTT Facilities USA joint press release, Jan 2011,

Qualifier/Restriction
May not be suitable for buildings with specialised air circulation needs such as hospitals, museums or laboratories. May require on-site engineering. Savings are derived entirely from reducing airflow throughout the building (to reduce heating/cooling load). Since a building's original damper controls would likely not have been designed with the DART or similar system in mind, reducing the airflow throughout the building would result in a concomitant reduction in inflow of outside air. Since the Ontario building code requires a certain minimum quantity of fresh air to circulate the building, on-site engineering adjustment of dampers may be required.
Base Technology & Equipment Description
Any large commercial building with a constant air ventilation (CAV) HVAC system.
Competing Technologies
It is possible to replace CAV systems with variable air ventilation (VAV) systems as a building retrofit, but the cost is considerable, as is the disruption to normal building use. Installation of a VAV system requires such extensive renovation that it is often considered an appropriate retrofit only for buildings that are being "gutted". Competing control systems include: • OpenViewNet (Honeywell): web-enabled operator interface for EXCEL5000 building control system. • Wireless Pneumatic Thermostat (Cypress Envirosystems): inexpensive and simple to install, this device does not enable direct control over fan speeds (as DART does).

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y) (from space-heating only)	See below.	See below.	See below.
Offices	180,974	152,019	28,956

Hhttp://www.federspielcontrols.com/downloads/pr/pr_2011011801.pdf

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Educational Services	99,153	83,287	15,864
Accommodation and Food Services	293,382	246,441	46,941

As of the drafting of this document, three different publically available space-heating savings values had been so far estimated for the DART system:

- 32% from a lab-based simulation conducted by Iowa Energy Center's Energy Resource Station (ERS)[30]
- 35% from a demonstration project in two buildings that are part of the University of California's Santa Barbara campus
- 26% from a demonstration project installed at Jordan Hall Annex at Stanford University.

Navigant's interview with the analyst responsible for the Jordan Hall evaluation was very revealing with respect to the savings. He noted that at the time of the evaluation the Stanford building was scheduled for occupancy continuously, 24 hrs/day 7 days/week and that a majority of the savings occurred during evening hours, when the building was basically unoccupied and most facilities would normally be shut down completely. He estimated that since as much as 60% of savings accrued overnight (when there is relatively little load throughout the building). In a facility with a more common occupied schedule (12 hours/day 5 days/week) the realized savings will likely be less than those originally reported.

The analyst was, however, enthusiastic about the device and described it as an excellent stop-gap measure for buildings with CAV systems for which retro-fitting VAV systems was prohibitively expensive.

In the PG&E report, it is noted that one aspect of the DART design is that air flows are determined by the highest loaded zone within a building (relative to the design load of that zone). Since the savings estimated at the Iowa Energy Center's Energy Resource Station (ERS) lab-test assumed that all building zones were perfectly balanced at the design load, these likely exaggerate the savings that could be expected in an actual installation. When Navigant inquired whether, in an older building with heating loads not balanced at the

[30] It should be noted that although nominally conducted under the auspices of the ERS and presented to the California Energy Commission (CEC), the report itself was prepared by Federspiel Controls, the company that sells the DART system.

Federspiel, C. and Federspiel Controls LLC, Wireless Controls to Convert Constant Volume HVAC to VAV Operation, undated, provided on request by the ERS.

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design load, savings might be as little as half of those reported in the ERS study, the PG&E analyst conceded that it was possible.

Navigant has therefore conservatively elected to apply savings numbers that are half of those reported in the ERS report – i.e., Navigant's working assumption is that installation of the DART system will result in a 16% reduction in annual space-heating natural gas consumption.

To determine savings, Navigant has estimated the natural gas space-heating energy intensities of buildings in three commercial segments (Offices, Educational Services and Accommodation and Food Services) based on data published by NRCan[31]. Unfortunately although NRCan provides the percentage of total space-heating energy consumption in Ontario that is gas and provides an estimate of the total Ontario floor space occupied by each segment, no indication is made as to what percentage of that floor space is heated by natural gas.

Navigant has therefore assumed that the distribution of floor space by heating fuel exactly matches the distribution of energy consumption by fuel.

Table 7 - Estimated Space-Heating Energy Intensities

Space Heating	A	B	C	D = A/(B x C)
Segment	Annual NG Use (m^3, millions)	% of Floor Space Assumed to Be Heated By Natural Gas	Total Floor Space (million m^2)	Energy Intensity (m^3/m^2)
Offices	1,770	78%	116	19.5
Educational Services	558	79%	33	21.3
Accommodation and Food Services	305	80%	12	31.6

Because of the high degree of variation in building size, savings should be estimated for individual buildings, rather than a single prescriptive figure used. For screening purposes and simplicity, however, Navigant has assumed a certain size for buildings in each segment. The building size assumed for each building type was chosen to be consistent with the typical size of the type of building in which the DART system might be installed, as implied by [redacted] of Federspiel Controls. All of these elements are used to calculate

[31] NRCan, *Comprehensive Energy Use Database*,
Hhttp://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/index.cfm

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savings, below.

Table 8 - Natural Gas Space-Heating Savings

Segment	Assumed Building Size		% Savings	Annual Savings
	ft^2	m2	Space Heating	Natural Gas (m^3)
Offices	100,000	9,290	16%	28,956
Educational Services	50,000	4,645		15,864
Accommodation and Food Services	100,000	9,290		46,941

Electricity Use (kWh/y) (from fans and space-cooling only)	See below.	See below.	See below.
Offices	789,833	605,888	183,945
Educational Services	300,775	235,294	65,481
Accommodation and Food Services	751,730	592,356	159,375

Electricity savings for space-cooling were calculated in the same manner as natural gas savings, above (i.e., using NRCan-derived energy intensities) and using the same assumption as above, that savings (as a percentage of consumption) were half of those reported in the ERS study.

For fan savings, Navigant used the HVAC supply fan energy intensities provided in an appendix to B.C. Hydro's 2007 Power Smart Conservation Potential Review prepared by Marbek Resource Consultants[32]. Note that the segments identified in the Marbek report differed somewhat from those of NRCan. Both are shown in Table 10, below.

[32] Marbek Resource Consultants for B.C. Hydro, *Conservation Potential Review 2007*, November 2007.

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Table 9 – Estimated Space-Cooling Energy Intensities

Space Cooling	A	B	C	D = A/(B x C)
Segment	Annual Electricity Use (GWh)	% Floor Space Cooled by Electricity	Floor Space (million m^2)	Energy Intensity (kWh/m^2)
Offices	3,077	94%	113	28.9
Educational Services	1,065	94%	30	37.2
Accommodation and Food Services	577	94%	11	53.5

Table 10 - Estimated Fan Energy Intensities

NRCan Segment	Marbek Segment	Supply Fan Energy Consumption (kWh/m2 per year)
Offices	Large Office	56.1
Educational Services	University/College	27.6
Accommodation and Food Services	Large Hotel	27.4

Table 11 – Electricity Space-Cooling and Fan Savings

Segment	Assumed Building Size		% Savings		Annual Savings
	ft^2	m2	Space Cooling	Fan Use	Electricity (kWh)
Offices	100,000	9,290	19%	26%	183,945
Educational Services	50,000	4,645			65,481
Accommodation and Food Services	100,000	9,290			159,375

Water use (L)	0	0	0
This measure provides no water savings.			
Equipment Cost, $	**Breakdown of equipment vs. installation cost is unknown. Manufacturer could only provide rough estimate for total installed cost.**		
Installation Cost, $			
Total Installed Cost $	See below.	See below.	See below.

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Offices	$0	$200,000	$200,000
Educational Services	$0	$100,000	$100,000
Accommodation and Food Services	$0	$200,000	$200,000
Annual Maintenance Costs $	Unknown	Unknown	Unknown
[redacted], Federspiel Controls' [redacted] could provide little detail on costs, noting that they are very site-specific. He noted that costs range, on average between $100,000 and $600,000 for complete installation, and that the demonstration projects at the University of California and Stanford University likely fell in the lower end of that range.			

OTHER INPUT ASSUMPTIONS

Equipment Life	20 years
This is a new technology and therefore no example of a DART installation has yet come to the end of its useful life. Most building control technologies are generally expected to last (with occasional maintenance) as long as the building itself. Navigant has, in this case, conservatively estimated the EUL of this measure to be 20 years.	

Customer Payback

Customer payback is calculated two ways:

- Including gas savings only
- Including gas, electric, and water savings

Customer payback is calculated assuming the following retail rates:

- Gas: $0.21/m^3$
- Electricity: $0.0871/kWh
- Water: 1.829/m^3

Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right)$$

Payback including gas, electricity, and water is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings + 0.0871 * Electric\ Savings + 1.829 * Water\ Savings}\right)$$

Table 12 - Average Customer Payback (Years)

`	Annual $ Savings			Payback (Years)	
Segment	Electricity	Gas	Cost	NG only	All Resources
Offices	$16,003	$6,081	$200,000	32.9	9.1
Educational Services	$5,697	$3,331	$100,000	30.0	11.1
Accommodation and Food Services	$13,866	$9,858	$200,000	20.3	8.4

Market Size

The percentage of buildings equipped with CAV HVAC systems was drawn from the previously cited Marbek B.C. Hydro conservation potential study[33].

Although Union Gas maintains customer counts, at the time of writing no count of building types was available. Navigant has therefore, under guidance from Union Gas staff, assumed that 40% of all buildings counted in the NRCan CIBEUS database reside in Union Gas territory. The NRCan, Marbek and CIBEUS segments are mapped to one another in the table below. Navigant has endeavoured to match segments as best possible across the different sources but professional judgment was applied for some of the mapping.

Because the DART system is only suitable for buildings greater than a certain size, and because Navigant has been unable to find information regarding the distribution of building size by segment within Ontario, Navigant has assumed a certain percentage of buildings in each segment conform to the required size. These assumptions are shown in column B of Table 13, below.

[33] Marbek Resource Consultants for B.C. Hydro, *Conservation Potential Review 2007*, November 2007.

Table 13 - Applicable Market Potential

			A	B	C	D = A x B	E = D x C
NRCan Segment	Marbek Segment	CIBEUS Segment	Approx Number of Buildings in Union Gas Territory	Number of Buildings of Appropriate Size (Assumption)	CAV System Present	Applicably Sized Buildings	Applicably Sized Buildings with CAV
Offices	Large Office	Office	2,734	10%	62%	273	169
Educational Services	University/College	Education	1,906	60%	70%	1,143	800
Accommodation and Food Services	Large Hotel	Commercial and institutional accommodation	781	40%	80%	312	250

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. This measure is considered to be weather sensitive, thus weather sensitive avoided costs are use.

Total Net TRC is calculated as follows:

Total Net TRC = Customers(TRC Benefits – TRC Costs)*

Where:

Customers = Maximum number of buildings that could adopt the technology

Table 14 - Weather-Sensitive Total Resource Cost Test (TRC)

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Segment	TRC Benefit	TRC Cost	Net TRC Benefit per Building	TRC Ratio	Total Net TRC Benefit Potential
Offices	$253,894	$200,000	$53,894	1.3	$9,134,098
Educational Services	$106,384	$100,000	$6,384	1.1	$5,109,163
Accommodation and Food Services	$282,916	$200,000	$82,916	1.4	$20,717,063
Weighted Average for All Buildings	**$163,044**	**$134,381**	**$28,663**	**1.2**	
Total					**$34,960,324**

Comments on Likelihood of Data being Available for Fund Study

Given the paucity of publically available data on energy savings, the implication by [redacted] of Federspiel Controls that a large portion of DART installations are in data centres, and the wide possible range of installation costs (a function of each building's HVAC idiosyncrasies) Navigant recommends that this measure be considered for a demonstration project to better assess costs and savings or, at most, for inclusion in a Union Gas custom DSM program.

Navigant does not believe that there is sufficient information available at this time for this technology to be promoted with prescriptive or even quasi-prescriptive savings. Navigant has used the best publically available information to attempt to estimate such savings but notes that the assumptions required to make such estimates are such that savings (and cost) numbers should be regarded more as directionally accurate than numerically precise.

That said, the DART system appears to be a very promising technology for Union Gas territory. Not only does it appear to generate considerable energy savings, but there is a considerable ancillary benefit in the enormous amount of data it generates. The proprietary software that runs the DART system collects minute by minute temperature data in every room in which a wireless thermometer is deployed. This data is aggregated into a user-accessible SQL relational database. This allows for considerably improved and more granular diagnostic checks of building systems (i.e., identifying malfunctioning equipment) and could, in a demonstration project, provide a valuable laboratory for testing other space-conditioning conservation technologies.

As mentioned above very little data for this measure is publically available. The best source for more data would be PG&E's data files. Navigant's contact at PG&E indicated that he could not share the detailed data without authorization. PG&E may agree to release data if a direct request is made by Union Gas.

Given the data available, Navigant believes that this technology has the potential to provide considerable conservation opportunities within Ontario, achievable at low cost (relative to VAV retrofits).

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Low Flow Hair Washing Nozzle

Union Gas ID: 162

Efficient Technology & Equipment Description
Hot water is used in salons to wash clients' hair for a variety of services, including hair cuts and color treatments. If less water were to be used, less energy would be required to heat the water. This technology is a hose and spray head designed to be used in salons to reduce the water flow rate at wash stations. The company claim is it uses 2.5 GPM compared to the standard 4–5 GPM.
Qualifier/Restriction
None known.
Base Technology & Equipment Description
Baseline sprayers used between 4 and 5 gallons per minute. We assume an average of 4.5 GPM.[34]
Competing Technologies
None known.

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y)	1,524	848	676

Assumptions and inputs:

- Average water inlet temperature: 54.4 °F[35]
- Average salon water heater set point temperature: 120 °F
- Water heater thermal efficiency: 0.78[36]
- Average Temperature of water used for washing: T_{wash} = 105 °F [37]

[34] Phone interview with staff at Niagara Conservation. www.niagaraconservation.com

[35] Water main temperature for Buffalo, NY obtained from: National Renewable Energy Laboratory. *Building America Benchmark Analysis*. 2010

[36] Minimum thermal efficiency for compliance with ASHRAE 90.1 standard.

[37] Assumed to be the same as residential showers. Residential shower temperature obtained from: National Renewable Energy Laboratory. *Building America Research Benchmark Definition*. December 2009

Annual gas use is calculated as follows: $$GasUse = W_{use} * Phot * 8.33 * (T_{out} - T_{in}) * \frac{1}{Eff} * 10^{-6} * 27.8$$ Where: W_{use} = Water Use (gallons) Phot = Percentage of water used that is hot T_{out} = Water heater set point temperature (°F) T_{wash}= Average Temperature of water used for washing T_{in} = Water inlet temperature (°F) Eff = Water heater thermal efficiency 8.33 = Energy content of water (Btu/gallon/°F) 10^{-6} = Factor to convert Btu to MMBtu 27.8 = Factor to convert MMBtu to m^3 Where Phot = (T_{wash} - T_{in})/ (T_{out} – T_n) Baseline gas use, high efficiency gas use, and gas savings are calculated as: G_{eff} = Annual natural gas use with efficient equipment, 848 m^3 G_{base} = Annual natural gas use with base equipment 1,524 m^3 Gas Savings = 676 m^3			
Electricity Use (kWh/y)	0	0	0
This measure is not expected to reduce electricity use.			
Water use (L)	383,906	213,581	170,325
The manufacturer estimated the saving will be 45,000 US gallons per spray.[38] Little data is available on the daily water use of a salon; therefore we assume this is true. Units of gallons are converted to Litres using 1 US Gal = 3.785 Litres			

[38] Flyer provided by Niagara Conservation staff shows key metrics of technology.

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The baseline and high efficiency replacement water usage is calculated based on the flow rates of the efficient (2.5 GPM) and baseline (4.5 GPM) measures.

Equipment Cost, $	C$14.28	C$26.60	C$12.33
Installation Cost, $	C$0	C$0	C$0
Total Installed Cost $	C$14.28	C$26.60	C$12.33
Annual Maintenance Costs $	None known	None known	n/a

Baseline efficiency equipment cost was obtained from internet research. Various websites were consulted to determine costs of standard salon sprayers (baseline). Table 15 shows the details of each. The analysis assumed the average cost of $15 USD (C$14.28). These costs represent basic salon sprayers. More elaborate designs are available at a higher price (up to $50) however the additional cost seems purely due to aesthetic design qualities.

High efficiency equipment cost was obtained from Niagara Conservation.[39]

Conversion of US Dollars to Canadian dollars at exchange rate 1 USD = 0.9518 Canadian.

Table 15: Baseline cost research findings

Product	Cost	Company Name	Date Resaerched	Website/Source
soft spray hose	$ 15.00	Minerva Beauty	4/29/2011	http://www.minervabeauty.com/shampoo-bowls-and-chairs/spray-hose.htm
Shampoo Spray Hose #561	$ 18.00	Salon Interiors	4/29/2011	http://www.saloninteriors.com/mm5/merchant.mvc?Screen=PROD&Store_Code=SI&Product_Code=561
Shampoo Spray Hose PIB-561 Black USA 1/4"Standard	$ 12.00	Midwest Salon	4/29/2011	http://www.midwestsalon.com/shampoo%20bowl%20parts%20page%201%20Italica%20Metric%20Shampoo%20Backwash%20Parts.htm

OTHER INPUT ASSUMPTIONS

[39] Phone interview with staff at Niagara Conservation

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Equipment Life	10 years
Manufacturer warranties product for 10 years.**Error! Bookmark not defined.**	

Customer Payback

Customer payback is calculated four ways:

- Including gas savings only assuming early retirement scenario (where the cost used is the full installed cost of the measure)
- Including gas savings only assuming a new construction or replace on burnout scenario (where the cost used is the incremental installed cost).
- Including gas, electric, and water savings assuming early retirement
- Including gas, electric, and water savings assuming new construction or replace on burnout

Customer payback is calculated assuming the following retail rates:

- Gas: $0.21/m^3
- Electricity: $0.0871/kWh
- Water: 1.829/m^3

Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right)$$

Payback including gas, electricity, and water is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings + 0.0871 * Electric\ Savings + 1.829 * Water\ Savings}\right)$$

Payback Period (Years)	Valuing Gas Only	Valuing Gas, Electricity and Water

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	Early Retirement	0.19	0.06	
	New Construction or Replace on Burnout	0.09	0.03	

Market Size

There are 2,682 customers in Union Gas territory that are classified as "Retail-Salon Barber Personal Care". Navigant assumes on average each customer has 2 spray wash stations.

We estimate the maximum market size to be:
5,364 spray heads

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. TRC is calculated for two scenarios: 1) early retirement scenario and 2) new construction or replace on burnout.

This measure is considered to be non-weather sensitive, thus baseload avoided costs are used.

Total market TRC is calculated as follows:

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

Where:

Customers = Maximum number of units that could be installed

	TRC Unit Benefits	TRC Unit Costs	TRC Benefit/ Cost Ratio	Total Market TRC
Early Retirement	$3,571	$26.60	134.2	$19,011,201
New Construction/ Replace On Burnout	$3,571	$12.33	289.7	$19,087,783

Comments on Likelihood of Data being Available for Fund Study

Product information about the salon sprayer itself was readily available through the manufacturer, Niagara Conservation. Navigant asked for case studies to verify product's savings claims but were unable to obtain any.

Additional estimates of water consumption may be desirable. While interviews and observations are two possible ways of obtaining this data, there appears to be significant variability between perceptions of different stylists and different salons.

Requesting customer water bills may be a useful method for obtaining accurate data. Some salons also have computerized tracking systems that can provide data about how many clients were served in a given period of time. Combining that data with assumptions about the amount of water used per wash could provide a more reliable estimate of baseline water use.

A large uncertainty is the current market penetration of low flow spray nozzles in the market. Given the extreme cost effectiveness of this measure, it is possible there is significant natural market uptake. However no data exists on market penetration.

Additionally, Union Gas may want to consider a pilot study of this technology to understand the user experience and satisfaction with the product. It may be worth looking at the relationship between reduced water flow and length of time that water is running. If the reduced water flow only requires the water to run for a longer amount of time, or, if stylists choose to remove the sprayer after purchasing, then the savings in this analysis will not be achieved.

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Shipping Dock Opportunities

Union Gas ID: 316

Efficient Technology & Equipment Description
The under-leveler dock seal[40] is a technology designed to close off the area beneath and around the dock leveler (where the leveler, trailer and dock seal or shelter all meet). This technology forms a seal between the truck and the dock decreasing leakage of conditioned air which reduced space heating energy use. The seal consists of a black-vinyl, compressible sealing curtain held in place by spring-loaded arms and flexible stays. These mechanisms keep the seal engaged against the leveler and pit sides, while a separate header curtain maintains the seal even the leveler is in an above-dock position. Energy savings vary depending on outside temperature and dock position.
Qualifier/Restriction
The seal fits a variety of leveler types with minimal modifications according to the manufacturer.
Base Technology & Equipment Description
Standard dock seals or shelters which insulate only three sides of the opening.
Competing Technologies
Various companies produce similar product; however while they may differ in design they all act, in principle, the same way.

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y)	3,267	528	2,739
Navigant calculated gas savings using a case study provided at the manufacturer's website[41]. We compared the Heating Degree Days (HHD) of the US cities presented in the case study to the average HHD for Toronto and Ottawa in Canada. Navigant determined that Minneapolis (one of the case study cities presented) is the city with the most similar weather conditions to the cities located within Union Gas' territory.			

[40] Pit Master Under-leveler Dock Seal website: http://ritehite.ca/products/seals-and-shelters/under-leveler-seals/pitmaster/

[41] http://www.ritehite.com/products/seals-and-shelters/under-leveler-seals/pitmaster/

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Navigant took the energy cost savings data in US dollars for Minneapolis ($904/year) and back calculated gas savings using an average price of $0.36/cubic meter[42] and calculated a gas savings value of 2,490m³ per year. From our HHD comparison, we determined that HDD in Canada are 10% higher than in Minneapolis and we adjusted the gas savings value using this 10%. Our final gas savings value is 2,739m³. $Efficient\ technology\ Gas\ Savings = (904/0.36) * 110\%$ In order to calculate the base case, Navigant sourced another case study[43] which shows an 84% reduction in space heating energy use when this technology is installed. Navigant was able to back-calculate the baseline energy use (which represents the baseline heat loss at a loading dock). $Base\ Technology\ Gas\ Use = \left(\frac{2,739}{84\%}\right) = 2,970$			
Electricity Use (kWh/y)	0	0	0
No electricity savings are expected.			
Water use (L)	0	0	0
No water savings are expected.			
Equipment Cost, $	0	CAD$ 775	CAD$ 775
Installation Cost, $	0	CAD$ 475	CAD$ 475
Total Installed Cost $	0	CAD$ 1,250	CAD$ 1,250
Annual Maintenance Costs $	0	CAD$ 50	CAD$ 50

[42] Source: Energy Information Administration (EIA). The gas price is an average of the commercial gas price from 2005 to 2008. http://www.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_SMN_a.htm

[43] Material Handling Management Climate Control. Facility Operations by Mary Aichlmayr. Source: http://www.ritehite.com/content/literature/651.pdf

From conversations with the manufacturer[44] Navigant gathered the following cost information:

The product costs between CAD$ 750 and CAD$ 800. We are assuming an average product cost of CAD$ 775.

The manufacturer charges between CAD$ 1,000 and CAD$ 1,500 for a full installation including equipment cost for one dock. We used the following formula to calculate installation cost:

$$Installation\ Cost = \left(\frac{(1{,}000 + 1{,}500)}{2}\right) - Equipment\ Cost$$

In terms of maintenance costs, the manufacturer indicated several minor parts need to be changed every 1 to 2 years the cost is CAD$ 100. Based on this, we assumed an average maintenance cost of CAD$ 50 per year.

OTHER INPUT ASSUMPTIONS

Equipment Life	7 years
The manufacturer[45] indicated that the equipment life is 7 years.	

Customer Payback

Customer payback is calculated assuming a gas retail cost of $\$0.21/m^3$. Since this is an add on technology there is no distinction between retrofit and new construction costs.

Payback is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right) = 2.2\ years$$

[44] Interview with [redacted]. April 26th, 2011.

[45] Interview with [redacted], April 26th, 2011.

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Market Size

Navigant assumes this product is most applicable to non-refrigerated warehouses. Data from Union gas indicates there are 4,191 customer of this type in their service territory.

Additionally, Navigant, conservatively assumes:

- A warehouse has 5 loading docks at which this technology could be installed
- 15% of docks have a similar technology already installed

The total market size is 17,810 docks.

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. Since this is an add on technology there is no difference between the early retirement or new construction scenario.

This measure is considered to be weather sensitive, thus weather sensitive avoided costs are use.

