Final Report:

Custom Measure Life Review

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Ontario Energy Board

Ontario Energy Board

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Contents

Executive Summary

Union Gas Limited (Union) and Enbridge Gas Distribution Inc. (Enbridge) provide a range of demand side management (DSM) programs to their customers. One such offering is the C&I custom program. The Commercial and Industrial (C&I) custom programs. The C&I custom programs contribute a significant portion of the lifetime natural gas savings achieved by the utilities each year. A key input into determining the lifetime savings is the measure life of the installed equipment.

The Ontario Energy Board (OEB) decided to complete research specifically geared toward reviewing the measure lives used by the utilities. There were two main research goals of this study.

1. Review the measure lives used by the utilities to determine if they are reasonable and appropriate based on the current literature.
2. Determine if additional Ontario-specific measure life research is warranted in the future.

In order to accomplish these goals, Michaels Energy completed a detailed literature review on 20 different custom measure lives from jurisdictions across North America. After completing the literature review, Michaels Energy compiled recommended measure lives for each of the 20 researched measures. The recommended measure lives can be seen in Table 1.

Table 1

Recommended Measure Lives

Measure	Recommended Measure Life
All other industrial equipment	20
Boiler - Industrial Process	20
Boiler - Space heating	25
Pipe Insulation	14
Boiler - Domestic Hot Water	25
Boiler Controls	15
Energy Curtains	10
Heat Recovery - Commercial	15
Heat Recovery - Industrial	20
Exhaust Fan Controls	15
Heat Reflector Panels	15
Economizers - Conventional and condensing	20
Steam Trap	6
Infiltration Controls - Air Doors	15
Infiltration Controls - Dock Seals	10
IR Poly	5
VFD retrofit on MUA	15
Heat Exchanger	17
Building Automation System	15
Ovens & Thermal Oxidizers	20
Reverse Osmosis (RO) Water Conditioner	20
Building Envelope	25

Based on the results of the literature review, 15 of the 20 measures use lifetime estimates that are consistent with the available literature. There are five measures where Michaels Energy does recommend that the measure life be updated.

- Boiler Controls – Reduced from 20 years to 15 years. This measure does not include burner modification measures, such as linkageless controls.
- VFD for Make-up Air Units – Increased from 10 to 15 years to be consistent with the literature and available primary data.
- Infiltration Controls: Door Seals and Air Doors – Reducing the life from 15 to 10 years for dock door and ramp seals, but leaving air doors at 15 years.
- Pipe Insulation: Reduce the measure life from 20 to 14 years.
- Building Automation Systems: Reduce the measure life from 20 years to 15 years.

Additionally, the literature review revealed that there are two individual measures which would benefit from primary research.

- Pipe Insulation Measures
- Building Automation Systems

In addition to those specific measures, Michaels Energy suggests implementing an ongoing data collection effort for custom measures. This would create a dataset that could be continually mined for updates to custom measure lives in the future, as well as inform other measure lives throughout the province.

1. Introduction and Methods

Union Gas Limited (Union) and Enbridge Gas Distribution Inc. (Enbridge) provide a range of demand side management (DSM) programs to their customers. The commercial and industrial (C&I) custom programs offered by the utilities constitute a notable portion of the portfolio budgets (18%), portfolio savings (43%), and shareholder incentives(31%)[1].

Due to the size of the C&I custom programs, the lifetime savings achieved by the programs are a significant factor in determining if the utilities achieved their savings targets, and whether a shareholder incentive will be paid. A key input into determining the lifetime savings is the measure life of the installed equipment. Lifetime savings, or cumulative cubic meters (CCM), are calculated by multiplying the first year savings by the measure life, as shown in the equation below.

$$CCM = First\_Year\_Savings \times Measure\_Lifetime$$

Measure life, in the context of this research, is considered to be equivalent to the definition provided in the Uniform Methods Project (UMP), Chapter 13, Section 2.1.1.1[2].

[This is the median number of years that a measure is in place and operational after installation. This definition implicitly includes equipment life and measure persistence (defined below), but not savings persistence.

- *"Equipment life" is the number of years installed equipment will operate before it fails.*
- *"Measure persistence" takes into account business turnover, early retirement or failure of the installed equipment, and any other reason the measure would be removed or discontinued.]*

The Ontario Energy Board (OEB) decided to complete research specifically geared toward reviewing the measure lives used by the utilities. Through a competitive bid process, the OEB contracted with Michaels Energy. There were three main research goals of this study.

1. Review the measure lives used by the utilities to determine if they are reasonable and appropriate based on the current literature.
2. Understand the source basis used to estimate measure life.
3. Determine if Ontario-specific measure life research is warranted in the future.

In order to accomplish these goals, Michaels Energy first selected 20 different custom measure lives currently found in Union's and Enbridge's custom measure life tables[3]. The measure life for each of the selected measures was examined via a detailed literature review using program documents, research and manufacturer data.

[1] 2016 – 2018 OEB EM&V Plan, Table 2-4.
[2] Violette, Daniel, M. Chapter 13: Assessing Persistence and Other Evaluation Issues Cross-Cutting Protocols. Uniform Methods Project. https://energy.gov/sites/prod/files/2013/11/f5/53827-13.pdf
[3] EB-2016-0246, Exhibit B, Tab 1, Tab 2, Page 11-15. Filed 2016-12-21.

1.1 | Measure Selection

Michaels Energy used a data-driven framework to select 20 different measures for further review. Union and Enbridge provided Michaels Energy 2016 custom program tracking data. Michaels Energy worked with the utilities to map the tracking data to the appropriate measure category from the custom measure life tables.

Each measure category was analyzed using six different criteria to determine if it would be selected for the secondary literature review[4]. The criteria used were as follows:

- **Measure Frequency:** The number of units claimed by Enbridge, Union, or both based on 2016 program data.
- **Measure Impacts:** Even if a measure has small numbers of individual projects completed each year, their natural gas impacts (cumulative savings) may be significant to the custom programs as a whole.
- **Age of Referenced Sources:** Older sources may still be valid, but additional investigation was completed to ensure any more recent sources confirm assumptions or suggest an alternate value.
- **The Basis of Referenced Sources:** Cited sources were examined to determine if they are based on primary data, secondary data, a specific jurisdiction, or engineering assumption. Measures which were sourced from primary data were less likely to be included, assuming other criteria mentioned here are also met.
- **Differences Between Utilities:** Technologies which have different measure lives for each of the two utilities. In some instances, this may be acceptable, for example, different types of customers who routinely utilize a particular measure.
- **Michaels Experience:** Leverage Michaels Energy's previous experience evaluating custom programs to identify measures which are inconsistent with values we typically use.

In order to determine which measures were selected for further research, Michaels Energy examined each of the characteristics listed above and assigned a point value to each measure. The higher the assigned points, the more likely the measure should be selected for inclusion and further review. For example, the most popular measure from 2016, space heating boilers, would receive 20 points, while measures which had no participation would be given 0 points.

Michaels Energy believes that measures which constitute a large portion of savings should receive a higher priority for review. Therefore, cumulative savings was given the most weight in our points system at 40. Source age was given the least with 10. The other characteristics were scored out of 20 points each.

A summary of the final scoring can be seen in Table 2.

[4] Michaels Energy combined Union and Enbridge program data and analyzed a combined set of measures for both utilities.

Table 2
Full Scoring Matrix

Measure	Sector	Cummulative Savings	Source Basis	Frequency	Source Age	Utility Differences	Total Points
All other industrial equipment	Industrial	38	20	13	10	0	81