Total market TRC is calculated as follows:

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

Where:

Customers = Maximum number of units that could be installed

	TRC Unit Benefits	TRC Unit Costs	TRC Benefit/ Cost Ratio	Total Market TRC
Retrofit	$4,155	$1,250	3.3	$51,741,196

Comments on Likelihood of Data being Available for Fund Study

The manufacturer indicated they are willing to provide any information needed to Union Gas for further assessments of this technology.

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A large uncertainty is the number of docks that currently utilize this technology. The manufacturer did not have an estimate they were willing to be quoted on. Additional research is needed to understand the current market penetration.

High Temperature Dishwasher Arm Early Replacement

Union Gas ID: 328

Efficient Technology & Equipment Description
High temperature dishwasher rinse arms can wear out over time as a result of the heavy use and high temperature (180°F) of the water. As the arm wears out, the spray orifices increase in size and subsequently water use increases (wasting water and energy). The wear on the arms from high temperatures is greater than that experienced from low temperature models (140°F). Replacing the rinse spray arms will bring water used back to OEM rated output. The efficient technology replacement in this case is a new rinse arm.
Qualifier/Restriction
Must be replaced on conventional, high temperature, door type dishwashers.
Base Technology & Equipment Description
A rinse arm that is older than 2 years on a high temperature door type dishwasher.
Competing Technologies
None

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y)	4,482	3,586	896
Gas savings are achieved via reduced hot water use. Gas savings are calculated based on the energy savings at the restaurant's water heater. Assumptions and inputs: • Average water inlet temperature: 54.4 °F[46]			

[46] Water main temperature for Buffalo, NY obtained from: National Renewable Energy Laboratory. *Building America Benchmark Analysis*. 2010

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• Average restaurant water heater set point temperature: 140 °F • Water heater thermal efficiency: 0.78[47] Annual gas use is calculated as follows: $GasUse = W_{use} * 8.33 * (T_{out} - T_{in}) * \frac{1}{Eff} * 10^{-6} * 27.8$ Where: W_{use} = Water Use (gallons) T_{out} = Water heater set point temperature (°F) T_{in} = Water inlet temperature (°F) Eff = Water heater efficiency 8.33 = Energy content of water (Btu/gallon/°F) 10^{-6} = Factor to convert Btu to MMBtu 27.8 = Factor to convert MMBtu to m^3 Baseline gas use, high efficiency gas use, and gas savings are calculated as: G_{eff} = Annual natural gas use with efficient equipment, 3,586 m^3 G_{base} = Annual natural gas use with base equipment, 4,482 m^3 Gas Savings = 896 m^3			
Electricity Use (kWh/y)	18,128	14,502	3,626
Electricity savings are also achieved via reduced hot water use. Electricity is used by booster water heaters in high temperature dishwashers to heat water from 140°F to 180°F for dishwashers. Assumptions and inputs: • Average water inlet temperature: 140 °F [48]			

[47] Minimum thermal efficiency for compliance with ASHRAE 90.1 standard.

[48] Outlet temperature of restaurant water heater

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- Booster water heater set point temperature: 180 °F
- Booster water heater electric efficiency: 0.95 [49]

Annual electric savings calculated as follows:

$$ElectricUse = W_{use} * 8.33 * C_p * (T_{out} - T_{in}) * \frac{1}{Eff}$$

Where:

W_{use} = Water use (gallons)

C_p = 0.000293 = Heat Capacity of water (kWh/(lb*°F))

8.33 = density of water (lbs./gallon)T_{out} = Booster water heater set point temperature (°F)

T_{in} = Water inlet temperature (°F)

Eff = Water heater efficiency

Baseline electric use, high efficiency electric use, and electric savings are calculated as:

E_{eff} = Annual electric use with efficient equipment, 14,502 kWh

E_{base} = Annual electric use with base equipment, 18,128 kWh

Electric Savings = 3,626 kWh

Water use (L)	667,674	534,139	133,535

No data exists on the amount that water use increases from worn dishwashers arms. However, Union Gas staff familiar with the technology have discussed this measure with EcoLab (a major dishwasher service provider) and estimates that water use by a worn rinse are is approximately two to three times more than a brand new rinse arm (increasing water use 100-200%).[50] This would indicate that the spray orifices have increase 40-70% in diameter.

However, Navigant assumes a conservative 25% increase in water use by worn arms (corresponding to a 12% increase in orifice size).

[49] US DOE. *Savings Calculator for ENERGY STAR Qualified Commercial Kitchen Equipment*. January 2011.

[50] Interview with [redacted], [redacted]. Union Gas. April 20th, 2011

Water use is calculated as shown below:

$$Water\ Use = (Gallons\ per\ Rack) * (Racks\ per\ Day) * (Operation\ Days\ per\ Year) * 3.785$$

Where:

Gallons per Rack:

Conventional dishwasher with new arm = 1.44 [51]

Conventional dishwasher with worn arm = 1.8 [52]

3.785 = Litres/US Gal

Assumptions:

Racks per Day = 280 [53]

Operation Days per Year = 350 [54]

Results:

Water Use by Baseline = 667,674 litres

Water Use by Replacement = 534,139 litres

Water Savings = 133,535 litres

Equipment Cost, $	$0	$320	$320
Installation Cost, $	$0	$0	$0
Total Installed Cost $	$0	$320	$320
Annual Maintenance Costs $	none	none	

Equipment cost was obtained as a price quote from Hobart, a major manufacturer of

[51] US DOE 2011.

[52] 25% increase over baseline

[53] US DOE 2011.

[54] Navigant Estimate. US DOE 2011 assumes 365 days.

commercial dishwashers, via phone. The cost of one "rinse arm" on a model AM15 door type high temperature dishwasher was quoted to be $168 US.[55] Two rinse arms are required for each machine. Customer service representatives stated replacement part costs do not vary by region; however, bulk discounts may apply decreasing the cost. EcoLab staff discussed with Union Gas staff that incremental installation costs could be $0 as the replacement could be conducted relatively quickly during a routine maintenance call.[56] Price was converted to Canadian Dollars assuming 1 USD = 0.9518 CAD

OTHER INPUT ASSUMPTIONS

Equipment Life	2 years
Discussions between Union Gas staff and EcoLab have focused on this issue.[57] In discussions there was no definitive data indicating the lifetime; however, it was mutually agreed that the lifetime of the arm is approximately 2-3 years. The lifetime is defined as how long it would take for the spray orifices to "wear out increasing water use significantly." Navigant assumes 2 years as a conservative estimate.	

Customer Payback

Customer payback is calculated two ways: • Including gas savings only assuming early retirement scenario (where the cost used is the full installed cost of the measure) • Including gas, electric, and water savings assuming early retirement Customer payback is calculated assuming the following retail rates: • Gas: $0.21/m^3$ • Electricity: $0.0871/kWh

[55] Hobart Customer Service Representative – Parts Department. Interviewed on April 25th, 2011.

[56] [redacted], 2011

[57] [redacted], 2011

- Water: 1.829/m^3

Payback including gas only is calculated as:

$$Payback = \left(\frac{0.21 * Gas\ Savings}{Cost}\right)$$

Payback including gas, electricity, and water is calculated as:

$$Payback = \left(\frac{0.21 * Gas\ Savings + 0.0871 * Electric\ Savings + 1.829 * Water\ Savings}{Cost}\right)$$

Payback Period (Years)	Valuing Gas Only	Valuing Gas, Electricity and Water
Early Retirement	1.7	0.6

Market Size

Union Gas staff estimate there are approximately 4,000 high temperature door type dishwashers in Union's service territory.[58]

Navigant also assumes:

- 85% of restaurants use gas for water heating.[59]
- 13% of dishwashers are less than 2 years old not requiring a new spray arm[60]

We estimate the maximum market size to be:
2,960 dishwashers

TRC Result

[58] [redacted]. 2011

[59] Navigant assumption based off of industry experience

[60] US DOE 2011 estimates dishwasher lifetime to be 15 years. Assuming an even distribution of age across all installed dishwashers, those less than 2 years old account for 2/15 = 13% of the population.

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TRC benefits include the avoided cost of natural gas, electricity, and water. TRC is calculated assuming an early retirement scenario.

This measure is considered to be non-weather sensitive, thus baseload avoided costs are used.

Total market TRC is calculated as follows:

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

Where:

Customers = Maximum number of dishwashers that could be retrofitted

	TRC Unit Benefits	TRC Unit Costs	TRC Benefit/ Cost Ratio	Total Market TRC
Early Retirement	$1,070	$320	3.3	$2,219,098

Comments on Likelihood of Data being Available for Fund Study

No data currently exists on the actual flow increase due to worn arms or the time it takes for the arms to wear considerably.

Ecolab is considering testing these using flow meters or measuring the orifice sizes on worn rinse arm. When this data becomes available there will be a better understanding of the savings and lifetime.

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Programmable Thermostats - New Buildings

Union Gas ID: 330

Efficient Technology & Equipment Description
The efficient technology is a programmable thermostat assuming full set-back. A full set-back refers to the period of time in which the thermostat is turned off while occupants are no longer in the building. According to the U.S. Department of Energy, turning a thermostat back 10°–15° for 8 hours, can save about 5%–15% a year on a residential heating bill, which is a savings of as much as 1% for each degree if the setback period is eight hours long. The percentage of savings from setback is greater for buildings in milder climates than for those in more severe climates.[61] A primary benefit of programmable thermostats is that one can automatically calibrate a schedule for the set-back. As a result, the commercial building is not heated when business hours have ended, or most of the occupants have left the heated space.
Qualifier/Restriction
Because of the widely touted benefits, programmable thermostats may be already installed in a high proportion of heating systems in new construction. The U.S. Department of Energy website, Database of State Incentives for Renewables and Efficiency lists rebates for Commercial programmable thermostats in multiple utilities in almost every state.[62]
Base Technology & Equipment Description
Standard non-programmable thermostat.
Competing Technologies
None.

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y)	1,459 – 5,256 m^3 /thermostat	1380 – 4704 m^3 /thermostat	79 – 552 m^3 /thermostat
Gas savings was determined by using several factors 1) a space heating energy intensity per building sector 2) an assumed percentage calculated to reflect the building energy intensity of new buildings over existing stock buildings 3) estimated heating savings based on thermostat setback and 4) and applicable areas to which thermostats could control.			

[61] U.S. Department of Energy "Thermostats and Control Systems" Hhttp://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12720H. Accessed April 27, 2011

[62] , Database of State Incentives for Renewables and Efficiency Hhttp://dsireusa.org/incentives/index.cfm?EE=1&RE=0&SPV=0&ST=0&sector=Commercial&technology=programmable_thermostats&sh=1H. Accessed April 27, 2011.

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Space Heating Energy Intensities

Energy intensities for each of the NRCan market segments were calculated using the energy used in natural gas space heating for 2008, applied over applicable floor space heated with natural gas.[63] Unfortunately although NRCan provides the percentage of total space-heating energy consumption in Ontario that is heated by natural gas and provides an estimate of the total Ontario floor space occupied by each segment, no indication is made as to what percentage of that floor space is heated by natural gas.

Navigant has therefore assumed that the distribution of floor space by heating fuel exactly matches the distribution of energy consumption by fuel.

New Building Energy Factors – New Building Intensities Compared to Stock Building Energy Intensities

Energy intensities of new buildings were expected to be different than that of stock buildings. Navigant compared the natural gas heating intensity of the most recent building vintages indicated in the U.S. Energy Information Administration (EIA) Commercial Building Energy Consumption Survey (CBECS), which was for buildings constructed from 1990 to 2003[64], to the natural gas heating intensity of the overall building stock in the latest CBECs.[65] NRCan Market Segments and CBECS were matched up according to the pairs in the table below. Space heating energy intensities from Accommodation and Food Services were applied to both Food Service and Lodging categories as found in CBECS. Though not all of the NRCan segments were covered, the segments below represent about 80% of total building sector energy use in NRCan's 2008 data.[66] A corresponding category in CBECs was not found for the NRCan segment of "Other" – therefore it was assumed that the space heating energy intensity of new buildings was the same as that of the stock.

Below in Table 16, Navigant calculated

$$Space\ Heating\ Energy\ Intensity\ of\ New\ Buildings =$$
$$Space\ Heating\ Energy\ Intensity \times New\ Building\ Natural\ Gas\ Intensity\ Factor$$

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[63] Natural Resources Canada "Office of Energy Efficiency" Commercial/Institutional Sector – Ontario - http://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/trends_com_on.cfm

[64] US EIA, CBECS Table C32.

[65] US EIA. CBECS Table C24.

[66] NRCan Table 3. Secondary Energy Use and GHG Emissions by Activity Type

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Table 16 – Space Heating Energy Intensity of New Buildings

NRCan Market Segment	Space Heating Energy Intensity (m³/ft²)	CBECs	New Building Intensity Factor	Space Heating Energy Intensity of New Buildings (m³/ft²)
Wholesale Trade	2.20	Warehouse and Storage	70%	1.82
Retail Trade	2.10	Service	111%	2.43
Transportation / Warehousing	2.20	Warehouse and Storage	70%	1.75
Information / Cultural Industries	2.00	Public Assembly	100%	2.40
Offices	1.90	Office	80%	1.43
Educational Services	2.00	Education	67%	1.60
Health Care and Social Assistance	3.10	Health Care	84%	2.26
Arts, Entertainment, and Recreation	3.70	Public Assembly	100%	3.70
Accommodation and Food Services	3.00	Food Service	115%	4.03
Other Services	2.20	NA	100%	2.20

Heating Savings and Thermostat Zones

The NRCan market segments were categorized according to Union Gas market segments, enabling Union Gas specific floor space (ft2) of thermostat zone areas to be used. Hospitals were not included because many of the rooms are occupied 24/7 and would not benefit from temperature setback.

Navigant has conducted a similar analysis for programmable thermostats in existing buildings and used many of the same base assumptions with regard to space heating. Heating savings percentages specific to each Union Gas Market Segment corresponding Setback/Forward Duration were applied to each NRCan Market Segment.[67]

Below in Table 17, Navigant calculated

$$Gas\ Savings\ per\ Thermostat = Space\ Heating\ Energy\ Intensity\ New\ Buildings \times Heating\ Savings\ Percentage \times Thermostat\ Zone$$

[67] Hhttp://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdfH, "Commercial Thermostats" Page 199

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Table 17– Gas Savings in New Buildings

NRCan Market Segment	Union Gas Market Segments	Space Heating Energy Intensity of New Buildings (m^3/ft^2)	Heating Savings Percentage	Thermostat Zone (ft^2)	Gas Savings (m^3/Thermostat)
Wholesale Trade	Industrial	1.54	7.1%	3,000	328
Retail Trade	Retail	2.32	5.4%	600	75
Transportation / Warehousing	Warehouse	1.54	10.5%	3,000	486
Information / Cultural Industries	Information and Cultural	2.00	11.8%	650	153
Offices	Office	1.51	11.8%	650	116
Educational Services	Educational Services	1.33	11.8%	986	155
Health Care and Social Assistance	Hospitals	2.60	0.0%	-	-
Arts, Entertainment, and Recreation	Recreation	3.70	5.4%	2,500	500
Accommodation and Food Services	Food Service	3.45	5.4%	1,175	219
Other Services	Agriculture	2.20	5.4%	3,000	356

Electricity Use (kWh/y)	1,061 – 28,188 kWh /thermostat	936 – 26,666 kWh /thermostat	125 – 1,522 kWh /thermostat

The electricity savings is based on energy intensity from space cooling for different market segments as described in the previous gas savings section. Not all buildings have cooling; therefore the saturation of space cooling was included.[68] Otherwise, the electricity savings by segment type were calculated and grouped in the same way as the gas savings presented above.

[68] NEUD database space cooling for 1990-2006, (as of January 2009)

Table 18 – Space Cooling Energy Intensity of New Buildings

NRCan Market Segment	Space Cooling Energy Intensity (kWh/ft²)	CBECs	New Building Intensity Factor	Space Cooling Energy Intensity of New Buildings (kWh/ft²)
Wholesale Trade	5.1	Warehouse and Storage	111%	5.64
Retail Trade	4.4	Service	138%	6.06
Transportation / Warehousing	3.2	Warehouse and Storage	111%	3.54
Information / Cultural Industries	4.8	Public Assembly	173%	8.29
Offices	3.6	Office	103%	3.72
Educational Services	4.9	Education	131%	6.41
Health Care and Social Assistance	5.4	Health Care	92%	4.95
Arts, Entertainment, and Recreation	7.5	Public Assembly	173%	12.96
Accommodation and Food Services	7.0	Food Service	155%	10.83
Other Services	4.3	NA	100%	4.30

Data for the cooling savings percentage and space cooling market saturation were obtained from previous Navigant work.[69] Below in Table 19, Navigant calculated

$$Electricty\ Savings\ per\ Thermostat =$$
$$Space\ CoolingEnergy\ Intensity\ New\ Buildings\ \times Cooling\ Savings\ Percentage\ \times$$
$$Space\ Cooling\ Market\ Saturation \times Thermostat\ Zone$$

[69] Hhttp://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdfH, "Commercial Thermostats" Page 201

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Table 19 – Electricity Savings in New Buildings

NRCan Market Segment	Union Gas Market Segments	New Building Space Cooling Energy Intensity (kWh/ft^2)	Cooling Savings Percentage	Space Cooling Market Saturation	Thermost at Zone	Savings (kWh/ thermostat)
Wholesale Trade	Industrial	5.64	7.5%	85%	3,000	1,078
Retail Trade	Retail	6.06	5.4%	85%	600	167
Transportation / Warehousing	Warehouse	3.54	11.8%	10%	3,000	125
Information / Cultural Industries	Information and Cultural	8.29	10.5%	75%	650	425
Offices	Office	3.72	10.5%	86%	650	219
Educational Services	Educational Services	6.41	10.5%	45%	986	299
Health Care and Social Assistance	Hospitals	4.95	0.0%	75%	-	-
Arts, Entertainment, and Recreation	Recreation	12.96	5.4%	87%	2,500	1,522
Accommodation and Food Services	Food Service	10.83	5.4%	70%	1,175	481
Other Services	Agriculture	4.30	5.4%	69%	3,000	481

Water use (L)	0	0	0
This technology is not expected to result in water savings.			
Equipment Cost, $	$178.42	$481.74	$303.32
Installation Cost, $	NA	NA	$0
Total Installed Cost $	$178.42	$481.74	$303.32
Annual Maintenance Costs $	NA	NA	NA

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Programmable thermostats can vary widely in cost, so Navigant used an average of a low and high-end model.[70]

Table 20– Programmable Thermostat Prices

Honeywell Model Number- Programmable Thermostat	Price
TB7100A1000	$273.98
Y7355B1002	$689.50
Average	$481.74

For non-programmable thermostats, Navigant used the average of three digital non-programmable thermostat offerings. [71]

Table 21– Non-programmable Thermostat Prices

Honeywell Model Number	Price
TB6575A1000	$177.73
TB6575A1016	184.87
TB8575A1016	$172.67
Average	$178.42

Navigant did observe that some offerings seemed to include thermostats that could be used as programmable and non-programmable, in which case the incremental cost of the technology is $0. However, these tended to be more expensive models than the thermostats that had only the non-programmable setting.[72]

In new building construction the incremental installation cost of a programmable

[70] "Commercial Thermostats" Honeywell, Hhttp://customer.honeywell.com/Honeywell/UI/Pages/Catalog/H Accessed April 27, 2011.

[71] Ibid, Honeywell website

[72] Ibid, Honeywell website

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thermostat is $0 since it takes the same time to install a programmable thermostat as does a non-programmable thermostat.

Based on Navigant's experience with control technology, maintenance costs were assumed to be minimal.

OTHER INPUT ASSUMPTIONS

Equipment Life	15 years
Navigant has assumed the effective useful life of this measure to be fifteen years, in accordance with that given on the Energy Star® website.	

Customer Payback

Customer payback is calculated two ways:

- Including gas savings only
- Including gas, electric, and water

Customer payback is calculated assuming the following retail rates:

- Gas: $0.21/m^3$
- Electricity: $0.0871/kWh
- Water: $1.829/m^3$

Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right)$$

Payback including gas, electricity, and water is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings + 0.0871 * Electric\ Savings + 1.829 * Water\ Savings}\right)$$

Market Segment	Payback Period (Years) Valuing Gas Only	Payback Period (Years) Valuing Gas, Electricity

		and Water
Accommodation and Food Services	6.6	3.4
Arts, Entertainment, and Recreation	2.9	1.3
Educational Services	9.3	5.2
Information / Cultural Industries	9.4	4.4
Offices	12.5	7.0
Other Services	4.1	2.6
Retail Trade	19.2	10.0
Transportation / Warehousing	3.0	2.7
Wholesale Trade	4.4	1.9

Market Size

Navigant determined market size for new buildings that could receive programmable thermostats by using several assumptions:

$$40\% = Percentage\ of\ Ontario\ buildings\ within\ Union\ Gas\ Territory$$
$$1.2\% = Growth\ rate\ of\ new\ building\ construction$$
$$75\% = Percentage\ of\ new\ buildings\ that\ already\ include\ a\ programmable\ thermostat$$

Navigant determined the number of buildings within each NRCan Market Segment in Union Gas's territory by multiplying the number of buildings in each segment by 40%.

The growth rate was the average growth rate of new floorspace from 2008 to 2035 in CBECs.[73]

While there is no data on the fraction of new buildings that are already installing programmable thermostats as a baseline, anecdotal information and Navigant's professional judgment suggests a large fraction are doing so. This is supported by the fact that the technology is cost-effective and on an upfront cost basis, only marginally more expensive than the baseline technology. As discussed in the cost section, it is possible in some cases for the incremental cost is $0. Navigant also assumed that every building would install only one programmable thermostat.

[73] Ibid, U.S. Energy Information Administration, Annual Energy Outlook 2011

Therefore, Navigant arrived at a market size for each segment as follows:

$$Union\ Gas\ Market\ Size\ within\ each\ NRCan\ Market\ Segment$$
$$= Number\ of\ Buildings\ within\ each\ NRCan\ Market\ Segment\ in\ Ontario\ \times 40\% \times 1.2\% \times 75\% \times 1\ thermostat/building$$

NRCan Market Segment	Maximum Market Size (Number of Units)
Accommodation and Food Services	7
Arts, Entertainment, and Recreation	3
Educational Services	6
Information / Cultural Industries	4
Offices	8
Other Services	1
Retail Trade	10
Transportation / Warehousing	2
Wholesale Trade	7

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. This measure is considered to be weather sensitive, thus weather sensitive avoided costs are use.

NRCan Market Segment	TRC Unit Benefits	TRC Unit Costs	TRC Benefit/ Cost Ratio	Total Market TRC
Accommodation and Food Services	$938	$303	3.1	$4,445
Arts, Entertainment, and Recreation	$2,481	$303	8.2	$6,534
Educational Services	$630	$303	2.1	$1,962
Information / Cultural Industries	$727	$303	2.4	$1,696
Offices	$467	$303	1.5	$1,312
Other Services	$1,282	$303	4.2	$979
Retail Trade	$323	$303	1.1	$200
Transportation / Warehousing	$1,319	$303	4.3	$2,032
Wholesale Trade	$1,694	$303	5.6	$9,737
Weighted Average for All Buildings	**$905**	**$303**	3.0	
Total TRC				$28,897

Comments on Likelihood of Data being Available for Fund Study

There is ample information that vouches for the savings of programmable thermostats, but substantially less information on the effect that programmable thermostats would have on new buildings, particularly as building codes become more stringent and buildings are more energy-efficient.

While Navigant assumed a large fraction of new buildings are already installing programmable thermostats, no data is available on this matter. However, as discussed anecdotal information and Navigant's professional judgment reveals the untapped market is very small.

Boiler Outdoor Reset Controls

Union Gas ID: 72

Efficient Technology & Equipment Description
A boiler without outdoor reset controls maintains a building's set-point temperature by turning the boiler on, or off, as required to supply sufficient heat to maintain the set-point. The most commonly deployed analogy for this process is that of driving a car only by cutting the gas entirely or applying full throttle. In this analogy, the outdoor reset controls act as a form of cruise control to smooth the manner in which the boiler provides space heat and thus realize higher levels of efficiency. Outdoor reset controls continuously adjust the boiler supply water temperature to compensate for fluctuations in outdoor temperature. If it is relatively mild outside, the supply water may be heated to a lower temperature and still maintain the building's set-point temperature by running continuously instead of running at a very hot temperature for short intervals. There exist many internet resources for developing a deeper understanding of how this technology works. An excellent technical primer is an article by John Siegenthaler for PME[74].
Qualifier/Restriction
As described below in the Market Size section of this sheet, it appears that all new boilers come fitted with these controls as standard, and that a very high proportion of existing/older buildings have already had such controls installed.

[74] John Siegenthaler, *Outdoor Reset Control – No Quality Hydronic System Should Be Without It*, February, 2001.
Hhttp://www.pmengineer.com/Articles/Feature_Article/cdd55d5472298010VgnVCM100000f932a8c0____

This technology may not be compatible with very old boilers.
Base Technology & Equipment Description
Base technology is a boiler without outdoor reset controls.
Competing Technologies
Indoor boiler reset controls may be used instead of (or in some cases, in addition to) outdoor reset controls. Indoor reset controls measure boiler water temperature losses to determine heating system load and thus calculate the optimum minimum boiler temperature, as opposed to making this determination using outdoor temperatures only. A useful side-by-side comparison is published by Intellidyne[75], although readers should maintain a certain degree of scepticism given that it is essentially advertising copy intended to sell indoor and not outdoor reset controls. That said, the fact that Intellidyne offer a written money-back guarantee for their promises 10% annual savings indicate that this technology does bear further investigation.

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y)	19.5 – 32.1 m^3 per m^2	18.6 – 30.5 m^3 per m^2	0.9 – 1.5 m^3 per m^2
Fortunately, due to the ubiquity of this measure in many utilities' DSM programs, there are available a number of different estimates of deemed savings for the implementation of this technology. These are shown in **Error! Reference source not found.**, **Error! Reference source not found.**. In most cases the values were quite similar, however there was one outlier (10%) but as this came from a less robust source, Navigant has correspondingly weighted it at only 10% to calculate the weighted average savings which have been applied in this case. *Table 22 - Savings Values Used in Other Jurisdictions*			

[75] Hhttp://www.energybank.ca/v4/files/Reset_Control_Comparison.pdf

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Source	% Savings	Weight	Comments	Link
Nexant, *Arkansas Deemed Savings Quick Start Program Commercial Measures*	3.80%	30%	Savings are cited as coming from a CenterPoint Energy Report. Link in report no longer functioning, unable to verify original source. Savings number also used as deemed savings by Minnesota Department of Commerce's Office of Energy Security	http://www.aepefficiency.com/oklahoma/ci/downloads/Deemed_Savings_Report.pdf
Mass Save, *Massachusetts Technical Reference Manual*	5.00%	30%	Savings are cited as coming from a 2009 GDS Associates report, Natural Gas Energy Efficiency Potential in Massachusetts. Navigant was unable to obtain a copy of this report at the time of writing.	http://www.ma-eeac.org/docs/MA%20TRM_2011%20PLAN%20VERSION.PDF
Xcel Energy, *Appendix E - Technical Reference Manual*, from Xcel's 2011 DSM plan	3.75%	30%	Xcel reports that implementing this measure increases boiler efficiency on average from 80% to 83%. No indication of whether this empirically derived or simply an assumpion.	http://www.xcelenergy.com/SiteCollectionDocuments/docs/2011-co-dsm-plan-Technical-Reference-Manual.pdf
The Energy Observer, *Upgrade that Boiler!*, March 2009 issue	10%	10%	No source given.	http://www.michigan.gov/documents/dleg/EO_03-09_271516_7.pdf
Weighted Average Savings:	**4.77%**			

To determine savings, Navigant has estimated the natural gas space-heating energy intensities of buildings in nine commercial segments based on data published by NRCan[76]. Unfortunately although NRCan provides the percentage of total space-heating energy consumption in Ontario that is gas and provides an estimate of the total Ontario floor space occupied by each segment, no indication is made as to what percentage of that floor space is heated by natural gas.

Navigant has therefore assumed that the distribution of floor space by heating fuel exactly matches the distribution of energy consumption by fuel.

Energy Intensity data is combined with Commercial and Institutional Building Energy Use Survey (CIBEUS) survey data which contains information on the average floorspace of commercial buildings by type in Ontario.[77] Reliable data was only available for six commercial building types that match those found in Comprehensive Energy Use Database. Combining this data reveals the baseline energy use for various building types. Energy savings are

[76] NRCan, *Comprehensive Energy Use Database*,
Hhttp://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/index.cfm

[77] NRCan, *Commercial and Institutional Building Energy Use Survey*
Hhttp://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/Cibeus/section_03.cfm?attr=0

estimated to be 4.77% of these baseline uses.

Table 23 - Estimated Savings By Segment

Segment	Base Energy Intensity (m3/m2)	% Savings	Efficient Energy Intensity (m3/m2)	Annual Savings (m^3/m^2)	Annual Savings (m^3/ft^2)
Retail Trade	22.4	4.77%	21.29	1.07	0.10
Transportation and Warehouseing	22.9	4.77%	21.79	1.09	0.10
Offices	19.5	4.77%	18.56	0.93	0.09
Educational Services	21.3	4.77%	20.32	1.02	0.09
Health Care and Social Assistance	32.1	4.77%	30.54	1.53	0.14
Accommodation and Food Services	31.6	4.77%	30.06	1.50	0.14

Electricity Use (kWh/y)	0	0	0
This technology does not provide water savings.			
Water use (L)	0	0	0
This technology does not provide water savings.			
Equipment Cost, $	**$0**	$1000	$1000
Installation Cost, $	**$0**	$1,500	$1,500
Total Installed Cost $	**$0**	$2,500	$2,500
Annual Maintenance Costs $			

Although there exist a number of incremental cost savings assumptions in the literature, Navigant thought it best to obtain locally specific information on costs. To this end, Navigant contacted two installer/suppliers of this technology, one in the Toronto[78] area, the other in Guelph[79].

The Toronto-based installer/supplier estimated that the equipment usually cost between $800 and $1,000 with installation also costing between $800 and $1,000.

[78] Hydronic Engineering Systems

[79] Jes-Don Dunford Limited

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The Guelph-based installer/supplier estimated that the equipment should cost at most $1,500, but that installation costs could vary between $500 and $2,000, depending on the building.

Additionally, both installer/suppliers confirmed that most of the cost associated with the equipment and installation is, for the most part, *not* a function of size. Based on this, Navigant has made the simplifying assumption that all costs are fixed and identical regardless of building size.

Based on these conversations, Navigant believes that the costs cited above are reasonable estimates of the average equipment and installation costs.

OTHER INPUT ASSUMPTIONS

Equipment Life	20 years

All of the sources that Navigant consulted in preparing this substantiation document (listed in Table 22) suggest 20 years as the effective useful life of this technology.

Customer Payback

Customer payback (in years) is presented below for average building size. Average building size for Ontario was used as a proxy for average building size in Union Gas' territory. Number of buildings and total area of buildings were obtained from NRCan's CIBEUS database, table 3.2[80].

Table 24 - Customer Payback (Years)

[80] Natural Resources Canada, Office of Energy Efficiency, *Commercial and Institutional Building Energy Use Survey*
Hhttp://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/Cibeus/section_03.cfm?attr=0

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Segment	CIBEUS Segment	Annual Savings (m3/m2)	Average Area of Building Type (m^2)	Average Area of Building Type (ft^2)	Payback (years)
Retail Trade	Non food retails	1.07	743	7,994	15.0
Transportation and Warehouseing	Warehouse/wholesale	1.09	3,083	33,182	3.5
Offices	Office	0.93	4,724	50,851	2.7
Educational Services	Education	1.02	4,938	53,148	2.4
Health Care and Social Assistance	Health care	1.53	2,012	21,662	3.9
Accommodation and Food Services	Commercial and institutional accommodation	1.50	2,919	31,421	2.7

Average floor area for "Commercial and institutional accomodation" unavailable in CIBEUS - Quebec value used as proxy.

Market Size

When Navigant spoke to the two supplier/installers previously mentioned, the contacts were asked their opinion as to how what proportion of commercial buildings in Ontario already have this kind of measure.

The Toronto-based supplier/installer said that all new buildings would have this installed as a matter of course, indicating that there is no applicable market in new build. He also stated that he believed that a very high proportion of the existing building stock had already retrofitted this technology (if it was not there to begin with). He indicated that he understood that a previously offered incentive for this technology[81] had been withdrawn precisely because so many commercial buildings were retrofitting this technology anyway (i.e., very high free-ridership). The Toronto-based supplier/installer also said that this technology could not always be applied to an existing building if it was a very old ("antiquated" was the word he used) boiler system.

The Guelph-based supplier/installer corroborated much of what Navigant learned from the Toronto-based supplier/installer. He noted that all new boiler systems actually came with this technology built-in, and that while it was possible to connect the boiler system without

[81] The supplier did not specify what organization offered the expired incentive.

activating the reset control component he believed it was extremely unlikely that any newly installed boiler would not have this feature activated. The Guelph-based supplier/installer also believed that this technology had a very high degree of penetration in existing building stock, although not so high as implied by the Toronto-based supplier/installer. The Guelph-based supplier/installer said that he thought there it might be possible that as many as 50% of existing building stock heated by boilers did not have these controls fitted.

Given the differing responses, Navigant has assumed (conservatively) that 75% of building stock more than five years old has already retrofitted this technology and that all buildings five years old or newer had this technology installed with the boiler.

To estimate the percentage of buildings that are more than five years old, Navigant has used the same NRCan data set as was used to calculate energy intensities. By comparing the ratio of present floor-space to floor-space five years ago, a proxy percentage number of buildings built within the last five years (and by extension a proxy percentage of buildings built previous to this) may be found. Unfortunately the NRCan data extends only until the end of 2008. Navigant has therefore assumed that the number of square meters of building that have been built from Jan 1, 2005 through Dec 31, 2010, as a percentage of the total building square meters on Dec 31, 2010, is identical to the number of square meters of building that have been built from Jan 1, 2003 through Dec 31, 2008 as a percentage of the total building square meters on Dec 31, 2008.

Additionally, this measure clearly only applies to buildings using boilers as their principal engine for space heat. NRCan does not provide sufficiently granular data for this. In 2007, however, Marbek Resource Consultants produced a number of building archetype profiles for a B.C. Hydro conservation potential study which provide a percentage breakdown of buildings with gas-fired boilers. Navigant is unaware of any structural reason why the distribution of heating systems within commercial buildings on Vancouver Island would be significantly different from the distribution within Ontario. While not ideal, this remains the best publically available data detailing this distribution.

In summary the applicable market is commercial buildings that:

- Have natural gas fired boilers
- Are more than five years old
- Are not so old that controls cannot be retrofitted (assumed to be 1% of all natural gas boilers more than five years old).
- Are not amongst the assumed 75% of such buildings which already have retrofitted this

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technology

To calculate the applicable market, all of the factors above must be multiplied by the number of buildings of each type in Union Gas' service territory. Although Union Gas maintains customer counts, at the time of writing no count of building types was available. Navigant has therefore, under guidance from Union Gas staff, assumed that 40% of all buildings counted in the NRCan CIBEUS database reside in Union Gas territory. The NRCan, Marbek and CIBEUS segments are mapped to one another in the table below. Navigant has endeavoured to match segments as best possible across the different sources but professional judgment was applied for some of the mapping.

Table 25 - Applicable Market by Segment

			A	B	C	D = C x 99%	E	F = B x D x (1 - E)	G = F x A
NRCan Segment	Marbek Segment	CIBEUS Segment	Number of Buildings	% With NG Boiler (Marbek)	% Five Years Older or More (NRCan)	% New Enough For Controls (Assumption)	% Penetration of Applicable Buildings	% Applicable Population	Number Applicable Population
Retail Trade	Medium Non-Food Retail	Non food retails	2,552	8%	87%	86%	75%	2%	44
Transportation and Warehouseing	Warehouse	Warehouse/wholesale	567	3%	100%	99%	75%	1%	4
Offices	Medium Office	Office	2,734	25%	91%	90%	75%	6%	154
Educational Services	Medium School	Education	1,906	70%	92%	91%	75%	16%	304
Health Care and Social Assistance	Hospital	Health care	933	85%	92%	91%	75%	19%	180
Accommodation and Food Services	Medium Hotel/Motel	Commercial and institutional accommodation	781	62%	93%	92%	75%	14%	111

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. TRC is calculated for two scenarios:

1. the boiler is used for water heating, thus non-weather sensitive avoided costs are used
2. the boiler is used for space heating, thus weather sensitive avoided costs are used

Table 26 – Standard Total Resource Cost Test (TRC)

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Segment	Average Area of Building Type (m2)	TRC Unit Benefits	TRC Unit Costs	Net TRC Benefit Per Building	TRC Benefit/Cost Ratio	Total Net TRC Benefit Potential
Retail Trade	743	$2,254	$2,500	-$246	0.9	-$10,767
Transportation and Warehouseing	3,083	$9,576	$2,500	$7,076	3.8	$29,801
Offices	4,724	$12,495	$2,500	$9,995	5.0	$1,543,283
Educational Services	4,938	$14,301	$2,500	$11,801	5.7	$3,591,688
Health Care and Social Assistance	2,012	$8,760	$2,500	$6,260	3.5	$1,126,896
Accommodation and Food Services	2,919	$12,510	$2,500	$10,010	5.0	$1,112,027
Avg. TRC Weighted By Appliable Building Population:					**4.7**	
Total Net TRC Potential:						**$7,392,928**

Table 27 – Weather Sensitive Total Resource Cost Test (TRC)

Segment	Average Area of Building Type (m2)	TRC Unit Benefits	TRC Unit Costs	Net TRC Benefit Per Building	TRC Benefit/Cost Ratio	Total Net TRC Benefit Potential
Retail Trade	743	$2,278	$2,500	-$222	0.9	-$9,693
Transportation and Warehouseing	3,083	$9,681	$2,500	$7,181	3.9	$30,241
Offices	4,724	$12,631	$2,500	$10,131	5.1	$1,564,329
Educational Services	4,938	$14,457	$2,500	$11,957	5.8	$3,639,167
Health Care and Social Assistance	2,012	$8,856	$2,500	$6,356	3.5	$1,144,098
Accommodation and Food Services	2,919	$12,646	$2,500	$10,146	5.1	$1,127,187
Avg. TRC Weighted By Appliable Building Population:					**4.7**	
Total Net TRC Potential:						**$7,495,329**

Comments on Likelihood of Data being Available for Fund Study

As mentioned above, there is a considerable amount of publically available data regarding the savings this measure achieves. Unfortunately, all savings estimates appear to be the result of engineering, rather than empirical, estimates. That said, the wide-spread adoption of this technology indicate that regardless of the robustness of these estimates, profit-motivated customers have adopted this measure in large numbers, implying that it is reasonably cost-effective.

There are a reasonable number of hydronic heating specialists throughout Ontario that supply and install this technology, and costs seem relatively standard – this is "off-the-shelf" technology.

Navigant believes that this measure provides cost-effective savings and could make a good addition to Union Gas' portfolio of commercial prescriptive programs. It should be noted, however, that any such program will likely have a high degree of free-ridership, a point which could result in some regulatory friction.

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Commercial Weatherization - Air Sealing

Union Gas ID: 183

Efficient Technology & Equipment Description
Air sealing a building prevents infiltration of conditioned air into unconditioned areas: to the attic, through foundation, and around windows and doors. The technology cuts down on wasted conditioned air which reduces HVAC energy use. The practice not only decreases heating and cooling loads, but also it decreases fan energy due to increased flow and/or run time. Research suggests that first-cost influences in new commercial building construction can lead to lesser quality construction practices and use of materials, which in turn lead to leaky systems.[82] Research conducted by Navigant suggested that cost savings resulting from air sealing can vary from 3 - 36%, according to one study conducted by the National Institute for Standards and Technology. [83] Case studies provided by one contractor's website in the Great Lakes Region indicated gas savings of 10% and 14%.[84] An information sheet developed by the Ontario Centre for Environmental Technology Advancement and Marbek Resource Consultants suggested that 5% savings of space heating energy is typical, though results vary.[85]
Qualifier/Restriction
The ability for any one commercial building to be eligible for air sealing work depends in large part to the use of the building and the construction of its shell.
Base Technology & Equipment Description
No air sealing work is done.
Competing Technologies
None.

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings

[82] Delp, W.P., et al. 1997. "Field Investigation of Duct System Performance in California Light Commercial Buildings." LBNL Report, LBNL-40102.

[83] Emmerich, S; McDowell T; Anis, W. "Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use" National Institute of Standards and Technology, June 2005

[84] "Projects Completed" Zerodraft Great Lakes Region LLC, Hhttp://www.zerodraftglr.com/Projects_Completed.html. Accessed May 1H, 2011.

[85] Ontario Centre for Environmental Technology Advancement and Marbek Resources Consultants, Ltd. "Energy Saving Tips for the Commercial & Institutional Sectors"

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Gas use (m^3/y)	2.11 m^3/ft^2	1.90 m^3/ft^2	0.21m^3/ft^2

Navigant assumed a gas savings percentage of 10% and applied it to the natural gas space heating energy intensity for commercial buildings in Ontario (obtained from NRCan) to calculate the estimated base case consumption and savings resulting from air sealing.[86] This calculation reflected the assumption that gas savings from duct sealing would be applicable to only buildings that were space heated by natural gas.

The savings percentage of 10% was based on research conducted by Navigant. According to one study conducted by the National Institute for Standards and Technology, cost savings resulting from air sealing can vary from 3% to 36%, which was assumed to be proportional to energy savings. Also, case studies on two projects conducted in schools provided by one contractor's website in the Great Lakes Region indicated gas savings of 10% and 14%. Lastly an information sheet developed by the Ontario Centre for Environmental Technology Advancement and Marbek Resource Consultants suggested that 5% savings of space heating energy is typical, though results vary. Navigant assumed that 10% would be a reasonable approximation from this available literature.

Electricity Use (kWh/y)	3.30 kWh/ft^2	3.00 kWh/ft^2	0.30 kWh/ft^2

Navigant assumed that the electricity savings from air sealing measures in Commercial buildings would be similar to that achieved by duct sealing measures based on research and availability of information.

Using duct sealing as a proxy, Navigant concluded air sealing can result in as much as 9% of electricity savings.[87] Navigant applied this savings percentage to the electricity space cooling energy intensity for commercial buildings in Ontario to calculate the estimated base case consumption and savings resulting from air sealing.[88] This calculation reflected the assumption that electricity savings from duct sealing would be applicable to only buildings that were space cooled by electricity.

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[86] Natural Resources Canada, "Table 24: Space Heating Secondary Energy Use and GHG Emissions by Energy Source," http://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/tablestrends2/com_on_24_e_4.cfm?attr=0

[87] Ibid, "Energy Efficiency and Conservation Measure Resource Assessment for the Residential, Commercial, Industrial, and Agricultural Sectors.", Page 58

[88] Natural Resources Canada, "Table 32: Space Cooling Secondary Energy Use and GHG Emissions by Energy Source," http://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/tablestrends2/com_on_32_e_4.cfm?attr=0

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The calculated savings were within range of calculated savings done by other studies that estimated anywhere from 0.10 kWh/ft^2 to 1.3 kWh/ft^2 taking into account just electricity savings from both ventilation and air conditioning.[89,90]

Water use (L)	0	0	0
This technology was not expected to result in any water savings.			
Equipment Cost, $	NA	NA	NA
Installation Cost, $	NA	NA	NA
Total Installed Cost $	C$0	C$0	C$0.23/ft^2
Annual Maintenance Costs $	NA	NA	

One contractor that serves the Great Lakes region in the U.S. provided two case studies on its website to inform the total installed costs.[91] The contractor sealed windows, doors, overhead doors, roof wall intersections, and vents. Projects costs were averaged between the two projects to obtain an average cost of C$.23/ft^2. The data provided and calculated are summarized below. Navigant determined the assumed project cost based on multiplying the savings by the payback time, and divided the project cost by the area of the schools to obtain a total installed cost per square foot.

*Table 28 – Installed Cost, Case Studies**

Building type: Schools		
Area (ft^2)	500,000	132,000
Savings	$ 20,739	$ 6,465
Payback	4.4	5.7
Assumed Project Cost	*$ 91,252*	*$ 36,848*
Cost per square foot	*$ 0.18*	*$ 0.28*
Average cost:		***C $ 0.23***

*italics indicate calculated data

[89] Ibid, "Energy Efficiency and Conservation Measure Resource Assessment for the Residential, Commercial, Industrial, and Agricultural Sectors.", Page 58

[90] Modera et al. "Sealing Ducts in Large Commercial Buildings with Aerosolized Sealant Particles" Lawrence Berkeley Laboratory, http://eetd.lbl.gov/ie/pdf/LBNL-42414.pdf

[91] "Projects Completed" Zerodraft Great Lakes Region LLC, Hhttp://www.zerodraftglr.com/Projects_Completed.html. Accessed May 1H, 2011.

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OTHER INPUT ASSUMPTIONS

Equipment Life	15 years
Previous work by Navigant to examine the lifetime of air sealing measure in the residential sector found the average lifetime is 15 years. We do not see any reason for this to be different in the commercial sector.[92]	

Customer Payback

Customer payback is calculated two ways:

- Including gas savings only
- Including gas, electric, and water savings

Since this is an add on technology for existing buildings only, there is no new construction scenario.

Customer payback is calculated assuming the following retail rates:

- Gas: $0.21/m^3
- Electricity: $0.0871/kWh
- Water: 1.829/m^3

Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right)$$

Payback including gas, electricity, and water is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings + 0.0871 * Electric\ Savings + 1.829 * Water\ Savings}\right)$$

Payback Period (Years)	Valuing Gas Only	Valuing Gas, Electricity and Water

[92] http://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf. Accessed April 29, 2011.

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	Early Retirement	5.2	3.3	

Market Size

The total estimated market size is 216,583,945 ft^2 of commercial building sector space in Union Gas territory.

Navigant determined this estimate from available NRCan data and making several assumptions:

$$Market\ size = Total\ Floor\ Space\ in\ Ontario\ Commercial\ Buildings\ \times 40\%\ \times 80\%\ \times 90\%\ \times 66\%$$

where

$$40\% = Share\ of\ Ontario\ buildings\ that\ are\ in\ Union\ Gas\ Territory$$

$$80\% = Share\ of\ buildings\ that\ use\ natural\ gas\ for\ space\ heating\ or\ electricity\ for\ space\ cooling$$

$$90\% = Percentage\ of\ the\ buildings\ that\ overlap\ and\ use\ both\ gas\ space\ heating\ and\ electric\ space\ c$$

$$66\% = Share\ of\ buildings\ that\ are\ the\ target\ market\ for\ air\ sealing.$$

Total floor space in Ontario Commercial buildings was derived from NRCan.[93] Navigant assumed buildings that are 20 years or older are those most suited for air sealing and comprised the target market for air sealing. This share of buildings was determined using data from NRCan that was only available up until the year 2000. Thus the population of buildings older than 20 years was assumed to be built before 1980. [94] Navigant acknowledges that this percentage may be different today since this data set is 10 years old and that national estimates from NRCan may differ from Ontario Union Gas's territory.

[93] Natural Resources Canada, Table 3.2 - Total number of buildings and total building floor space by principal building activity, number of workers, weekly hours of operation and type of ownership by region ; Hhttp://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/cibeus/tables/cibeus_3_2_4.cfm?attr=0H Accessed April 30, 2011

[94] Natural Resources Canada, Table 2.4 Total number of buildings and total building floor space by building floor space, number of floors, predominant type of windows, predominant exterior walls type and predominant roof type by year of construction, http://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/Cibeus/tables/cibeus_2_4_1.cfm?attr=0

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The share of buildings that use natural gas for space heating or electricity for space cooling is about 80%, based on NRCan data.[95] Lastly, based on Navigant's professional judgment, a share of 90% was applied to the previous percentage to obtain the proportion of buildings that have both gas space heating and electric space cooling; Navigant assumed that any given building would have the same amount of floorspace heated and cooled by respective energy sources.

The resulting total square footage represents 8,759 buildings that have an average floorspace of 24,726 square feet.

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. This measure is considered to be weather sensitive, thus weather sensitive avoided costs are use.

Total market TRC is calculated as follows:

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

Where:

Customers = Maximum floorspace of buildings that could install this measure

	TRC Unit Benefits	TRC Unit Costs	TRC Benefit/ Cost Ratio	Total Market TRC
Early Retirement	$0.77	$0.23	3.3	$116,828,314

Comments on Likelihood of Data being Available for Fund Study

There is limited literature that indicated the savings from air sealing alone in the commercial

[95] Natural Resources Canada, Table 24: Space Heating Secondary Energy Use and GHG Emissions by Energy Source Hhttp://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/tablestrends2/com_on_24_e_4.cfm?attr=0H Accessed April 30, 2011

sector; the data that was available showed a very wide range of savings possible. However, research is readily available in the residential sector. [96, 97, 98] Programs from other utilities often combine air sealing with added insulation or some other HVAC retrofits in the commercial sector making it difficult to attribute cost and savings specifically to air sealing.

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[96] "Measures and Assumptions for DSM Planning Appendix C: Substantiation Sheets" Navigant Consulting, April 16, 2009 Hhttp://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdfH, Accessed April 30, 2011

[97] "Methodology for Estimated Energy Savings from Cost-Effective Air Sealing and Insulating," Energy Star. Hhttp://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_methodologyH. Accessed April 30, 2011.

[98] "Building America Research in Action: Air Sealing in Existing Homes," U.S. Department of Energy, Hhttp://apps1.eere.energy.gov/buildings/building_e2_news/detail.cfm/articleId=9H. Accessed April 30, 2011.

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Boiler Circulating Pump VSD

Union Gas ID: 311

Efficient Technology & Equipment Description
High pressure coil tube steam boilers use large single speed pumps to supply boiler feed water. These pumps are usually single speed and controlled simply by water levels in the boiler's steam tank. The efficient technology is a control system would allow for variable speeds to be achieved by the feed water pump. The improved matching of pumping needs could improve boiler burner operation. Unless otherwise stated, all information for this product was obtained from the only manufacturer of this equipment.[99] Inlet water from the building is pumped by the single speed feed water pump to increase pressure. The pressurized water enters the boiler system in the steam tank. Ideally the water level in the steam tank should be kept constant to enable high quality and constant pressure steam to enter the building's steam system. Water is drawn from the steam tank and sent to the boiler coil tubes where it is heated by the boilers burners and turned to steam. The steam quality from these boilers is generally poor (containing some amounts of liquid water). Therefore the steam is sent back to the steam drum. Any liquid water falls and rejoins the water already in the tank while the remaining steam is directed to the building's steam distribution system via the top of the tank. The feed water pump is controlled by the water level in the steam tank, if its drops the pump is turned on and water is added. When it reaches a certain level the pump is turned off. Additionally the boiler burners are controlled by the steam pressure in the steam tank. If pressure is too low, burner output is increased. This control system allows the feed water pump to modulate speed and pressure eliminating the constant switching between on and off. The previous binary operation would often cause the steam tank to either be under-filled or over-filled subsequently cause steam pressure to fluctuate. The fluctuating steam pressure would in turn cause fluctuations in boiler burner output based on the boiler control system. The equipment manufacturer said the primary motivation of installing this technology is to improve steam quality (more consistent pressure and temperature) and reduce electricity use by the feed water pump. This is best applies to buildings in which the steam system goes through large fluctuations in demand multiple times a day. The manufacture postulates that its possible gas can be saved as the burner would be operated at a more constant rate (similar to cruise control on a car); however, no estimate of savings is available.

[99] Interview with [redacted]. [redacted]. Thermogenics Inc. Interviewed April 25th, 2011.

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The largest improvement in steam quality and energy savings will be realized in coil tube boilers that are used for process heating. Savings are greatest in these applications because major changes in steam demand are more likely to occur. The technology will do little to improve those used for HVAC or water heating.
Qualifier/Restriction
Must be used on coil-tube boilers manufactured by Thermogenics. The manufacturer has only delivered this technology on new boilers. No retrofit applications have been completed. The technology cannot be retrofitted on other boiler brands.
Base Technology & Equipment Description
A coil tube boiler utilizing a single speed feed water pump with boiler size ranging from 200 to 600 HP.
Competing Technologies
None.

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y)	568,980	unknown	unknown

No gas savings data is available from the manufacturer or from field tests. The manufacturer does not claim that this technology saves gas. They do claim it can save electricity and improve steam quality. Both Thermogenics staff and Union Gas staff familiar with the technology have expressed that savings will be hard to calculate based on engineering principals and estimates alone. Advanced simulation, or field data is needed to determine if gas savings is achievable.

However, Navigant can estimate the baseline energy use.

As a baseline, Navigant assumes the following:

- 300 HP boiler
- Operating at 50% load, 16 hours per day, 5 days per week, 50 weeks per year

$$Baseline\ Energy\ Use = (Boiler\ HP) * \left(\frac{33{,}475\ btu}{1\ HP}\right)\left(\frac{1\ m^3}{35{,}300\ btu}\right) * Fully\ Loaded\ Operation\ Hours/yr$$

Where:

$$Fully\ Loaded\ Operation\ Hours = 50\% * 16 * 5 * 50 = 2000\ hours$$

$$Baseline\ Energy\ Use = (300) * \left(\frac{33{,}475\ btu}{1\ HP}\right)\left(\frac{1\ m^3}{35{,}300\ btu}\right) * 2000 = 568{,}980\ m^3/yr$$

Electricity Use (kWh/y)	Not available	Not available	Not available
The manufacturer claims "significant electricity savings" are achieved through the use of the variable speed drive on the feed water pump. However no data exists on the baseline energy use or actual savings achievable. Navigant's professional experience shows variable speed drives can reduce electricity use 60-90% depending on the application.			
Water use (L)	N/A	N/A	N/A
This technology is not expected to save water.			
Equipment Cost, $	0	N/A	N/A
Installation Cost, $	0	N/A	N/A
Total Installed Cost $	0	$18,400	$18,400
Annual Maintenance Costs $	0	unknown	

Thermogenics staff provided cost information. Total installed cost varies depending on boiler size and if the equipment is installed as a retrofit on existing equipment or is added as an option to a new boiler order.

	75BHP-300BHP	350BHP-600BHP
Installed in the field on an existing unit	$18,400	$20,400
Installed new in manufacturing	$9,300	$11,300

We assume the majority of the potential in the Union Gas market is for retrofits and that

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the average boiler size is 300 HP. Therefore Navigant assumes a cost of $18,400 for this analysis.

OTHER INPUT ASSUMPTIONS

Equipment Life	12 years

The manufacturer has only installed a few of these devices and cannot comment on the lifetime. However, based on Navigant's professional experience variable speed drives can last 10-15 years depending on the application. For these purposes we assume 12 years.

Customer Payback

Without a reliable estimate for the amount of gas or electric savings Navigant cannot calculate the payback period. However, Navigant can calculate the payback under several possible percent gas savings scenarios. Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right)$$

Hypothetical Percent Gas Savings Scenario*	Baseline Energy Use (m^3)	Energy Savings (m^3)	Cost Savings	Payback Period
1%	568,980	5,690	1,195	15.4
2%	568,980	11,380	2,390	7.7
3%	568,980	17,069	3,585	5.1
4%	568,980	22,759	4,779	3.8
5%	568,980	28,449	5,974	3.1

*Note: Actual percent savings is unknown; these are meant to be illustrative of the payback period under hypothetical savings scenarios. It is possible that this technology does not save any gas.

Market Size

Union Gas staff estimate there are 500 high pressure steam boilers in Union Gas territory.[100] Thermogenics staff mentioned they manufacture the majority of large coil tube boilers in Ontario and that coil-tube boilers are small portion of all boilers.

Thus Navigant assumes:

- 25% of the 500 boilers are coil tube boilers
- 90% of the coil tube boilers are made by Thermogenics

The retrofit market is sized at: 112 boilers

The new construction market (assuming boiler life is 30 years): 4 boilers

Total market size: 116 boilers.

TRC Result

Without a reliable estimate for the amount of gas or electric savings Navigant cannot calculate the TRC results.

Comments on Likelihood of Data being Available for Fund Study

Thermogenics indicated they have not collected any data on the gas or electricity savings potential of this technology. Only a few new construction installations have been made; however, with no baseline data savings cannot be estimated. Its possible simulations could be used to estimate the baseline energy use for these installations. The results could be compared against the current energy use to understand if savings are possible.

Thermogenics staff seemed willing to provide cost data; however at the time of writing, no data was provided.

[100] Interview with [redacted]. [redacted]. Union Gas. April 20th, 2011.

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Infrared Heater Controls

Union Gas ID: 329

Efficient Technology & Equipment Description
The use of infrared heater controls can result in additional energy savings up to 15% compared to conventional warm air thermostats. Infrared heater controls are claimed by manufacturers to be more accurate than conventional thermostats in sensing heating needs of a commercial facility because infrared heater controls contain sensors to measure both radiant temperature and ambient air temperatures, while conventional warm air thermostats sense just ambient air temperatures.[101] Infrared heaters typically owe their higher efficiencies than conventional space heater because they heat thermal mass directly, without heating air. Because of the nature of this technology, the goal of achieving a true "comfort temperature" as defined by the manufacturer needs to take into account both radiant output and ambient air temperature. Using a conventional thermostat causes infrared heaters to release more heat than necessary to achieve a "comfort temperature" and higher ambient air temperature results in heat loss. Schwank claims they are the only manufacturer who builds heater controls that sense radiant heat output. They offer two types of heater controls, a TruTemp thermostat and a ThermoPlus control system. According to the manufacturer, the TruTemp thermostat is most applicable to the small commercial building sector within Union Gas's territory since ThermoPlus is used for large facilities with multiple heating zones that may have separate schedules (e.g., an assembly line). The TruTemp control manages up to seven heaters, are only compatible with 1-stage heaters, and are specifically designed for Schwank heaters, though one representative stated that they are compatible with other manufacturers' heaters.[102] The manufacturer claims that Enbridge offers a rebate that covers the purchase of a Schwank infrared heater with the heater control feature; however, Navigant is unable to verify this.
Qualifier/Restriction
The infrared heater control is compatible with other brands of infrared heaters. However, the manufacturer claimed that the energy savings resulting from other combinations of heater control and heaters would vary.
Base Technology & Equipment Description

[101] http://www.schwankgroup.com/en/prod-energyman-trutemp.asp

[102] http://www.schwankgroup.com/en/prod-energyman-trutemp.asp

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Conventional thermostats are the assumed base technology.
Competing Technologies
There are no applicable competing technologies.

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y)	20,847	19,283	1,563

Schwank sells two basic types of infrared heaters – luminous heaters and tube heaters. Both types of infrared heaters have a range of BTUh inputs, ranging from about 21,500 to 200,000 btu/h input for its luminous heaters and 45,000 to 200,000 btu/h input for its tube heaters.[103] TruTemp is compatible with either heater, so Navigant assumed an average infrared heater input of 115,000 btu/h. Navigant also assumed an operating time of 2133 hours/year.[104]

Schwank claims that the infrared heater controls save as much as 15% on annual heating costs. No case studies were provided by the manufacture and third party reports of savings could not be found. Based on Navigant Consulting's professional experience with equipment manufacturers catering to niche markets or selling emerging technologies, manufacturer savings claims are often overstated by as much as 100%. Thus absent additional reports and data, Navigant discounted by half the manufacturer savings claims to achieve an average of 7.5% savings for each heater control.

Each TruTemp heater control can manage up to 7 infrared heaters. Navigant assumed that each heater control conservatively managed 3 heaters, since increasing the number of heaters per heater control reduces the ability for the temperature sensor to accurately monitor the true comfort temperature, assuming that the heaters are spaced apart from each other.

$$Number\ of\ heaters\ \times \frac{115{,}000 Btu/h}{heater} \times \left(\frac{2{,}133h}{year}\right) \times \frac{m^3}{35{,}300 Btu} = Base\ Case\ Consumption$$

$$Base\ Case\ Consumption\ \times (1 - Percentage\ Savings) = Efficient\ Technology\ Consumption$$

[103] http://www.schwankgroup.com/en/prod-intro.asp

[104] http://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

<table>
<tr><td colspan="4">Where:
$$Number\ of\ heaters = 3$$ $$Percentage\ Savings = 7.5\%$$ $$Energy\ value\ of\ natural\ gas = \frac{m3}{35{,}300\ Btu}$$</td></tr>
<tr><td>Electricity Use (kWh/y)</td><td>198</td><td>183</td><td>15</td></tr>
<tr><td colspan="4">Infrared heaters require an electrically powered circulating fan. Navigant assumes that the energy savings from infrared heater controls results from having to operate the infrared heater less frequently due to more accurate temperature monitoring, since one-stage heating applications offer only one heat output. Therefore, electricity savings are also expected to achieve 7.5%.

Navigant assumed that for a heater with an input rate of 115,000 btu/h, an appropriately-sized fan would have a power draw of 0.031 kW, based on previous analysis conducted by Navigant.[105]
$$Number\ of\ heaters \times \frac{1\ fan}{heater} \times 0.031kW \times \left(\frac{2133h}{year}\right) = Base\ Case\ Consumption$$ $$Base\ Case\ Consumption \times (1 - Percentage\ Savings) = Efficient\ Technology\ Consumption$$</td></tr>
<tr><td>Water use (L)</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="4">This technology is not expected to result in water savings.</td></tr>
<tr><td>Equipment Cost, $</td><td>0</td><td>$206</td><td>$206</td></tr>
<tr><td>Installation Cost, $</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Total Installed Cost $</td><td>0</td><td>$206</td><td>$206</td></tr>
<tr><td>Annual Maintenance Costs $</td><td>Unknown</td><td>Unknown</td><td></td></tr>
<tr><td colspan="4">The retail price to the consumer for a TruTemp heater control is $206; the price for the wholesaler is about $103.[106] Correspondence with a Schwank representative indicated that most infrared heater controls are sold as an option by the distributor with the unit. The controls are rarely sold alone since they are only available through Schwank</td></tr>
</table>

[105] http://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

[106] Conversation with [redacted], Schwank Heaters [redacted] for Ontario. April 28, 2011

distributors. The representative indicated that the controls have been sold separately but that such sales occur infrequently.[107] Navigant assumed that these sales were negligible.

Because sales of thermostats usually occur with the sale of infrared heater systems, Navigant assumed that that installation costs did not apply to the installation of either a conventional thermostat or an infrared heater control. Information on annual maintenance costs was not available.

OTHER INPUT ASSUMPTIONS

Equipment Life	20 years

Infrared heater controls were assumed to have the same lifetime as that of infrared heaters, since the thermostat is a crucial part of an infrared heater being able to operate properly.[108]

Customer Payback

Customer payback is calculated two ways:

- Including gas savings only
- Including gas, electric, and water savings

Customer payback is calculated assuming the following retail rates:

- Gas: $0.21/m^3
- Electricity: $0.0871/kWh
- Water: 1.829/m^3

Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right)$$

Payback including gas, electricity, and water is calculated as:

[107] Email correspondence with [redacted], Schwank [redacted] – Northeast U.S.. April 29, 2011

[108] "Prescriptive Incentives for Selected Natural Gas Technologies", Prepared for Enbridge Consumers Gas and Union Gas Ltd., Prepared by: Jacques Whitford Environment Limited, Agviro Inc., and Engineering Interface Ltd., September 27, 2000.

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$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings + 0.0871 * Electric\ Savings + 1.829 * Water\ Savings}\right)$$

	Valuing Gas Only	Valuing Gas, Electricity and Water
Payback Period (Years)	0.6	0.6

Market Size

The market size was estimated to be about 220 customers. The estimate was determined using Union Gas's list of number of customers, broken out into segment codes. Navigant determined which building segments were relevant[109] (based on Schwank's suggested list of infrared heating applications) and discounted this population by the percentage of the market that currently has infrared heating systems. Navigant assumed that each potential customer would purchase only one infrared heater control per heating system.

$$\sum Number\ of\ potential\ Union\ Gas\ customers\ \times 5\% = 2{,}208\ (Number\ of\ customers\ with\ infrared\ heaters)$$

where

$$5\% = Percentage\ of\ existing\ floor\ space\ that\ is\ heated\ by\ infrared\ heaters^{110}$$

$$Market\ for\ replacement\ of\ infrared\ heaters = Number\ of\ customers\ with\ infrared\ heaters\ \div Infrared\ heater\ lifetime$$

where

$$20 = Infrared\ heater\ lifetime$$

$$\sum Number\ of\ potential\ Union\ Gas\ customers\ \times 1.2\%\ \times 20\%$$

where

$$1.2\% = New\ building\ growth\ rate^{111}$$

$$20\% = Percentage\ of\ new\ buildings\ that\ are\ heated\ by\ infrared\ heaters^{112}$$

[109] Most consisting of: select retail facilities, select service facilities, the majority of entertainment facilities, churches, and warehouses.

[110] "Prescriptive Incentives for Selected Natural Gas Technologies", Prepared for Enbridge Consumers Gas and Union Gas Ltd., Prepared by: Jacques Whitford Environment Limited, Agviro Inc., and Engineering Interface Ltd., September 27, 2000. Union Gas Heating Product Database.

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$$Total\ Market = Market\ for\ replacement\ of\ infrared\ heaters + Market\ for\ new\ buildings\ that\ could\ use\ infrared\ heaters$$

Navigant estimated that sales could occur in the existing building market and the new construction market. The existing market was assumed to be the number of customers wanting to replace existing infrared heaters and was calculated by dividing the number of customers with infrared heaters by the lifetime of an infrared heater.

The new construction market was estimated based on what the number of potential Union Gas customers, multiplied by the average growth rate of new floorspace from 2008 to 2035[113] and multiplied by the estimated percentage of infrared systems in new space heating applications. One report estimated that between 10% and 25% of new space heating applications were infrared systems.[114] Navigant used 20% as a midpoint value.

Navigant notes that the market estimate of 220 customers is fairly conservative, as Schwank claims that it sells 3,600 units annually into Ontario.[115] The estimated market size for infrared heater controls in Union Gas's territory would thus represent about 6% of total sales into Ontario. However, given Union Gas's share of Ontario customers and potential limited applications for infrared heating systems in small commercial buildings, 6% of total sales may be reasonable.

TRC Result

TRC benefits include the avoided cost of natural gas and electricity. This measure is considered to be weather sensitive, thus weather sensitive avoided costs are use.

Total market TRC is calculated as follows:

[111] U.S. Energy Information Administration, Annual Energy Outlook 2011

[112] Ibid, Agviro Inc;

[113] Ibid, U.S. Energy Information Administration, Annual Energy Outlook 2011

[114] Ibid, Agviro Inc;

[115] Ibid, Email correspondence with Rich Morgenroth

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

Where:

Customers = Maximum number of units that could be installed

	TRC Unit Benefits	TRC Unit Costs	TRC Benefit/ Cost Ratio	Total Market TRC
Early Retirement	$4,517	$206	21.9	$946,773

Comments on Likelihood of Data being Available for Fund Study

Schwank seems to be the primary manufacturer of these infrared heater controls; several commercial HVAC contractors in the Ontario region have not heard of this technology and state that they have not seen these technologies before.[116,117]

The manufacturer also claims that Enbridge already offers a rebate that covers the purchase of a Schwank infrared heater with the heater control feature.[118] Navigant Consulting was unable to confirm this information. Union Gas could make a request to Enbridge for additional information and the background data used to justify the rebate.

Since infrared heater controls are rarely sold separately from infrared heating systems, in future analyses, infrared heater controls could be incorporated into Union Gas's substantiation documents for infrared heaters and considered as an added feature on the technology.

[116] Conversation with [redacted], [redacted]. April 28, 2011

[117] Conversation with [redacted], [redacted]. April 28, 2011

[118] Conversation with [redacted]. April 28, 2011

Greenhouse Heat Curtains

Union Gas ID: 310

Efficient Technology & Equipment Description
Greenhouse heat curtains decrease heat losses in greenhouses (conduction, convection, and radiation losses). Greenhouse heat curtains are installed inside the greenhouse and are typically installed horizontally near the greenhouse gutter line. It is assumed that the curtains are deployed overnight, and open during daytime hours.[119] Heat curtains can be single or double layer. Curtains can either be installed in a truss-to-truss system or a gutter to gutter system. There are three ways to configure the truss-to-truss system. 1) At gutter height, minimizing heated area and making installation easy. 2) Slope-flat-slope, where the profile of the curtain follows each slope of the roof part way up the truss, with a flat section joining the two sloped segments. The benefit of the slope-flat-slope curtain system is that it can be installed over equipment, and mounted above the gutter. 3) Slope-slope, where the profile of the system parallels a line drawn from the gutter to the peak of the truss. This configuration minimizes the amount of cold air trapped above the curtain and maximizes clearance from equipment mounted above gutter height.[120] The alternative to truss to truss installations are gutter to gutter systems, where a single layer of fabric is used per house, rather than having multiple panels.[121] There are different materials that are used as thermal curtains. Some better allow condensation to drain and others feature higher energy conservation. Double-layer heat curtains have an added benefit of providing an air gap, which traps heat. The additional thermal resistance due to the air gap depends on the size of the air gap.[122] Heat curtains often double as shade cloths, so technology options vary to the extent in their levels of diffuse light transmission. Pacific Gas and Electric's analysis of technology assumes for a single heat curtain system, that it has a 40% energy savings factor. According to [redacted] from Union Gas heat curtain manufacturers claim savings as high as 57%. However, measured over the use of both day and night-time energy needs, greenhouse heat curtains average to about 30-40%.

[119] "Greenhouse Thermal Curtains" Pacific Gas & Electric Company. February 5, 2008, http://www.socalgas.com/regulatory/documents/a-08-07-022/amendedWorkpapers/SW-AgB/Greenhouse%20Thermal%20Curtains%20PGECOAGR101%20R0.pdf

[120] "Technical Support FAQs – Internal & external Greenhouse Curtain Systems" Griffin Greenhouse & Nursery Supplies. Accessed April 20, 2011, http://www.griffins.com/tech_service/faqs_greenhouses_curtains.asp

[121] "Curtain Systems" National Greenhouse Manufacturers Association. http://www.ngma.com/standardpdf/curtainsystems2010.pdf

[122] Ibid

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Qualifier/Restriction
Technology cost-effectiveness depends on weather conditions and temperature set-points, which in turn depend on the types of plants grown in the greenhouses. In Ontario, typical applications are growing green peppers, tomatoes and flowers, which require temperatures of 68-75 degrees F.[123] Some older greenhouses may not be compatible with the installation of this technology. It could be the case that only certain size greenhouses and respective greenhouse gas curtains would find the technology cost-effective, since costs/acre tend to decrease as greenhouses scale in size.
Base Technology & Equipment Description
Not having heat curtains is the assumed base case technology.
Competing Technologies
Adding IR film alone can be a possible technology alternative; It costs $74.50 for a 500 square-foot roll, plus an additional $.50/ft^2 for installation[124]

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y)	199,316 m^3/acre	137,528 m^3/acre	61,788 m^3/acre

[redacted] from Union Gas provided Navigant with data on three projects conducted in 2010 in Union Gas territory. Energy savings were modelled by the U.S. Department of Agriculture's (USDA) Virtual Grower energy model after selecting appropriate energy curtain technologies.[125] The projects below reflect greenhouses that grow vegetables (green peppers and tomatoes), have a year-round operation, and have a temperature range of 68 to 75 degrees.

Table 29 - Union Gas Project Data

Project	Acres	Gas Savings (m^3)	Installed Cost (C$)	New/Existing Greenhouse
A	7.29	623,638	$ 374,930	Existing

[123] Conversation with [redacted] Union Gas, April 21, 2011

[124] Conversation with [redacted] at Innovative Insulation. April 18, 2011

[125] U.S. Department of Agriculture, "Products and Services" Hhttp://www.ars.usda.gov/services/software/download.htm?softwareid=108H. Accessed April 26, 2011

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B	31.9	1,147,172	$ 1,593,424	New
C	0.4	25,542	$ 29,657	Existing

Gas savings were normalized per acre and then averaged across the three projects (Table 30). Base case consumption for each of the projects was calculated based on an assumption that greenhouse heat curtains achieved 31% savings, which was suggested by [redacted] as a reasonable level based on modelled projects in USDA's Virtual Grower software. Navigant's review of other literature revealed that savings range from 27-40%.[126,127] However, this range of savings represents data from Wisconsin and California, where the greenhouse industry grows different plants, has different growing seasons and may use different materials to construct greenhouses. Because 31% is within the range of studies, this savings value to be reasonable for Ontario. Efficient technology consumption was determined by subtracting the gas savings per acre from the base case consumption per acre. In reality, base case energy use will vary according to the type of crops grown, the regional climate, and other factors subject to a greenhouse's size, design and age of construction.

Table 30– Calculated Gas Savings Data

Project	Gas Savings per Acre	Base Case Consumption per Acre	Efficient Technology Consumption per Acre
A	85,547	275,958	190,411
B	35,962	116,005	80,043
C	63,855	205,984	142,129
Average Values	61,788	199,316	137,528

Electricity Use (kWh/y)	NA	NA	NA
This measure is not expected to result in any electricity savings.			
Water use (L)	NA	NA	NA
This measure is not expected to result in any water savings.			

[126] "Tropical Gardens Sees More Green Case Study" Focus on Energy, 2008. Hhttp://www.focusonenergy.com/files/Document_Management_System/Business_Programs/tropicalgardensgreenhouse_casestudy.pdfH, Accessed April 26, 2011

[127] Ibid, Pacific Gas & Electric Company

Equipment Cost, $	$0	C$34,000/acre[128]	
Installation Cost, $	$0	C$15,000/acre[129]	
Total Installed Cost $	$0	C$50,000/acre[130],	
Annual Maintenance Costs $	$0	NA; Minimal maintenance requirements[131]	

The installation costs were based on a representative project example provided by [redacted] for which a 3.5 acre greenhouse incurred approximately C$120,000 in equipment costs, and C$52,000 in installation costs for a single-layer heat curtain made of XLS15 Firebreak material sold by VRE Systems, which claims 57% energy savings when in use.[132]

Total installed cost per acre was corroborated based on the data on the three Union Gas projects supplied, below in Table 31.

Table 31 – Calculated Cost Data

Project	Acres	Installed Cost (C$)	Installed Cost per Acre (C$)
A	7.29	$ 374,930	51,431
B	31.9	$ 1,593,424	49,951
C	0.4	$ 29,657	74,143
Average Value			58,508

This data supplied by [redacted] were chosen since installation costs can vary substantially depending on regional wage rates, and depending on the degree to which existing equipment (pipes, etc) need to be adjusted to accommodate the heat curtains.[133]

To illustrate, Innovative Insulation cited a total installed cost of about C$26,000/acre,

[128] Conversation with [redacted] at Union Gas. April 20, 2011

[129] Ibid, [redacted]

[130] Ibid, based on 2010 data from [redacted]

[131]Ibid, [redacted]

[132] VRE Systems "Product Index" http://www.vresystems.com/pagefiles/pdf/LS-21-XLS-Firebreak.pdf, Accessed April 27, 2011.

[133] Ibid, [redacted]

excluding shipping costs. Another vendor cited installation costs of about C$1-C$2.50 per square foot, which translates to C$43,560/acre to C$108,900/acre.[134] Pacific Gas & Electric's (PG&E) study assumes that single-layer heat curtains have a total installed cost of C$62,000/acre. For double-layer heat curtains, PG&E assumed a total installed cost of C$108,000/acre. One study from the University of Connecticut indicates that typical costs range from US$2.00-$2.50/square foot total installed costs, which translates to C$83,000/acre to C$104,000/acre.[135]

OTHER INPUT ASSUMPTIONS

Equipment Life	5 years

Pacific Gas and Electric's study indicated an equipment life of 5 years, based on interviews with vendors that cite an approximate useful life.[136] This estimate matches what VRE Systems specifies for its XLS Firebreak fabric options.[137] If curtains are used only once or twice a day, the useful life can be as long as 12 years.[138]

Customer Payback

Customer payback is calculated two ways since this technology only affects gas savings to a significant degree:

- Including gas savings only assuming early retirement scenario (where the cost used is the full installed cost of the measure)
- Including gas savings only assuming a new construction or replace on burnout scenario (where the cost used is the incremental installed cost).

Since the base technology is not employing any curtain – the early retirement scenario and the new construction or replacement scenario will result in the same customer payback as new construction projects will still require the same installation and associated costs as a retrofit.

Customer payback is calculated assuming the following retail rates:

- Gas: $0.21/m^3$

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134 Conversation with [redacted] at VRE Systems, April 28, 2011

135 John Bartok, "Selecting an Energy/Shade Screen System" University of Connecticut, Hhttp://www.umass.edu/umext/floriculture/fact_sheets/greenhouse_management/jb_EnergyShadeScreen.pdfH.

136 Ibid, PG&E

137 VRE Systems, http://www.vresystems.com/pagefiles/pdf/LS-21-XLS-Firebreak.pdf, Accessed April 27, 2011

138 Ibid, [redacted].

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Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right)$$

Payback Period (Years)	Gas Only
Early Retirement	3.8
New Construction or Replace on Burnout	3.8

Market Size

There are 298 Union Gas customers listed as "Agr-Greenhouse & Nursery." Navigant assumed that 20% of these greenhouse operations did not already have heat curtains based on a conversation with staff at VRE Systems who suggested that 75 – 90% of greenhouses in Ontario already have heat curtains. In Ontario, most greenhouse growers install heat curtain in new buildings, or install them within a year since they are widely accepted as a cost-effective technology; this differs from growers in the United States who have not embraced the technology as readily. The vendor indicated that most of their installations were for new greenhouses or for replacing existing curtains.[139]

Navigant also assumed that all greenhouses could accommodate heat curtains, since there are a variety of installation configurations available for any given greenhouse. The vendor also indicated that in 90-95% of applications, greenhouses can easily install heat curtains in a truss-to-truss configuration. In some instances greenhouse growers may need to have a slope-slope configuration in order to accommodate piping or mechanisms that can open the roof of the structure which can be more expensive.[140]

[139] Ibid, Conversation with [redacted]

[140] Ibid, Conversation with [redacted]

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According to the Ontario Ministry of Agriculture, Food, and Rural Affairs, the average operation in southern Ontario was about 93,200 ft^2, which corresponds to 2.14 acres per operation.[141]

Based on the above information, Navigant estimates a total market size of 128 acres of greenhouse space.

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. TRC is calculated for two scenarios: 1) early retirement scenario and 2) new construction or replace on burnout.

This measure is considered to be weather sensitive, thus weather sensitive avoided costs are use.

Total market TRC is calculated as follows:

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

Where:

Customers = Maximum number of greenhouse acreage that could adopt the technology.

	TRC Unit Benefits	TRC Unit Costs	TRC Benefit/ Cost Ratio	Total Market TRC
Early Retirement	$71,632	$49,000	1.5	$2,886,638
New Construction/ Replace On Burnout	$71,632	$49,000	1.5	$2,886,638

Comments on Likelihood of Data being Available for Fund Study

[141] "The Ontario Floriculture Industry" Ontario Ministry of Agriculture, Food, and Rural Affairs" http://www.omafra.gov.on.ca/english/crops/facts/greenflor.htm, Accessed April 27, 2011.

Data on energy savings resulting from greenhouse heat curtain installation is fairly well modeled based on the USDA Virtual Grower tool. There are numerous vendors of greenhouse heat curtains, and several utilities in the U.S. already offer rebates for the technology.

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Restaurant Water Heater Tune Up

Union Gas ID: 260

Efficient Technology & Equipment Description
This is a restaurant water heater audit and retrocommissioning measure for existing restaurants with natural gas water heating. There are a multiple strategies to decrease energy use by restaurant hot water heaters. Water heaters can be made more efficient by: installing tank insulation, installing pipe insulation, optimizing the thermostat set point, checking and fixing the flue damper, and adding a time controller to the hot water re-circulation loop (if present). Pilot studies have shown that not all of these measures are necessarily needed on every restaurant water heater.[142] For example: • A water heater may already have insulation • A water heater temperature set point is already optimal • The building construction does not allow access to hot water pipes to add insulation. However, in each of these cases, although one measure may not be applicable, the water heater can still benefit from other measures. This is the likely case for the average water heater encountered in the field.
Qualifier/Restriction
Only applies to retrofit applications.
Base Technology & Equipment Description
The baseline can vary widely by customer. Some may already have one or more of these measures installed but could still benefit from the others. However some may be in need of all measures. We assume the baseline is an average restaurant based on US DOE CBECS data.
Competing Technologies
Installing a high efficiency water heater would remove the need for: tank insulation, thermostat optimization and the need to check the flue damper.

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings or Incremental Cost

[142] Food Service Technology Center. *Energy Saving Potential for Commercial Water Heating Through Retro-Commissioning.* September 2008.

Gas use (m^3/y)	6,689	6,398	291

There are five possible sub measures that can be part of this measure. As each acts to reduce water heating energy use and their interactive effects must be accounted. Total savings is not a simple summation of the individual savings. Additionally, it is expected that all five measures will most likely not be needed for every customer. Some customers may already have one or more measures installed.

High efficiency energy use is calculated as:

$$HE\ Energy\ Use = WH_E * (1 - Save_1) * (1 - Save_2) * (1 - Save_3) * (1 - Save_4) * (1 - Save_5)$$

Where:

WH_E = Baseline water heater energy use by restaurants
$Save_1$ = Percent savings from Pipe Insulation
$Save_2$= Percent savings from Flue damper adjustment
$Save_3$= Percent savings from Temperature Setback
$Save_4$= Percent savings from Time Controller
$Save_5$= Percent savings from Water Heater Insulation

Baseline restaurant water heating energy use (WH_E)is estimated as below:

$WH_E = EI_{WH} * SQFT_{Rest}$

Where:

Restaurant WH_E = Water heating energy use in a typical restaurant
EI_{WH} = Natural Gas Intensity of Water Heating in a typical restaurant (m^3/sqft)
$SQFT_{Rest}$ = Average restaurant floorspace (sqft) = 5,600 [143]

Natural Gas Intensity of Water Heating in a typical restaurant is calculated as follows:

$EI_{WH} = EI_{Rest} * WH_{share} * 0.0283$

Where:

EI_{Rest} = total gas energy intensity of a restaurant (cubic feet/sqft) = 152.9 [144]

[143] US DOE. Commercial Buildings Energy Consumption Survey. Table A1. 2003

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WH_{share} = share of a restaurants natural gas use dedicated to water heating = 28% [145]
0.0283 = conversion factor from cubic feet to cubic meters

Calculation Results:

EI_{WH} = 1.211 m^3/sqft
Restaurant WH_{EUC} = 6,689 m^3 (baseline energy use)

A 2008 field test pilot by the Food Service Technology Centre[146] performed three pilot restaurant water heater retrocommissionings. The study looked at four measures:

1. Installing pipe insulation,
2. Optimizing the thermostat set point,
3. Checking and fixing the flue damper,
4. Adding a time controller to the hot water re-circulation loop

Navigant analyzed the case study results. In some cases only 2 or 3 of the measures were installed as others were not needed. Navigant calculated (below) an average of 2.8% real-world savings achievable from these four measures combined.

FSTC Test Sites	Baseline Energy (therms)	Retrofit Energy Use (therms)	Percent Savings
Case 1	13,061	12,669	3.0%
Case 2	7,996	7,788	2.6%
Case 3	7,136	6,947	2.6%
Total	28,193	27,404	2.8%

The results of this study show:

$$(1 - Save_1) * (1 - Save_2) * (1 - Save_3) * (1 - Save_4) = (1 - 2.8\%)$$

Percent savings from water heater insulation in a restaurant ($Save_5$) is obtained from the Ontario Power Authority.[147] The OPA's "Water Heater Blanket (Commercial)" measure calculations show the following information with reveals a 1.6% savings potential from

[144] US DOE. Commercial Buildings Energy Consumption Survey. Table C27. 2003

[145] Calculated from: US DOE. Commercial Buildings Energy Consumption Survey. Table E7. 2003

[146] Food Service Technology Center. September 2008.

[147] Ontario Power Authority (OPA). *2011 Quasi-Prescriptive Measures and Assumptions Release Version 1.* October 2011.

electric water heater blankets in a restaurant.

Sector	Annual Base Measure Consumption (kWh/L)	Annual Conservation Measure Consumption (kWh/L)	Annual Electricity Savings (kWh/L)
Restaurants	128.36	126.27	2.1

We assume this percent savings value will be true for gas powered water heaters as well, therefore:

$(Save_5)$ = 1.6%

High efficiency restaurant water heating energy use is estimated as below

HE Energy Use = 6,689*(1-2.8%)*(1-1.6%) = 6,398

Savings = 291

Electricity Use (kWh/y)	0	0	0
This measure is not expected to reduce electricity use.			
Water use (L)	0	0	0
This measure is not expected to reduce water use.			
Equipment Cost, $	$0	$37.80	$37.80
Installation Cost, $	$0	$110.52	$110.52
Total Installed Cost $	$0	$148.32	$148.32
Annual Maintenance Costs $	None	None	

Itemized equipment costs include:

- Pipe insulation: $8.80 ($0.88/foot [148] assuming 10 feet of insulation)
- Water heater insulation: $16.00 [149]

[148] OPA. 2010

[149] OPA. 2010

- Clock Timer: $13.00 [150]

Total Labour (installation) costs were estimated by Navigant. In this calculation Navigant assumes:

- The audit and installation of necessary measures will require 3 hours of a plumber's time
- The average plumber hourly rate is $36.84/hour [151]

OTHER INPUT ASSUMPTIONS

Equipment Life	7 years

Each piece of equipment has a different lifetime:

- Pipe Insulation – 15 years [152]
- "Circulation Pump Timeclock Retrofit" – 15 years [153]
- Water Heater Insulation – 7 years [154]

Lifetime is uncertain for Flue damper adjustment and Temperature Setback as they could be counteracted by restaurant staff at any time.

To be conservative, Navigant assumes the total lifetime for this measure to be 7 years.

Customer Payback

Customer payback is calculated including gas savings only and assuming early retirement scenario (where the cost used is the full installed cost of the measure)

Customer payback is calculated assuming the following retail rates:

- Gas: $0.21/m^3

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150 Source: Hhttp://www.improvementscatalog.com/home/diy/timer-outlets

151 Human Resources and Skills Development Canada. *Schedule of Wage Rates : Ontario - Toronto Zone*. June 2010. Accessible at: Hhttp://www.hrsdc.gc.ca/eng/labour/employment_standards/contracts/schedule/ontario/toronto_zone/schedule.shtml

152 OPA. 2010

153 California Public Utilities Commission. *2008 Database for Energy-Efficient Resources: EUL/RUL Values*. Available online at: Hhttp://www.deeresources.com/index.php?option=com_content&view=article&id=65&Itemid=57

154 OPA. 2010

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Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right) = \mathbf{2.4\ years}$$

Market Size

There are 6,962 customers in Union Gas territory that are classified as either "Foodservice-Fastfood & Limited Serv" or "Foodservice-Full Service Rest". Navigant assumes each restaurant has one water heater.

Navigant also assumes

- 85% of water heating in the commercial sector fuelled by natural gas.[155]
- 13% of installed water heaters are ENERGY STAR rated and would not fully benefit from this measure.[156]

We estimate the maximum market size to be:
5,148 water heaters

TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. TRC is calculated assuming an early retirement scenario.

This measure is considered to be non-weather sensitive, thus baseload avoided costs are used.

Total market TRC is calculated as follows:

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

[155] NRCan, *Comprehensive Energy Use Database*
Hhttp://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/index.cfm

[156] US DOE. *ENERGY STAR Water Heater Market Profile*. September 2010.

Where:

Customers = Maximum number of restaurants that could benefit from this measure

	TRC Unit Benefits	TRC Unit Costs	TRC Benefit/ Cost Ratio	Total Market TRC
Early Retirement	$435	$148	2.9	$1,477,687

Comments on Likelihood of Data being Available for Fund Study

Data seems to be relatively available on all technologies and equipment costs are well understood. Baseline energy use of water heaters is also very well understood and studied by many other originations. Utilities offer some of the individual components of this audit as individual measures; however no similar restaurant water heater audit programs at other utilities have been identified.

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Water Heater Descaling

Union Gas ID: 309

Efficient Technology & Equipment Description
Domestic water that is high in mineral content (or "hard water") causes the buildup or scaling of mineral (calcium) deposits in water heaters. Scale collects and forms along the heat exchange surfaces and a significant amount of sediment can settle at the bottom of the tank. Scale build-up reduces system performance in a number of ways. Water heater efficiency decreases as the scale and sediment decreases heat transfer. Scaling can be avoided by regularly flushing water heaters and using chemicals to dissolve sediment on heat exchange surfaces. From conversations with a manufacturer[157], water heaters should be treated for scaling at least once per year. Commercial water heaters may be treated more often depending on usage.
Qualifier/Restriction
Must be used on gas water heaters that are more than 2 years old. This chemical can also be used for tankless water heaters.
Base Technology & Equipment Description
Navigant uses NRCan data to estimate the average energy intensity of water heating in Ontario.
Competing Technologies
Chemical and mineral based water softener systems would compete against this technology. Water softeners are used to reduce sediment in water thus decreasing scale build-up.

Resource Savings Assumptions

Measure Input	Base Case Consumption	Efficient Technology Consumption	Savings
Gas use (m^3/y)	2,470 - 17,474	2,379 - 16,827	91 - 647

A report commissioned by the Water Quality Association documented the energy efficiency reductions in water heaters due to sediment and scale buildup.[158] The study collected data under a laboratory setting to show the efficiency of a gas storage water heater decreases over time as sediment builds up according to the following equation:

[157] Customer Service Representative at J.C. Whitlam Manufacturing Company. http://www.flow-aide.com/

[158] D. D. Paul, et al. Battelle Memorial Institute. *Final Report Study on Benefits of Removal of Water Hardness (Calcium and Magnesium Ions) From a Water Supply.* 2010

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*E = Eo –1.485*t*

Where the study assumes:

E = the efficiency at time t
Eo = the initial efficiency of the water heater at t =0
t = the time in years

The study only documented the decrease in efficiency after 2 years, its unknown if this relationship holds true after two years. The study assumed E_o = 70.4 %, therefore E = 67.43%.

Based on those results, descaling would reduce water heater energy use by 3.7%.

To determine savings, Navigant has estimated the natural gas space-heating energy intensities of buildings in nine commercial segments based on data published by NRCan's Comprehensive Energy Use Database (CEUD)[159]. Unfortunately although NRCan provides the percentage of total water-heating energy consumption in Ontario that is gas and provides an estimate of the total Ontario floor space occupied by each segment, no indication is made as to what percentage of that floor space is served by natural gas water heaters.

Navigant has therefore assumed that the distribution of floor space by water-heating fuel exactly matches the distribution of total water energy consumption by fuel. In this case the database reveals that 85.3% of water heating in Ontario is powered by natural gas.

Energy Intensity data is combined with Commercial and Institutional Building Energy Use Survey (CIBEUS) survey data that contains information on the average floorspace of commercial buildings by type in Ontario.[160] Reliable data was only available for six commercial building types that match those found in CEUD. Combining this data reveals the baseline energy use for water heating for various building types. Energy savings are estimated to be 3.7% of these baseline uses.

[159] NRCan, *Comprehensive Energy Use Database*
Hhttp://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/index.cfm

[160] NRCan, *Commercial and Institutional Building Energy Use Survey*
Hhttp://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/Cibeus/section_03.cfm?attr=0

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Segment	Base Energy Intensity (m^3/m^2)	Average Area of Building Type (m^2)	Base Energy Use (m^3/yr)	% Savings	Efficient Energy Use (m^3)	Annual Savings (m^3)
Retail Trade	3.33	743	2,470	3.7%	2,379	91
Transportation and Warehousing	1.13	3,083	3,494	3.7%	3,364	129
Offices	2.82	4,724	13,302	3.7%	12,809	492
Educational Services	3.18	4,938	15,717	3.7%	15,136	582
Health Care and Social Assistance	6.25	2,012	12,580	3.7%	12,115	465
Accommodation and Food Services	5.99	2,919	17,474	3.7%	16,827	647

Electricity Use (kWh/y)	0	0	0
No electricity savings are expected.			
Water use (L)	0	606	(606)

Water use is expected to increase above baseline.

Plumbers must drain the water that is currently in the tank, flush loose sediments from the tank with water, and flush the tank once more after chemical descaling is completed We assume:

- 80 US gallons of water is drained from the tank (assuming an 80 gallon storage tank)
- 40 US gallons is used to flush the tank of loose sediment
- 40 US gallons if used to flush after chemicals are used.

Units of gallons are converted to Litres using 1 US Gal = 3.785 Litres

Equipment Cost, $	0	CAD $ 200	CAD $ 200
Installation Cost, $	0	CAD $ 129	CAD $ 129
Total Installed Cost $	0	CAD $ 329	CAD $ 329
Annual Maintenance Costs $	0	N/A	N/A

From conversations with a plumber Navigant determined there are two components to estimate the cost of this measure. [161]

Standard Water Heater Flushing: A plumber must first drain the tank (which itself can take 30 minutes). Once the tank is drained the water is turned on to agitate loose sediment and flush it out. Several flushes may be needed. At the end, the plumber must then refill the tank and turn the water heater back on. All this is estimated to take 2-3 hours. We will assume 2.5 hours.

Incremental Chemical Descaling: Once the tank has been flushed of loose sediment, and prior to the tank being refilled, the chemical cleaning begins. Based on the AO Smith instruction manual we estimate this to take about an hour. [162]

Total time is estimated to be approximately 3.5 hours. Navigant assumes CAD $36.84/hr as the labour rate for plumbers in Ontario[163]. The total installation cost is CAD $129.

From conversations with a manufacturer[164] a 5 gallon tank of chemicals costs CAD $200. Product literature suggests 5 gallons are needed for a typical commercial water heater. [165]

The total annual cost for this measure is CAD $329.

OTHER INPUT ASSUMPTIONS

Equipment Life	1 years

AO Smith, a major manufacturer of commercial water heaters, recommends water heaters should be flushed and descaled once a year. AO Smith reports significant amounts of scale can build up after only 6 months.[166]

Customer Payback

Customer payback is calculated two ways:

[161] Interview with staff at George Salet Plumbing Inc. April 28th, 2011.

[162] AO Smith. How, When and Why To Remove Water Scale From Tank Type Glass-Lined Water Heaters. Form No. 4800 Rev. 9

[163] Human Resources and Skills Development Canada. Schedule of Wage Rates : Ontario - Toronto Zone. June 2010. Accessible at: Hhttp://www.hrsdc.gc.ca/eng/labour/employment_standards/contracts/schedule/ontario/toronto_zone/schedule.shtml

[164] Customer Service Representative at J.C. Whitlam Manufacturing Company.1-800-321-8358. http://www.flow-aide.com/

[165] AO Smith. Form No. 4800 Rev. 9

[166] AO Smith. Form No. 4800 Rev. 9

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- Including gas savings only
- Including gas, electric, and water savings

Because water use increases, water use is viewed as a cost and not a savings in this calculation.

Customer payback is calculated assuming the following retail rates:

- Gas: $0.21/m^3
- Electricity: $0.0871/kWh
- Water: 1.829/m^3

Payback including gas only is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings}\right)$$

Payback including gas, electricity, and water is calculated as:

$$Payback = \left(\frac{Cost}{0.21 * Gas\ Savings + 0.0871 * Electric\ Savings + 1.829 * Water\ Savings}\right)$$

Payback in Years	Payback (Gas Only)	Payback (Gas, electric, and water)
Retail Trade	17.2	18.3
Transportation and Warehousing	12.1	12.6
Offices	3.2	3.2
Educational Services	2.7	2.7
Health Care and Social Assistance	3.4	3.4
Accommodation and Food Services	2.4	2.4

Market Size

The applicable market is commercial buildings that:

- Have natural gas water heaters
- Have water heaters that are more than 2 years old

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- Are not amongst the water heaters that receive regular sediment flushing

NRCan data show 85.3% of water heating in the commercial sector fuelled by natural gas.[167]

Assuming water heaters last 15 year, we estimate (conservatively) that 13% of water heaters are less than 2 years old. Thus 87% are more than 2 years old.

Anecdotal information reveals that only a fraction of commercial water heaters receive regular flushing every year. We assume only 10% are properly maintained in this manner.

To calculate the applicable market, all of the factors above must be multiplied by the number of buildings of each type in Union Gas' service territory. Although Union Gas maintains customer counts, at the time of writing no count of building types was available. Navigant has therefore, under guidance from Union Gas staff, assumed that 40% of all buildings counted in the NRCan CIBEUS database reside in Union Gas territory. The NRCan, Marbek and CIBEUS segments are mapped to one another in the table below. Navigant has endeavoured to match segments as best possible across the different sources but professional judgment was applied for some of the mapping.

			A	B	C	D	E = B x C x (1 - D)	F = E x A
NRCan Segment	Marbek Segment	CIBEUS Segment	Number of Buildings	% With NG Water Heater (NRCan)	% Two Years Older or More (NRCan)	% Current Pentration of Regular Maintenance	% Applicable Population	Water Heater Applicable Population
Retail Trade	Medium Non-Food Retail	Non food retails	2,552	85%	87%	10%	67%	1,698
Transportation and Warehouseing	Warehouse	Warehouse/wholesale	567	85%	87%	10%	67%	377
Offices	Medium Office	Office	2,734	85%	87%	10%	67%	1,819
Educational Services	Medium School	Education	1,906	85%	87%	10%	67%	1,268
Health Care and Social Assistance	Hospital	Health care	933	85%	87%	10%	67%	621
Accommodation and Food Services	Medium Hotel/Motel	Commercial and institutional accommodation	781	85%	87%	10%	67%	519

[167] NRCan, *Comprehensive Energy Use Database*

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TRC Result

TRC benefits include the avoided cost of natural gas, electricity, and water. This measure is considered to be non-weather sensitive, thus baseload avoided costs are used.

Total market TRC is calculated as follows:

Total Market TRC = Customers(TRC Benefits – TRC Costs)*

Where:

Customers = Maximum number of water heaters that could benefit from this measure

Market Segment	TRC Benefits	TRC Costs	TRC Ratio	Total Market TRC
Retail Trade	$23	$329	0.1	($520,154)
Transportation and Warehousing	$33	$329	0.1	($111,764)
Offices	$128	$329	0.4	($366,222)
Educational Services	$151	$329	0.5	($226,156)
Health Care and Social Assistance	$120	$329	0.4	($129,506)
Accommodation and Food Services	$168	$329	0.5	($83,711)
Total				**($1,437,513)**

Comments on Likelihood of Data being Available for Fund Study

Navigant's energy efficiency team is currently conducting tests to understand the impact of aging on the efficiency of storage water heaters. Age-related impacts will include among other factors the effect of scale build-up. As current little information exists on the effect of scale on efficiency. Plumbing contractors interviewed explained that most customers perform this to improve water quality and life of the water heater and not as an energy savings measure.

SEC INTERROGATORY #5

INTERROGATORY

[B/1/2, p. 15]

With respect to the Enbridge EUL table:

a. Please provide the basis for the EUL for Home Energy Conservation with furnace upgrade.

b. Please provide reference 7.

c. [also reference B/1/5, p. 6] Please advise which of the EULs is Equipment Life only, and which are adjusted for Measure Persistence. In the latter case, please advise the limitations presented by persistence, including business turnover forecasts, forecast early replacement, and any other limits

RESPONSE

a. As an outcome of the 2012 audit, Enbridge's Audit Committee reviewed the approach to Home Energy Conservation ("HEC") and endorsed a deemed 15 year measure life for Community Energy Retrofit ("CER") (now HEC) participation where a furnace upgrade is included and a deemed 25 year measure life for HEC projects completed without a furnace. The Technical Evaluation Committee ("TEC") recommended that the approach be applicable to savings claimed in 2014. Enbridge maintained the same approach through 2015 being a rollover year. The measure life was retained again in 2016 as HEC was already in market when the Board issued its Decision on EB-2015-0049.

   Effective 2017, Enbridge has adopted, based on best available information, the approach applied by Union Gas included in Union Gas' 2015-2020 Plan filing (EB-2015-0029), approved by the Board on January 16, 2016.

b. "Measure Life for Retro-Commissioning and Continuous Commissioning Projects" (Finn Projects, Dec 31, 2008) is attached to this response.

Witnesses: D. Bullock
L. Kulperger

c. Exhibit B, Tab 1, Schedule 5, p. 6 provides the Technical Reference Manual ("TRM") glossary. The TRM Glossary addresses the prescriptive and quasi-prescriptive substantiation documents contained in the TRM. The TRM Glossary does not provide definitions for custom projects and/or Enbridge's Measure Life Guide for commercial/industrial custom offers. The Measure Life table provides a guideline for the measure life only.

As per the Board's letter of August 21, 2015 (EB-2015-0245), an Evaluation Contractor ("EC") will be responsible for undertaking various studies which may include "examining the level of persisting natural gas savings from various programs and conducting other evaluation studies as required."

Witnesses: D. Bullock
L. Kulperger

Measure Life for Retro-Commissioning and Continuous Commissioning Projects

Report
For
Enbridge Gas Distribution

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Report Date: December 31, 2008

TABLE OF CONTENTS

Measure Life for Retro-Commissioning and Continuous Commissioning Projects

1. Executive Summary

This study was commissioned by Enbridge Gas Distribution (EGD) to establish acceptable measure life for operational improvements in Commercial premises for its Energy Efficiency Programs. EGD wishes to understand industry best practice on similar commissioning programs, and also establish measure life as well as the persistence of savings for various operational improvements, intended for:

- Retro-commissioning (RCx), or re-commissioning, with measure implementations without active monitoring
- Continuous commissioning (CCx) with active monitoring

While the focus of the report is on natural gas savings, the corresponding electrical savings are also identified. A comprehensive commissioning program will increase the energy savings and reduce the overall project payback period.

This study found that the sustainable measure life for retro-commissioning varies building by building and measure by measure, with significant impact from the operating staff and preventative maintenance procedures. There is insufficient substantiated data to assign a measure life to individual measures. RCx & CCx programs should be based on comprehensive programs with a number of measures so that the savings and payback period can be blended. In the case of RCx, it appears the optimal cycle would be to retroc-commission after 5 years. Energy savings are still generated after this period, however the reduction in savings would warrant carrying out retro-commissioning again.

There is no doubt that RCx and CCx programs save energy; in some cases these energy savings are substantial, such as the 10 buildings within the University Campus, originally investigated by Lawrence Berkeley National Lab [8] where savings for some buildings exceeded 80%. It is not expected that most projects will yield this level of savings; more likely the average savings would be in the 5% to 20% range, depending on the building type, building size and implemented measures.

The costs for retro-commissioning vary dramatically, again depending on the size, function and complexity of the facility as well as the measures implemented. Taking inflation into account the studies indicate that a median cost of $0.33 per sq.ft., in 2009 Canadian dollars, could be expected.

2. RETRO-COMMISSIONING & CONTINUOUS-COMMISSIONING

Retro-commissioning (RCx) is a systematic process of ensuring the building systems, such as HVAC and lighting, are being operated according to the building needs, whereas continuous-commissioning (CCx) is an "on-going process" to resolve operating problems, improve comfort, and continually optimize energy use for existing buildings. According to various retro-commissioning guideline and retro-commissioning incentives program offered by utility companies, retro-commissioning can dramatically improve building performance by as much as 20% [1, 2, 3, 4, 5]. It typically involves updating equipment scheduling, adding temperature reset schedules, and repairing malfunctioning dampers and valves. The initial savings from retro-commissioning has always been substantial; however, the life of these savings is not as predictable.

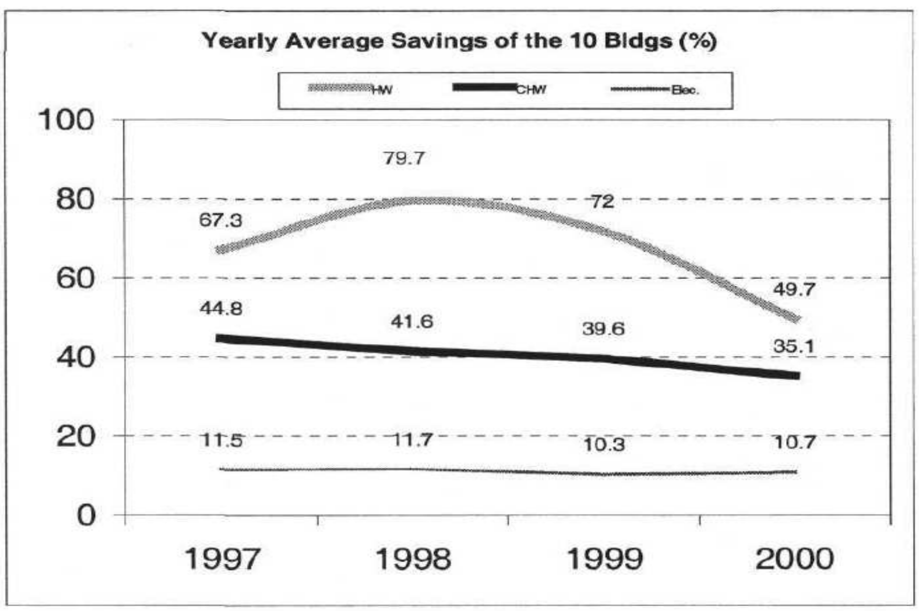
The primary differences between Retro-commissioning and Energy Auditing are that RCx services concentrate on O&M improvements and no-cost/low-cost savings opportunities, while energy audits concentrate on the savings opportunities, including no-cost/low-cost opportunities and capital retrofit projects. Hence the objectives of existing building commissioning services and energy audits have some common characteristics. Refer to Appendix A for additional details.

3. Literature Review

This section provides a literature review of saving persistency in retro-commissioning. Five studies are reviewed in detail in this section as they attempted to quantify the persistency. A list of articles that were reviewed is presented in Appendix B. The primary research includes Portland Energy Conservation Inc.'s (PECI) National Conference on Building Commissioning (NCBC), California Energy Commission's Public Interest Energy Research (PIER) Program, and the International Energy Program Evaluation Conference.

Study 1 – Investigate Commissioning Persistence (LBNL)

N. Bourassa of Lawrence Berkeley National Lab (LBNL) investigated commissioning persistence by evaluating the energy consumptions of ten buildings on the Texas A&M University Campus for four years (1997 to 2000) after their original commissioning. Each building was commissioned in 1996. The work included hot water (natural gas) space heating system, chilled water space cooling system, and electricity. The commissioning involved mechanical components, supply network, operation and control system [7]. According to N. Bourassa, the initial energy savings from commissioning decreased by an average of 9% over the 4 years [7]. In particular, the hot water (natural gas) savings fell by 9% from 1998 to 1999 and then by 30% in 2000. Note that the increased savings for hot water (natural gas) between 1997 and 1998 was due to the hot water loop rework during that period of time. N. Bourassa concluded that mechanical failures have accounted for 75% of the decrease while control changes accounted for the remainder.



The study clearly shows that although initial savings from commissioning is substantial, the need of re-commissioning after several years is very important.

The report also studied 10 buildings in California and Oregon that were commissioned before 1999. The analysis of the persistence of specific measures is the heart of the study, from which the qualitative conclusions about persistence are drawn. The availability and use of the commissioning report and written sequences of operation were investigated at all sites as a possible factor in ensuring building performance.

	BUILDING (year commissioned)	DOCUMENTS			CENTRAL PLANT				AIR HANDLING AND DISTRIBUTION								PREFUNCTIONAL TEST					OTHER		
		Commissioning report on site	Commissioning report used	Control sequences available	Chiller control	Cooling tower control	Boiler control	Hydronic control	Economizer control algorithm	Discharge air temperature reset	Simultaneous heating and cooling	VFD modulation	Dessicant cooling	Duct static pressure	Space temperature control	Terminal units	Piping and fitting problems	Valve modification	Wiring and instrumentation	Sensor placement or addition	Sensor error or failure	Scheduling	Skylight louver operation	Occupancy sensor
California	Lab and Office 1 (1995)	no	-	yes	[black]	[gray]		[gray]							[gray]				[gray]			[black]		
California	Office Building 1 (1996)	no	-	yes	[gray]	[black]		[gray]	[gray]	[gray]				[gray]					[gray]		[gray]			
California	Office Building 2 (1996)	no	-	no				[gray]	[black]			[gray]		[gray]								[gray]		
California	Office Building 3 (1994)	yes	yes	no								[gray]	[black]	[black]	[gray/gray]		[gray]	[gray]						
California	Office Buidling 4 (1994)	no	-																			[black]	[black]	[gray]
Pacific Northwest	Office Building 5 (1997)	no	-	yes	[black]		[black]	[gray/black]	[gray]												[black]			
Pacific Northwest	Medical Facility 1 (1998)	yes	yes	yes	[black]													[gray]		[gray]	[gray]	[gray]		
Pacific Northwest	Medical Facility 2 (1998)	yes	yes	yes					[gray]	[gray]	[gray]					[black/gray]		[gray]			[gray]	[black]		
Pacific Northwest	Lab and Office 2 (1997)	no	-	yes					[gray]	[gray]						[black]					[black]			
Pacific Northwest	Lab and Office 3 (2000)	no	-	no				[gray]			[gray]			[gray]								[black]		

The above table shows persistence of equipment and controls fixed during commissioning for both the California buildings and the Pacific Northwest buildings. Light gray boxes show measures that persisted, such as most of the hydronic control and VFD modulation and space temperature control. The black boxes show measures that did not persist, such as boiler control and scheduling. A square split In half horizontally indicates that more than one measure was investigated in the category.

STUDY 2 – FOLLOW UP STUDY ON THE PERSISTENCE OF RETROCOMMISSIONING (ESL)

This is a follow up study by the Energy Systems Laboratory (ESL) of Texas A&M University on the saving persistence of the ten buildings in the university campus, originally investigated by Lawrence Berkeley National Lab (LBNL). This study focuses on comparing the most recent consumption data with that of the 1997 data (year 1 since commissioning). Note the "most recent data" varies between 2001 to 2006 for the 10 buildings. The table below illustrated the savings of each building, calculated by ESL [8]:

Building Name	Type	Baseline Use (MMBtu) (MWh) / yr	1997		1998		1999		2000		2001		2002		2003		2004		2005-2006	
			Use (MMBtu) (MWh) / yr	Saving (%)	Use (MMBtu) (MWh) / yr	Saving (%)	Use (MMBtu) (MWh) / yr	Saving (%)	Use (MMBtu) (MWh) / yr	Saving (%)	Use (MMBtu) (MWh) / yr	Saving (%)	Use (MMBtu) (MWh) / yr	Saving (%)	Use (MMBtu) (MWh) / yr	Saving (%)	Use (MMBtu) (MWh) / yr	Saving (%)	Use (MMBtu) (MWh) / yr	Saving (%)
Blocker	CHW	22,955	16,723	27	19,530	15	20,164	12	21,083	** 8					20,850	9				
	HW	8,735	4,093	53	1,676	81	3,330	62	4,344	** 50					6,367	27				
	Elec	4,832	3,773	22	3,883	20	3,936	19	3,859	20					3,583	26				
Eller O&M	CHW	30,625	18,846	38	18,660	39	19,012	38	20,360	34							21,805	29		
	HW	7,584	2,578	66	1,154	85	1,831	76	4,712	38							NA	NA		
	Elec	4,891	3,698	24	3,675	25	3,823	22	3,874	21							3,841	21		
G.R.White Coliseum	CHW	18,872	8,717	54	8,511	55	14,548	23	15,858	16									6,837	64
	HW	21,155	6,091	71	549	97	4,923	77	10,111	52									3,276	85
	Elec	1,480	1,297	12	1,168	21	1,171	21	1,291	13									1,028	31
Harrington Tower	CHW	14,179	7,109	50	8,420	41	7,660	46	9,032	36									7,103	50
	HW	6,896	2,603	62	914	87	1,629	76	3,519	49									2,966	57
	Elec	1,666	1,297	22	1,336	20	1,341	20	1,353	19									1,293	22
Kleberg Building	CHW	59,271	34,864	41	34,969	41	36,731	38	41,965	29									20,964	65
	HW	40,812	6,523	84	1,215	97	8,030	80	10,591	74									7,421	82
	Elec	5,511	5,458	1	5,067	8	4,778	13	4,684	15									3,320	40
Koldus Building	CHW	* 21,964	12,177	45	12,988	41	12,740	42	11,804	46									12,487	43
	HW	2,103	704	67	399	81	634	70	649	69									3,488	-66
	Elec	2,850	2,511	12	2,597	9	2,624	8	2,592	9									2,553	10
Rich. Petroleum	CHW	28,526	13,599	52	15,637	45	15,078	47	17,702	38							17,625	38		
	HW	* 18,227	6,565	64	5,588	69	5,098	72	2,171	88							8,882	51		
	Elec	1,933	1,898	2	1,914	1	1,991	-3	2,153	-11							2,155	-11		
VMC Addition	CHW	40,892	23,115	43	24,080	41	22,915	44	23,307	43			25,849	37						
	HW	3,569	887	75	2,041	43	2,097	41	2,051	43			3,203	10						
	Elec	4,186	3,996	5	4,140	1	4,236	-1	4,056	3			4,169	0						
Wehner CBA	CHW	19,193	12,327	36	13,339	31	12,530	35	11,609	40	13,490	30								
	HW	13,393	10,876	19	9,715	27	6,581	51	6,350	53	7,309	45								
	Elec	2,555	2,410	6	2,446	4	2,552	0	2,581	-1	2,529	1								
Zachry Engr. Center	CHW	40,824	16,737	59	17,377	57	18,148	56	20,225	50									20,440	50
	HW	7,676	1,630	79	3,230	58	2,226	71	4,271	44									3,623	53
	Elec	7,502	6,762	10	6,793	9	7,099	5	6,955	7									4,377	42
Type		*Total*	*Total*	***Average***	*Total*	***Average***	*Total*	***Average***	*Total*	***Average***										
Chilled Water		297,298	164,215	44.8	173,509	41.6	179,527	39.6	192,946	35.1										
Hot Water		130,149	42,549	67.3	26,482	79.7	36,380	72.0	65,508	49.7										
Electricity		37,407	33,100	11.5	33,018	11.7	33,552	10.3	33,399	10.7										

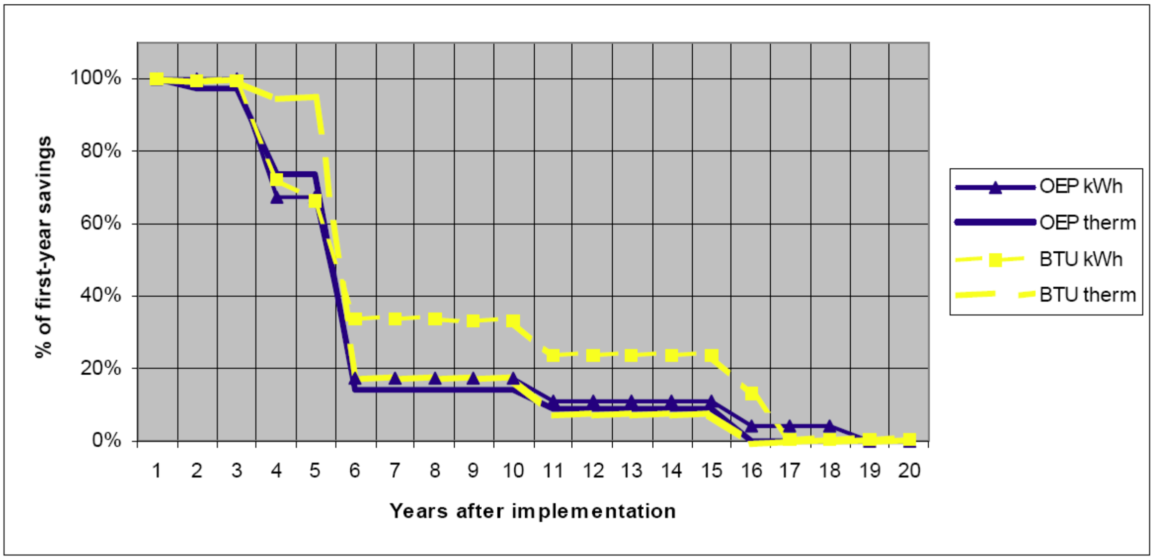
The results show high aggregate levels of savings persistence over the eight year average period for each building. The aggregate hot water (natural gas) usage for the most recent data year of the ten buildings showed savings of 60.6% vs. savings of 66.4% for 1997. Two buildings that required follow-up commissioning in 2001 (Kleberg and G.R. White) showed greater thermal savings after the follow-up than in 1997, suggesting that the 2001 effort was more thorough than that in 1997. If they are excluded from the analysis, the HW savings decreased from 54.4% to 40.5%. Even these savings show a high level of persistence over an average period of more than seven years.

Based on the finding of this study, it is evident that re-commissioning after several years is very important and highly beneficial. For the two buildings that had re-commissioning 4 years after the initial commissioning (Kleberg and G.R. White), the savings were able to be maintained at a consistence level or to increase from the initial level. In general the buildings that did not receive re-commissioning after the 4 year period saw a consistence decrease in savings over time.

Study 3 – How Much Does Recommissioning Really Save? (CPUC & SCE)

Three retro-commissioning programs offered in California, namely the 2002-2003 Oakland Energy Partners Large Commercial Building Tune-Up Program, the 2004-2005 Building Tune-Up Program, and the 2004-2005 Monitoring Based Commissioning of the University of California and California State University, were evaluated in this study for the re-commissioning savings. All three of these programs focused on tune-up opportunities that are low or no cost to the building owners. These measures usually involved building operating systems such as control strategies and schedules. For detail information of each program, refer to Appendix C.

The evaluation showed that the realized energy savings were significantly lower after four years [1]. It was concluded that savings from retro-commissioning will only remain at 1st year levels for the first three years, and then a decrease of up to 30% will occur for the next two years. Beyond the 6th year after the initial retro-commissioning, the energy savings are expected to be less than 40% of the 1st year levels.



This study also provided a list of life estimation, see table below, for measures that were implemented through the three programs of interest.[1]. It can be seen that the measure lives are generally shorter for those that can be changed easily by the building operator. These measures include controlling strategies, program schedule, and recalibration:

Measure Life Category (Excerpt from Report)	Relevancy (Elec/Gas/Both)	Estimated Measure Life (yrs)
Tune up boilers	Gas	1
Program schedule changes to EMCS (setpoint, start/stop schedules)	Both	3
Recalibrate terminal boxes	Both	3
Program logic changes to EMC (add reset control, optimum start/stop, control sequences)	Both	5
Repair and recalibrate damper controls	Both	5

Based on the findings of this study, it clearly suggested that if the main focuses of a commissioning are the building operation systems, one should consider re-commissioning after 5 years in order to avoid lower savings or even unnecessary losses. This study indicates that a significant decrease in savings from the initial commissioning would start to occur between years 4 to 6. The suggested timeline of re-commissioning is very consistence to Study 1 and Study 2, which both indicate re-commissioning after four years of the initial commissioning.

Study 4 – Evaluation of Retro-commissioning Persistence in Large Commercial Buildings (LBNL)

This study evaluated eight participants of the Sacramento Municipal Utility District (SMUD) retro-commissioning Program. SMUD is a public-power electric utility serving over 500,000 customers. This study attempted to identify and understand factors that can be used to improve the life of retro-commissioning benefits.

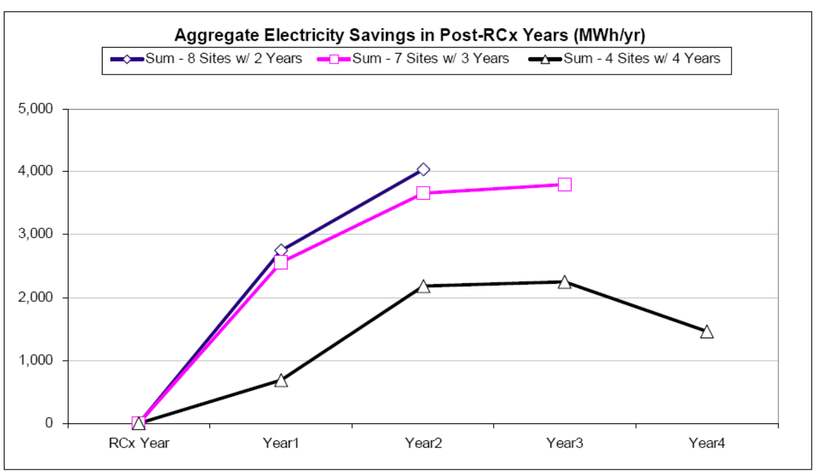
The re-commissioning implemented a total of 48 different corrective measures, with air distribution and cooling plant related measures as the two most focused areas. The table below summarizes the implemented measures and their persistency for each building.

Code Key		
Cooling plant		C
Heating plant		H
Air distribution		A
Lighting		L
Plug loads		R
Whole Buidling		W
Design, installation	Change equip.	DI1
	Install controller	DI2
Control	Reset	CR1
	Start/Stop	CR2
	Scheduling	CR3
	Modify setpoint	CR4
	Calibration	CR5
O&M	Manual operation	OM1
	Maintenance	OM2

Office1	Office2	Lab1	Hopsital1	Office3	Office4	Office5	Office6
C-CR2(y)	A-CR4(y)	W-OM1(y)	A-CR3(e)	A-CR5(y)	A-CR5(y)	A-DI1(y)	A-CR2(y)
C-CR2(y)	L-DI2(y)	A-DI2(y)	A-CR4(y)	A-CR1(n)	H-CR2(y)	A-OM2(y)	H-CR2(y)
H-CR2(y)	C-DI1(y)	A-DI2(y)	A-CR3(y)	C-CR2(n)	A-CR5(n)	A-CR1(n)	C-CR2(e)
A-CR4(y)		A-CR4(y)	A-CR3(y)		H-CR3(y)	A-OM2(y)	C-DI1(y)
A-CR5(y)			C-CR4(y)		C-DI2(y)	A-OM2(e)	C-CR4(y)
L-CR3(y)			C-CR4(y)			A-DI2(y)	C-CR1(e)
			C-DI1(y)			H-CR2(y)	A-CR5(y)
			L-OM1(y)				C-CR1(e)
			L-OM1(y)				
			L-CR3(y)				
			L-DI2(y)				
			L-DI2(y)				
Category & Status ID (y = Persists, n = Not-Persisting, e = Evolved)							

Although this study focuses on electrical savings, the above table shows persistence for the gas impacted savings, such as heating plant and air distribution.

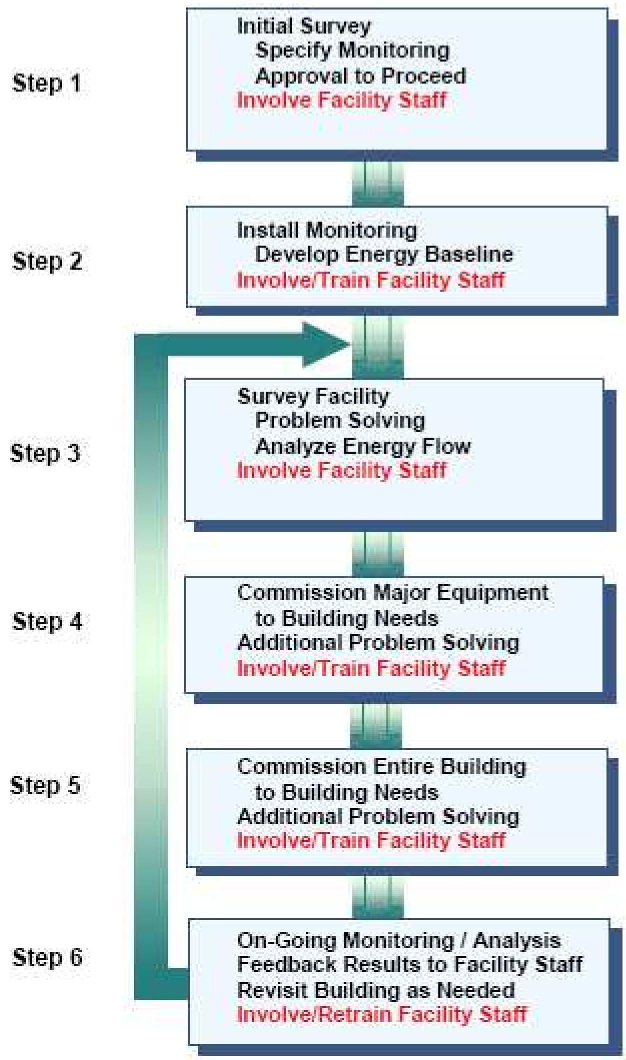
The report showed that the implementation rate of all recommended measures is 59% and the average electricity savings is 7.3% annually across the eight sites studied [9].



The above graph indicates that all sites showed an increase of energy savings during year 1 and 2. This is expected as the recommended measures are being implemented over a two-year period. During the 3rd year, the savings appeared to be flatten, and started to degrade in the forth year (see Figure below). Of the four sites that have four years of post retro-commissioning data, approximately 65% of the peak level savings have persisted beyond four years [9].

STUDY 5 – IS COMMISSIONING ONCE ENOUGH? (ENERGY SYSTEMS LABORATORY)

This study provided a case study of University building and demonstrated the need of Continuous Commissioning in order to have persistence savings. The process is mainly used to resolve operating problems, improve comfort, and optimize energy use. The study claimed the process has produced an average of 20% energy savings across 100 large buildings, and the payback has always been under 3 years. The process flow chart is described in the figure below [10].



The case study was completed for the Kleberg Building, a teaching/research facility on the Texas A&M University campus. It consists of classrooms, offices, and laboratories. The total floor area is approximately 165,030 ft^2. The building was first retro-commissioned in 1996. The initial savings for chilled water is 63.6% and for hot water is 84.2%. The building was monitored for 4 years, and in 2000, it was observed that the chilled water savings compared to pre-commissioning had been reduced to 37.7% and the hot water saving had been reduced to 62.2%. It was noticed that several problems had been developed since the initial commissioning [10]:

- The damper actuators were leaking and unable to maintain pressure in some of the VAV boxes. This caused cold air to flow through the boxes even when they were in the heating mode, resulting in simultaneous heating and cooling. Furthermore some of the reheat valves were malfunctioning. This caused the reheat to remain on continuously in some cases.
- A failed pressure sensor and two failed CO_2 sensors put all outside air dampers to the full open position.
- The majority of the VFDs were running at a constant speed near 100%
- VFD control on two chilled water pumps was AGAIN bypassed to run at full speed.
- Two chilled water control valves were leaking badly. Combined with a failed electronic to pneumatic switch and the high water pressure noted above, this resulted in discharge air temperatures of 50°F and lower and activated preheat continuously.
- Additional problems identified from the field survey included the following: 1) high air resistance from the filters and coils, 2) errors in a temperature sensor and static pressure sensor, 3) high static pressure set points in AHUs.

Based on this report, it is clear that the combination of control changes made to the building system after the initial commissioning and component failure led to the need of follow-up commissioning measures. The study demonstrated the need for continuous commissioning and concluded that large decrease in savings can be avoided through active monitoring with continuous commissioning.

4. Persistence of Benefits from Retro-Commissioning

The results of the investigation on the persistence of benefits from new building commissioning [11] are very relevant to retro-commissioning as well. The study concluded that the majority of the commissioning measures persisted. The items that did not persist were typically changes in occupancy scheduling and chiller control strategies. The persistence of commissioning benefits was found to be highly dependent on the working environment for building engineers and maintenance staff. Through this investigation, three main reasons that lead to commissioning benefits not persisting were identified:

1. Limited operator support and high operator turnover rates
2. Poor and lack of information transfer from the commissioning process
3. A lack of systems put in place to help operators track performance.

Four methods for improving persistence were proposed, focusing on operator training and system documentation.

1. Provide operators with training and support
2. Provide a complete systems manual at the end of the commissioning process
3. Track building performance
4. Start commissioning in the design phase to prevent nagging design problems

The same study identified patterns about the types of commissioning fixes that persist emerged. For the measures selected, well over half of commissioning fixes persisted. It is not surprising that hardware fixes, such as moving a sensor or adding a valve, did persist. Furthermore, when control algorithm changes are reprogrammed, these fixes often persisted, especially when comfort was not compromised.

The types of measures that tended not to persist were the control strategies that can be easily changed, such as occupancy schedules, reset schedules, and chiller staging. Four out of six occupancy scheduling measures did not persist. Chiller control strategies did not persist in three out of four cases, most likely due to the complex nature of control in chilled water systems.

The persistence of commissioning benefits was found to be highly dependent on the working environment for building engineers and maintenance staff. A working environment that was supportive of persistence included adequate operator training, dedicated operations staff with the time to study and optimize building operation, and an administrative focus on building performance and energy costs. Trained operators were knowledgeable about how the systems should operate and, with adequate time and motivation, they evaluated and improved building performance.

Other measures persisted because there was no reason for change, and the measure could persist without maintenance. For example, if a controls repair during commissioning did not affect comfort in the subsequent years, then the controls most likely were not modified. Additionally, if a controls fix was buried in the programming code, most operators could not change it without hiring the controls contractor. Hardware repairs, often found during prefunctional tests, also tended to persist because there was no reason to intervene.

Natural Resources Canada's Recommissioning (Rcx) Guide For Building Owners And Managers [12] is an adaptation of the document entitled *A Retrocommissioning Guide for Building Owners*, developed by Portland Energy Conservation, Inc. [5].

The guide suggests that RCx should be performed every three to five years and that the need for the next recommissioning process depends on several criteria such as changes in the facility's use, quality and schedule of preventive maintenance activities, and the frequency of operational problems. The guide suggests that in general a facility should be recommissioned if there are positive answers to two or more of the following questions:

- Is there an unjustified increase in energy use?
- Is energy use more than 10% higher than previous years?
- Have comfort complaints increased compared to previous months or years?
- Has night time energy or weekend/holiday use increased?
- Is the building staff aware of problems but unable to find the time or in-house expertise to fix them?
- Has control programming been modified or overridden to provide a quick fix to a problem?
- Are there frequent equipment or component failures?
- Have there been significant tenant improvement projects (build-outs)?
- Have there been significant changes in building use or the proportion of used to unused space?
- Have there been major upgrades on main energy consuming equipment (boilers, chilled water plant, large HVAC systems)?
- Has the operations staff changed since the last recommissioning process?

5. Implementation Costs for Retro-Commissioning

The costs for retro-commissioning can vary dramatically. A study of existing-buildings commissioning results for 150 existing buildings in 15 states [13], representing 22.2 million square feet of floor space, showed a range of costs from a minimum value of $0.03 to $3.86 per square foot[1]. For a total investment of $5.2 million (in inflation-corrected 2003 US dollars), the costs and fees are summarized in the table below:

	1st Quartile	Median	3rd Quartile
RCx Implementation Costs (US dollars)	$0.13 /sq.ft.	$0.27 /sq.ft.	$0.45 /sq.ft.
Commissioning agent fees (% of total RCx costs)	35%	67%	71%

The typical cost allocation is:

Planning and Investigation	69%
Implementation	27%
Verification, Reporting	4%

Across the sample of these 150 existing buildings, the median whole-building energy savings was 15% with a corresponding payback time of 0.7 years.

The Clover Park School District RCx [14], on the other hand, the normalized costs ranged from US $0.73 to $0.82 per sq.ft.

The National Energy Management Institute (NEMI) report on Retro-commissioning Existing Building Inventory [15] identified the following RCx costs:

Retro-commissioning Square Foot Costs
Current Dollar Values

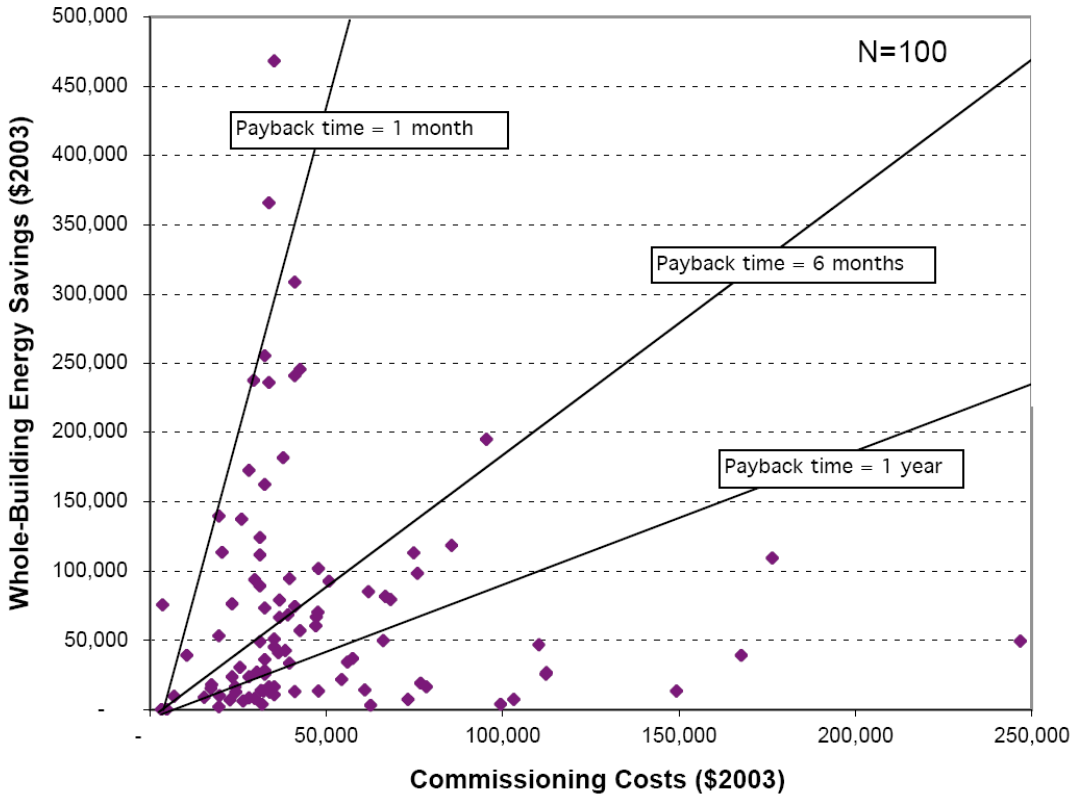
	Low	Medium	High
% of square foot charge U.S.	$ 0.05	$ 0.20	$ 0.43
% of square foot charge Canada.	C$0.10	C$0.30	C$0.55

Retro-commissioning Square Foot Costs by Building Type
Current Dollar Values

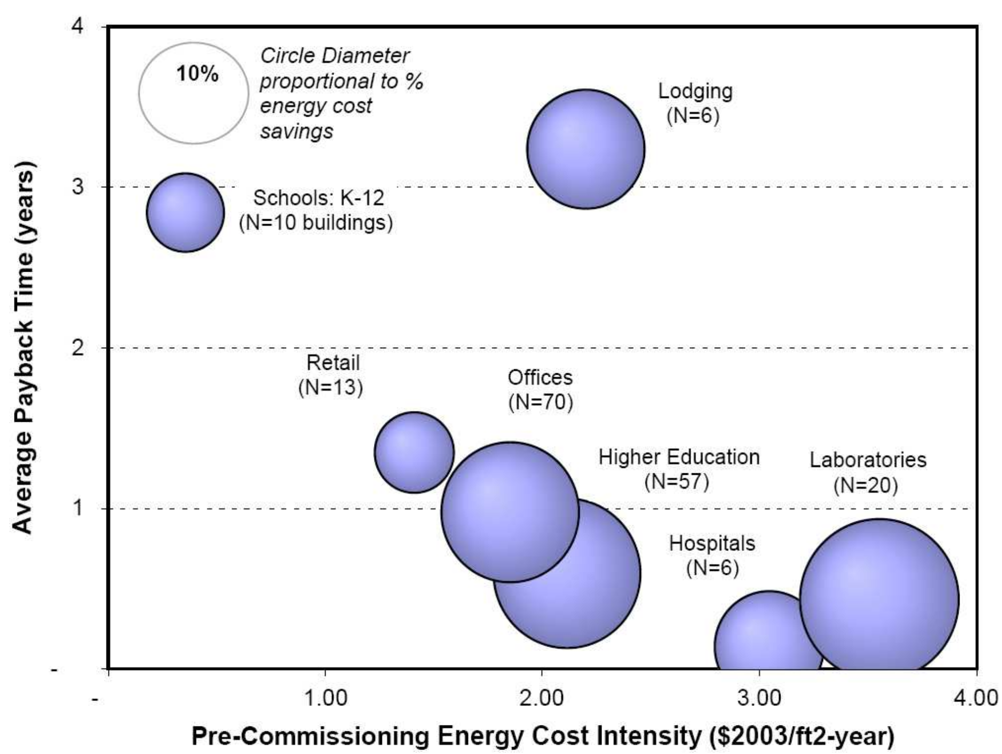
	United States	Canada
Commercial	$0.18	C$0.29
Industrial	$0.20	C$0.32
Institutional	$0.20	C$0.32
Residential (multi-family)	$0.18	C$0.29

[1] Costs in US dollars

Existing Buildings Commissioning (Costs, Savings, and Payback Times) [13]:



Key Results by Building Type (Existing Buildings) [13]:



6. CONCLUSION

The sustainable measure life for retro-commissioning varies building by building and measure by measure, with significant impact from the operating staff and preventative maintenance procedures. There is insufficient substantiated data to assign a measure life to individual measures. RCx & CCx programs should be based on comprehensive programs with a number of measures so that the savings and payback period can be blended. In these cases it appears the optimal RCx/CCx cycle would be every 5 years. Energy savings are still generated after this period, however the reduction in savings would warrant carrying out retro-commissioning again.

There is no doubt that RCx and CCx programs save energy; in some cases these energy savings are substantial, such as the 10 buildings within the University Campus, originally investigated by Lawrence Berkeley National Lab [8] where savings for some buildings exceeded 80%. It is not expected that most projects will yield this level of savings; more likely the average savings would be in the 5% to 20% range, depending on the building type, building size and implemented measures.

The costs for retro-commissioning vary dramatically, again depending on the size, function and complexity of the facility as well as the measures implemented. Taking inflation into account the studies indicate that a median cost of $0.33 per sq.ft., in 2009 Canadian dollars, could be expected.

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Appendix A - Operational Improvements

The common operational improvements for retro-commissioning are:

- Adjust temperature resets and setbacks/ups
- Sequencing and staging of HVAC equipment
- Adjust/repair dampers
- Optimize HVAC equipment load
- Optimize start/stop schedules
- Reduce simultaneous heating/cooling
- Optimize set-points
- Air and water balancing
- Occupancy changes
- Verification of controls
- Tune-up boilers
- Repair of pipe and equipment insulation

The Cost-Effectiveness of Commissioning New and Existing Commercial Buildings study produced the following Measures Matrices for 69 existing buildings [13]:

N (paired) = 702

Deficiencies		Design, Installation, Retrofit, Replacement				Operations & Control									Maintenance					Deficiency unmatched to specific measure	Total
		D1 Design change	D2 Installation modifications	D3 Retrofit/equipment replacement	D4 Other	OC1 Implement advanced reset	OC2 Start/Stop (environmentally determined)	OC3 Scheduling (occupancy determined)	OC4 Modify setpoint	OC5 Equipment staging	OC6 Modify sequence of operations	OC7 Loop tuning	OC8 Behavior modification/manual changes to operations	OC9 Other	M1 Calibration	M2 Mechanical fix	M3 Heat transfer maintenance	M4 Filtration maintenance	M5 Other		
HVAC (combined heating and cooling)	V	0	2	8	1	1	1	5	3	1	5	0	0	2	5	7	1	5	2	12	61
Cooling plant	C	4	11	19	0	26	5	4	10	4	27	3	12	2	4	10	1	0	0	13	155
Heating plant	H	4	0	5	0	15	7	1	4	0	7	1	5	1	4	7	1	0	0	18	80
Air handling & distribution	A	15	9	19	3	80	9	21	25	4	24	12	14	6	40	27	3	4	2	40	357
Terminal units	T	1	3	2	1	4	0	3	14	0	4	1	2	1	7	10	0	0	0	8	61
Lighting	L	3	1	17	1	1	2	4	0	0	0	0	5	0	2	1	0	0	0	1	38
Envelope	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plug loads	P	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Facility-wide (e.g. EMCS or utility related)	F	2	3	2	0	1	0	7	0	0	1	1	7	2	2	2	1	0	0	3	34
Other	O	0	0	2	0	0	0	0	2	0	1	0	1	0	0	3	0	0	1	12	22
Deficiency unmatched to specific measure		10	9	7	0	2	2	1	29	2	7	2	4	1	12	10	0	0	0		809
Total		39	38	81	6	130	26	46	87	11	76	20	51	15	76	77	7	9	5	800	

Yellow highlights indicate most common measures, deficiencies, and combinations.

Appendix B - Literature Summary

Attached is the list of all reviewed literature. The reasons for not being used are also included.

#	Authors	Title	Publisher	Used	Reason
1	N. Bourassa	Investigate Commissioning Persistence	Lawrence Berkeley National Lab (LBNL)	y	Quantifiable data included
2	D. E. Claridge, C. Toole	A Follow-up Study on the Persistence of Savings from the Retrocommissioning of Ten Buildings on a University Campus: Preliminary Results	Energy Systems Laboratory of Texas A&M University	y	Quantifiable data included
3	B. Tso, N. Hall, P. Lai, R. Pulliam	How Much Does Retrocommissioning Really Save? Results From Three Commissioning Program Evaluations in California	Energy Program Evaluation Conference	y	Quantifiable data included
4	N. Bourassa, M. A. Piette, N. Motegi	Evaluation of Retrocommissioning Persistence in Large Commercial Buildings	National Conference on Building Commissioning	y	Quantifiable data included
5	D. Turner, M. Liu, S. Deng, G. Wei, C. Culp, H. Chen, S.Y. Cho	Is Commissioning Once Enough?	Energy Systems Laboratory of Texas A&M University	y	Quantifiable data included
6	N. Amarnani, B. Robert, N. Hernandez	Retro-commissioning (RCx) Sustainable Savings: Are We There Yet?	National Conference on Building Commissioning	n	No info on persistence of RCx, focus on HVAC
7	M. Eardley	Persistence Tracking in a Retro-commissioning Program	National Conference on Building Commissioning	n	Subjective approach; No actual numbers on measures persistence
8	H. Friedmand, A. Potter, T. Hassl	Persistence of Benefits from New Building Commissioning	Portland Energy Conservation, Inc., Texas A&M University	n	Subjective approach; No actual numbers on measures persistence

#	Authors	Title	Publisher	Used	Reason
9	H. Friedmand, A. Potter, T. Hassl	Investigation of the Persistence of New Building Commissioning	Portland Energy Conservation, Inc., Texas A&M University	n	Subjective approach; No actual numbers on measures persistence
10		Commissioning for Federal Facilities	US Department of Energy Efficiency and Renewable Energy	n	No info on persistence
11	A. J. Kindya	What's the Point - Retro-Commissioning	Horizon Engineering Associates	n	No info on persistence
12		Commissioning for Great Buildings	Building Commissioning Association	n	No info on persistence
13	J. Soper	Continuous Commissioning Through an Operations and Maintenance Contract	National Conference on Building Commissioning	n	No info on persistence
14	A. Khan, A. Potter, T. Haasl	Retrocommissioning of Two Long-Term Care Facilities in California	Institute for Market Transformation, Portland Energy Conservation Inc.	n	No info on persistence
15	D. Dodds, Eric Baxter, S. Nadel	Retrocommissioning Programs: Current Effects and Next Steps	Portland Energy Conservation, Inc., American Council for an Energy-Efficient Economy	n	No info on persistence
16	M. Anderson, A. McCormick, A. Meiman, Karl Brown	Quantifying Monitoring-Based Commissioning in Campus Buildings: Utility Partnership Program Results, Lessons Learned, and Future Potential	National Conference on Building Commissioning	n	No info on persistence
17	J. Thorne, S. Nadel	Retrocommissioning: Program Strategies to Capture Energy Savings in Existing Buildings	American Council for an Energy-Efficient Economy	n	No info on persistence
18	I. Hasegawa, K. Yamanoto, H. Nakajima, M. Nakamura	A large complex building retro-commissioning case study in Japan	National Conference on Building Commissioning	n	No info on persistence; focused on HVAC

#	Authors	Title	Publisher	Used	Reason
19	H. Friedmand, A. Potter, T. Hassl	Strategies for Improving Persistence of Commissioning Benefits	Portland Energy Conservation, Inc., Texas A&M University	n	Subjective approach; No actual numbers on measures persistence
20	D. Turner, M. Liu, S. Deng, G. Wei, C. Culp, H. Chen, S.Y. Cho	Persistence of Savings Obtained from Continuous Commissioning	National Conference on Building Commissioning	n	Same study as #1
21	N. Bourassa, M. A. Piette, N. Motegi	Evaluation of Persistence of Savings from SMUD Retrocommissioning Program	Lawrence Berkeley National Lab (LBNL)	n	Same study as #4
22		A Cases Study on In-house Retro-commissioning at a DOE National Laboratory	US Department of Energy Energy's Federal Energy Management Programs	n	No info on persistence
23	T. Poeling	Turning Up the Retrocommissioning Process	National Conference on Building Commissioning	n	No info on persistence
24	K. Brown, M. Anderson, J. Harris	How Monitoring-Based Commissioning Contributes to Energy Efficiency for Commercial Buildings	ACEEE Summer Study (2006)	n	No info on persistence
25		Guideline to the Commissioning Process for Existing Buildings or "Retro-Commissioning"	The New York State Energy Research and Development Authority	n	No info on persistence
26	T. Haasl, R. Bahl, E.J. Hilts	The Marriott Retrocommissioning Program	National Conference on Building Commissioning	n	No info on persistence
27		Retro-commissioning Existing Building Inventory	NEMI	n	No info on persistence
28		Retrocommissioning Case Study: San Diego Marriott Hotel & Marina	Portland Energy Conservation, Inc.	n	No info on persistence
29		Energy Star Building Manual	Energy Star	n	No info on persistence

#	Authors	Title	Publisher	Used	Reason
30	N. Amarnani, B. Robert, H. Choy	Post-retrocommissioning HVAC Operations Monitoring Using Enterprise-wide Energy Management System	National Conference on Building Commissioning	n	Same as #6
31	R. Herbst	Financing Retro-Commissioning Services Utilizing Performance Contracts	National Conference on Building Commissioning	n	No info on persistence
32		Continuous Commissioning Guidebook for Federal Energy Managers	US Department of Energy Energy's Federal Energy Management Programs	n	No info on persistence

Appendix C - Review of Demand Side Management (DSM) Programs

Demand Side Management (DSM) programs have been commonly offered by utility companies across North America. This section reviews nine well-known programs being offered to large commercial buildings.

No.	Utility	Program	Offering Year
1	PG&E	Oakland Energy Partners Large Commercial Building Tune-Up Program (OEP)	2002-2003
2	PG&E, SCE	Building Tune-Up Program (BTU)	2004-2005
3	University Program (UC, CSU)	Monitoring-Based Commissioning (MBCx)	2004-2007
4	SMUD	SMUD Retrocommissioning Program	2006-2010
5	SCE	SCE RCx Program	2006-2008
6	SDG&E	San Diego RCx	2006-2008
7	PG&E	Pacific Gas & Electric (PG&E) RCx Program	2006-2008
8	ETO	Energy Trust of Oregon, Inc. Building Tune-Up and Operations	2006-2007
9	CenterPoint Energy	Retro-Commissioning Program	2008

1) **<u>Oakland Energy Partners Large Commercial Building Tune-Up Program (OEP)</u>**

This program targeted large commercial buildings in Oakland, such as office buildings, hotels, colleges, hospitals, and retail customers. The program provided qualified applicants with a no-cost engineering audit for identifying and recommending tune-up opportunities in building operations such as control strategies and schedules. The program focused on implementing tune-ups at a low or no cost, and with a quick payback. The program goals were to deliver services to 44 commercial buildings in Oakland, equivalent to 10.45 million square feet. The program's goal was to deliver 5,500 BTU/ft^2 of savings annually. It was evaluated to deliver approximately 3,900 BTU/ft^2 annually [1].

2) **<u>Building Tune-Up Program (BTU)</u>**

This program was very similar to the OEP program. It, however, had state-wide focus as it targeted existing medium and large, public and private, non-residential buildings in the service areas of Pacific Gas & Electric (PG&E) and Southern California Edison (SCE). The program focuses on improvements in building operations and related hardware to reduce energy use while maintaining a comfort and healthy environment. The program's goal was to deliver 7,100 BTU/ft^2 of savings annually to approximately 150 buildings. It was evaluated to deliver 4,900 BTU/ft^2 of saving annually for 36 buildings [1].

3) **Monitoring-Based Commissioning (MBCx)**

This joint program between University of California and California State University began in 2004 and concluded in early 2007. Its goal is to obtain energy and demand savings, and to establish a long-term comprehensive energy management system throughout the University network. The selected campus buildings received monitoring-based continuous commissioning. Campus staff received training on the monitoring systems for continuously commissioning the selected buildings. The program's goal was to achieve 4,600 BTU/ft^2 of savings to 17.5 million ft^2 of space area. The program claimed to have achieved 3,500 BTU/ft^2 of savings over 51 buildings [1].

4) **Sacramento Municipal Utility District (SMUD) RCx Program**

The Sacramento Municipal Utility District (SMUD) is a public electric utility serving over 500,000 customers. This program is designed and implemented by Portland Energy Conservation, Inc. (PECI). The program aimed to reduce energy consumption through low-cost operational improvements, such as simultaneous heating/cooling and sensor calibration, and on-site training of building operators. The program claimed a typical RCx project will result in savings of 5-20% of total building energy costs, with an average of 2 years simple payback [16]. The qualified buildings will receive an incentive for an engineering audit for identifying potential tune-up opportunities to the operations. Once measures are identified and selected, the program will provide incentives for implementation. The implementation incentives will aim to reduce the payback period of the customer to one year. Upon completing implementations, incentives are offered for training building staff to maintain the building systems. Enrolment in the Building Operator Certification (BOC) Program is also included. SMUD claimed that for a 250,000 ft^2 building, approximately $37.000.00 of incentives is provided [17].

5) **Southern California Edison (SCE) RCx Program**

This program is similar to the SMUB RCx Program, and is also designed and implemented by PECI. The focus of this program is on the building operation systems, and claimed to be able to reduce energy consumption up to 20%. This program provides incentives for engineering audit at $0.10 per ft^2, up to $80,000. It also offers incentives to energy savings at $0.039 per kWh saved, and aim to reduce the payback period of the customer to one year [2].

6) **San Diego Gas & Electric (SDG&E) RCx Program**

Similar to the SMUB and SCE RCx Program, this program is also administered by PECI. The program serves large commercial, lodging and hospitality, medical facilities, high technology, and retail customers. The program runs on a first-come, first-served basis until the funding runs out. This program offers up to $0.10 per ft^2 for RCx audits and incentives for limiting the payback period to 1 year for customers upon completing implementation. It will also offer incentives of $3,000 to $7,500 for follow-up commission and staff training [2]. San Diego Marriott Hotel & Marina was a participant of the program from 2004 to 2006. It claimed that program had resulted 1.47 million of kWh saving annually and 9,000 GJ of natural gas savings. The total cost of the project was $391,716 and the total cost savings was $272,500. The incentives offered by the program were $196,412 with a simple payback of less than 1 year [3].

7) **Pacific Gas & Electric (PG&E) RCx Program**

This program is the same as the one offered by SDG&E, and is also administrated by PECI. PG&E claimed that retrocommissioning can result in an average savings of 5% to 15% of total energy costs. Since the start of the program in early 2007, PG&E claimed the program is approaching the two-year goals of approximately 28 million of kWh savings and 20,000 GJ of natural gas savings [2].

8) **Energy Trust of Oregon, Inc Building Tune-Up and Operations (BTO) Program**

This program focuses on reducing energy usage and increasing the efficiency of mechanical equipment, lighting and control systems of existing commercial facilities in Oregon. This program is also administrated by PECI. This program offered two distinct services: 1) the annual boiler tune-ups over a three-year period, and 2) Whole-building tune-ups and retro-commissioning. This is different than focusing on the building operation systems. The initial incentives offering for the boiling tune-up were $600 for the first boiler in a building and $300 for any subsequent boilers in 2007; and $300 for the first boiler and $150 for any subsequent boilers in 2008. At the moment, Energy Trust of Oregon has found that savings vary among the boiler tune-ups and there are no trends to identify which boilers will yield substantial savings [2, 18, 19].

9) **CenterPoint Energy Retro-Commissioning Program**

The new program offered by CenterPoint Energy is targeted for commercial and industrial facilities. It is designed to achieve energy and peak demand savings through low-cost measures to improve the HVAC system operation. The program is being administrated by Nexant, Inc. This program involves a two-step process: evaluation and implementation. The program will subsidize the costs for an engineering audit to evaluate the building and identify opportunities for improvement. The implementation stage will involve the customer's own contractor or in-house staff to implement the agreed retro-commissioning recommendations that have a simple payback of one year or less [20].

Appendix D - Differentiating Between Retro-commissioning, Continuous-commissioning & Energy Auditing

Retro-commissioning (RCx) is a systematic process of ensuring the building systems, such as HVAC and lighting, are being operated according to the building needs, whereas continuous-commissioning (CCx) is an "on-going process" to resolve operating problems, improve comfort, and continually optimize energy use for existing buildings. According to various retro-commissioning guideline and retro-commissioning incentives program offered by utility companies, retro-commissioning can dramatically improve building performance by as much as 20% [1, 2, 3, 4, 5]. It typically involves updating equipment scheduling, adding temperature reset schedules, and repairing malfunctioning dampers and valves. The initial savings from retro-commissioning has always been substantial; however, the life of these savings is not as predictable.

The fundamental differences between Retro-commissioning and Energy Auditing [6] are shown in the table below:

Retro-Commissioning & Continuous-Commissioning	Energy Auditing
RCx & CCx are processes that are intended to allow the facility and all of its systems and assemblies to be operated and maintained to meet the current facility requirements	An energy audit is a systematic study to identify how energy is used in a building and to identify energy-saving opportunities
RCx & CCx are intended to see the work all the way through implementation	An energy audit typically ends upon submission of a report that details the energy savings opportunities that were analyzed
CCx is an ongoing process and RCx is intended to be carried out at regular intervals	An energy audit is typically performed once, unless conditions change or a long period of time has passed.

The primary differences are that RCx services concentrate on O&M improvements and no-cost/low-cost savings opportunities, while energy audits concentrate on the savings opportunities, including no-cost/low-cost opportunities and capital retrofit projects. Hence the objectives of existing building commissioning services and energy audits have some common characteristics.

Energy Savings Categories	RCx/CCx	Energy Audits
No-cost opportunities are energy saving measures that can be implemented by in-house staff without the need to purchase materials. Includes identification of low cost operating and maintenance improvements. Only in-house labor is needed. No-cost opportunities typically entail modifying existing programmed control sequences	✓ Primary focus	✓

Energy Savings Categories	RCx/CCx	Energy Audits
Low cost opportunities are those measures than can be paid for through the facility's operating budget (as opposed to its capital budget). Includes the identification of energy waste and fixing existing problems. These measures typically have simple paybacks of less than one year	✓ Primary focus	✓
Capital retrofit projects entail significant capital outlay, usually requiring funds from the facility's capital budget. These projects are almost always implemented by outside contractors and usually have simple paybacks greater than one year	×	✓ Primary focus

SEC INTERROGATORY #6

INTERROGATORY

[B/1/3, p. 1]

Please confirm that the TEC did not prioritize the measures, but rather provided ERS with all of the existing substantiation documents, many of which had not been approved by the TEC, and a recommended order in which to review those subdocs.

RESPONSE

In the initial stages of the Technical Reference Manual ("TRM") project, in April 2013, the Technical Evaluation Committee ("TEC") examined prescriptive measures that had garnered the most gas savings for each utility. Prescriptive measures approved by the Board at the time were grouped according to the Utilities' current and foreseeable DSM activities. Following this review, the TEC then provided Energy and Resource Solutions Inc. ("ERS") with existing substantiation documents and a list of measures to be included in the TRM.

As the TRM developed, measures were added and removed from the original list with endorsement from the TEC, resulting in the list of measures in the current application.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #7

INTERROGATORY

[B/1/3, p. 1]

Please confirm that the proposed TRM includes measures that are not cost effective. Please provide a list of all measures that are not cost-effective, or are marginally cost-effective, at current avoided costs, together with the cost-effectiveness calculations for each. Please explain why it is appropriate to include in the TRM measures that are not cost-effective.

RESPONSE

The Utilities confirm that the proposed Technical Reference Manual ("TRM") includes measures that may not currently be cost-effective. By definition, the TRM is a technical reference document, as specified in the TRM front section, endorsed by the Technical Evaluation Committee ("TEC") (Exhibit B, Tab 1 Schedule 3, p.1).

> *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.*

While there are no specific criteria used to determine measure inclusion in program offerings, the Utilities strive to address the key priorities and guiding principles outlined by the Board. These priorities and principles balance pursuing long-term energy savings, program cost-effectiveness, and available budget, while seeking broader participation from non-participants. As outlined in the Board's current Demand Side Management ("DSM") guidelines, the gas Utilities are afforded flexibility in deciding what programs to include in their proposed DSM plans with overall consideration for cost-effectiveness. Cost effectiveness was not a consideration as part of the TRM scope of work. In the context of the current DSM Framework, the screening of cost-effectiveness is made at the program level (i.e. Resource Acquisition) rather than the measure level. *"To recognize that all programs may not pass the TRC-Plus test, the utility should ensure its overall DSM portfolio has a TRC-Plus ratio of 1.0 or greater.*"[1] Inclusion or exclusion of a particular measure in DSM offerings is determined at the Utility's

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[1] EB-2014-0134 Filing Guidelines to the Demand Side Management Framework for Natural Gas Distributors (2015-2020), Dec 22, 2014, page 32

Witnesses: D. Bullock
L. Kulperger

discretion. It is appropriate therefore to include in a TRM, measures that may not be currently cost-effective.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #8

INTERROGATORY

[B/1/3, p. 2]

Please confirm that, notwithstanding the assumptions and algorithms in the proposed TRM, all results from the Utilities must be tested and calculated against best available information at the time. Please confirm that, with this Application, the Utilities are not seeking to modify that principle, or propose that the TRM assumptions be applied instead of better, more recent information.

RESPONSE

The Technical Reference Manual ("TRM") was developed to provide a common set of input assumptions underpinning prescriptive measure savings. As detailed in the Board's letter of August 21, 2015, the Evaluation Contractor ("EC") will lead a process to update the TRM in consultation with the Evaluation Advisory Committee ("EAC").

The Utilities will follow the Board's 2015-2020 DSM Plan (EB-2015-0029/EB-2015-0049) Decision and Order, dated January 20, 2016, as it pertains to the treatment and application of TRM input assumptions. In its Decision, at p. 74, the Board accepted the position of the Utilities that input assumptions for prescriptive measures should not be adjusted retroactively based on the results of the annual evaluations process for the purpose of determining eligible shareholder incentive amounts. The Board went on to state that:

> any updates to existing input assumptions, or new input assumptions identified during a year, should be applied prospectively when evaluating savings from prescriptive measures.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #9

INTERROGATORY

[B/1/3, p. 2]

When "utility/program administrators" estimate savings from the program using the TRM, what consequences are the Utilities proposing will flow from that reliance on the TRM?

RESPONSE

The Technical Reference Manual ("TRM") provides essential information and source materials underpinning prescribed energy savings assumptions and calculations for a defined set of energy efficient technologies that lend themselves to algorithms and standardized representative values for the province. Input assumptions detailed in the TRM provide the Utilities and other stakeholders with a degree of substantiation and predictability with regard to energy savings estimates generated from the underlying group of prescriptive and quasi-prescriptive measures at the time those savings are claimed.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #10

INTERROGATORY

[B/1/3, p. 3]

Please confirm that Commercial (other than Multi-Res) and Industrial subdocs do not apply to Low Income.

RESPONSE

As noted in the Technical Reference Manual ("TRM") Front Section (Exhibit B, Tab 1, Schedule 3, p. 3), "*all substantiation documents apply to the Low-Income market unless otherwise noted.*"

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #11

INTERROGATORY

[B/1/3, p. 4 and 6]

Please confirm that the Utilities and the EAC use the dual baseline method for calculating savings for early replacements. Please describe the dual baseline method, and identify the places in the TRM in which it is references. Please define the term RUL (Remaining Useful Life) and explain why it is not included in the TRM definitions.

RESPONSE

For the purpose of the Technical Reference Manual ("TRM"), savings are not established using a dual baseline method. The consultant was mandated to assess baselines as part of the project. Early replacement of equipment was considered by the consultant in discussion with the Technical Evaluation Committee ("TEC") and TRM subcommittee.

Dual baseline energy savings are calculated by combining two savings amounts; the difference between the efficiency improvement relative to the existing efficiency for the number of years that piece of equipment would have Remaining Useful Life ("RUL"); the second savings amount is based on an assumed baseline (e.g. minimum standards efficiency for the remaining life of the energy efficient measure) in comparison to the upgraded efficiency case.

RUL is the length of time an existing measure or piece of equipment is anticipated to last and perform as expected. The RUL definition has not been included in the TRM since the substantiation documents do not rely on dual baseline savings, as discussed above.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #12

INTERROGATORY

[B/1/3, p. 4]

Please confirm that none of the measure assumptions include any tests for the causal relationship between the utility program and the customer's decision to replace operable equipment. If there are any such tests in the assumptions, please identify.

RESPONSE

Confirmed. None of the measure assumptions proposed in the Technical Reference Manual ("TRM") include any such tests.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #13

INTERROGATORY

[B/1/3, p. 5]

Please reconcile the definition of Measure Life in Table 1 with the definition of Measure Life in Schedule 5. If in a given situation the two produce different results, which overrides the other?

RESPONSE

Table 1 in Exhibit B, Tab 1, Schedule 3, p.5 is included for guidance in the Technical Reference Manual ("TRM") front section as an overview of what information (with a brief descriptor) can be found in the Tables provided in each substantiation. The Glossary included in Exhibit B, Tab 1, Schedule 5 provides the definition and explanation of terms used in the TRM as proposed by Energy and Resource Solutions Inc. ("ERS").

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #14

INTERROGATORY

[B/1/3, p. 8]

Please confirm that no persistence study has been done, and the TEC has not expressed any opinion or endorsement on whether any of the Measure Lives properly account for any persistence.

RESPONSE

Confirmed.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #15

INTERROGATORY

[B/1/4, p. 1]

With respect to the TRM Common Assumptions Table:

a. [also reference B/1/5, p. 3] Please advise the current heat content of gas for Union Gas and Enbridge in their most recent QRAM applications. Please explain how the TRM heat content assumption is to be adjusted, if at all, to reflect up to date heat content.

b. Please provide the supporting evidence for residential household size and multiresidential household size in the Union Gas franchise area.

c. Please provide the basis on which the Utilities believe that the average standard efficiency of commercial water heaters has not changed since 2009.

d. Please provide any studies or other evidence showing that a 55 degree balance temperature in appropriate in the Utilities' franchise areas.

RESPONSE

a) As filed in Union's most recent April 2017 Quarterly Rate Adjustment Mechanism ("QRAM") Application (EB-2017-0089, Tab 2, p.1), the heat value conversion factor is 38.95 $GJ/10^3m^3$.

For the purposes of preparing its Gas Supply Plans, Enbridge has used a standard conversion factor of 37.69 MJ/m^3 for a number of years. Please refer to Enbridge's heat value approved in the most recent April 1, 2017 QRAM, as per Exhibit Q2-1, Tab 2, Schedule 1, p. 2, EB-2017-0092. Further Enbridge has committed to updating this heat value in 2017, please refer to EB-2016-0215 Filed: November 28, 2016 Exhibit N1, Tab 1, Schedule 1, p. 10.

The process for updating or adjusting any Technical Reference Manual ("TRM") input assumptions will be managed by the Evaluation Contractor ("EC"), with input and advice from the Evaluation Advisory Committee ("EAC").

Witnesses: D. Bullock
K. Culbert
L. Kulperger

b) The Common Assumptions Table does not rely on Union data in establishing the average single family or multi-family residential household size. In conducting their comprehensive review, with input from the TRM sub-committee, Energy and Resource Solutions Inc. (“ERS”) determined the appropriate data considered best available and substantiated information for the TRM.

c) Following direction from the Board to develop a TRM, the Technical Evaluation Committee (“TEC”) commissioned ERS to create an Ontario specific TRM common to both Utilities with updated measures, input assumptions and baseline considerations based on best available and substantiated information. The TRM as submitted in this application is a product of that work. As directed by the Board in the August 21, 2015 and the March 4, 2016 Board letters (EB-2015-0245), the TEC continued working with ERS until the TRM was finalized. Oversight of the evaluation activities related to the TRM have been transitioned to the OEB with guidance from the EAC, under the new Demand Side Management (“DSM”) evaluation governance. As an industry expert in the development of TRMs, ERS was commissioned by the TEC with the objective of providing best available and substantiated information.

d) Please see response to part (c) above

Witnesses: D. Bullock
K. Culbert
L. Kulperger

SEC INTERROGATORY #16

INTERROGATORY

[B/1/5, p. 2 and 7]

Please confirm that “Baseline” assumes that during the entire life of the measure all conditions will remain the same, e.g. no insulation or other complementary conservation measures will be installed, use and production will remain the same, etc. Please advise how assumptions of no change apply in dual baseline situations, where a future “standard efficiency” measure may be influenced by technical standards, building codes, and market changes.

RESPONSE

Confirmed. None of the Technical Reference Manual (“TRM”) measures include dual baselines.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #17

INTERROGATORY

[B/1/67, p. 6]

Please advise what adjustments have been made, or are intended, to the assumptions for natural gas use in Table 2 to reflect trends in installation of higher efficiency furnaces.

RESPONSE

Please see SEC Interrogatory response #3 c) found at Exhibit I.EGDI.SEC.3 c).

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #18

INTERROGATORY

[B/1/6, p. 100]

With respect to low-flow showerheads:

a. Please explain why it is still assumed that new construction homes will have a 2.5 gpm showerhead as a baseline.

b. Please explain why it is assumed that showering time will remain the same, at 7.6 minutes, for a 2.5 gpm and a 1.5 gpm or 1.25 gpm showerhead.

RESPONSE

Please see SEC Interrogatory response #15 (found at Exhibit I.EGDI.SEC.15 c).

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #19

INTERROGATORY

[B/1/6, p. 150]

Please explain why, if the range for defrost derating is 5-15%, it is appropriate to use a 5% derating and consider it "conservative".

RESPONSE

Please see SEC Interrogatory response #15 c) found at Exhibit I.EGDI.SEC.15 c).

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #20

INTERROGATORY

[B/1/6, p. 176]

With respect to Heat Reflector Panels:

a. Please confirm that the only basis for the measure life is the manufacturer's claim of the equipment life. Please explain how the measure life has been, or should be, adjusted for the RUL of the radiators, the boiler system, or the building. Please explain how useful life has been, or should be, adjusted for behavioural changes, including but not limited to de-installation, destruction or damage, etc.

b. Please confirm that the only basis for the other assumptions for this measure are internal analysis and conclusions from Enbridge, and no independent support for the assumptions has been presented.

RESPONSE

a. An independent contractor, Energy Resource Solutions ("ERS") was engaged by the Technical Evaluation Committee ("TEC") to develop a Technical Reference Manual ("TRM") and provide advice and expertise. In the absence of additional sources, in the case of Heat Reflector Panels, the manufacturer's durability estimate was found by the consultant to be the best available information from which to estimate a measure life. This substantiation document was included in the December 16, 2015 New & Updated DSM Measure joint submission (EB-2015-0344) following TEC endorsement on November 24, 2015.

   Moving forward, as directed by the Board, oversight of evaluation activities related to the TRM has been transitioned to the Board. The Evaluation Contractor ("EC") is tasked with the annual review and updating of the TRM and will have responsibility with guidance from the Evaluation Advisory Committee ("EAC").

b. ERS was selected by the TEC to draft the TRM and provide independent, third-party analysis and recommendations. In their review of the available research and evidence supporting assumptions pertaining to Heat Reflector Panels, ERS assessed load research data completed by Enbridge and found it to be an appropriate reference source.

Witnesses: D. Bullock
L. Kulperger

SEC INTERROGATORY #21

INTERROGATORY

[B/1/6, p. 212, 218, 237, 244]

Please confirm that the assumptions for these measures have been developed by Fisher-Nickel Inc., a firm associated with a utility, PG&E. Please confirm that the only other primary source is NGTC, a firm associated with Gaz Metro. Please confirm that these assumptions have not been verified by any independent third party sources.

RESPONSE

All references and sources in the proposed substantiation documents were reviewed by Energy and Resource Solutions ("ERS"), an independent, third party consulting firm engaged by the Technical Evaluation Committee ("TEC") to draft and provide recommendations and opinions on the Technical Reference Manual ("TRM") based on best available information. To verify the reasonableness of proposed sources, ERS regularly considered findings from a host of TRMs in comparable jurisdictions.

The sources in question were endorsed by the TEC and the independent third party consultant. At all times, the TRM subcommittee sought to make use of best available information at the time of its review.

Regarding the measures in question, several sources underpin input assumptions for natural gas-heated commercial kitchen equipment, including:

The **Alliance for Water Efficiency** is a stakeholder-based nonprofit organization dedicated to the efficient and sustainable use of water. Headquartered in Chicago, the Alliance serves as a North American advocate for water efficient products and programs, and provides information and assistance on water conservation efforts.

The **American Society for Testing and Materials International** ("ASTM") is an independent non-profit organization that develops and delivers voluntary consensus standards, including test methods, specifications, classification guides and practices to improve product quality, health and safety and consumer confidence. ASTM International has no official ties to Canada, though it is accredited by the Standards Council of Canada and commonly cited in Canadian government regulations and product requirements.

Witnesses: D. Bullock
L. Kulperger

AutoQuotes is an online catalogue containing product information on over 900,000 devices and technologies with input from more than 550 manufacturers.

ENERGY STAR is a U.S. Environmental Protection Agency ("EPA") voluntary program. ENERGY STAR promotes the use of energy efficient products, practices, and services through, objective measurement tools, and consumer education.

The **Food Service Technology Center** ("FSTC") is an independent EPA-recognized fuel-neutral testing facility dedicated to providing unbiased, third-party data on a wide array of commercial foodservice equipment. FSTC is the primary information resource for the EPA's ENERGY STAR program for commercial food service. The FSTC is considered to be the foremost authority and recognized industry leader in commercial kitchen energy efficiency and appliance performance testing. They are a regularly referenced source for North American TRMs for Food Service related technologies. Products distributed in Ontario are tested at their labs.

The **Natural Gas Technologies Centre** ("NGTC") was established in 1992 as a non-profit organization operating in the field of technological development and providing on-site and laboratory testing and technology evaluation. NGTC works with a variety of partners, including a number of government agencies, universities and industry associations, as well as natural gas companies and manufacturers.

The **North Eastern Energy Efficiency Partnership** ("NEEP") is a non-profit organization that accelerates energy efficiency uptake in northeastern and mid-Atlantic US states. Through policy development, education and enterprise, NEEP partners with government, utilities, industry and consumers to help transform markets.

Witnesses: D. Bullock
L. Kulperger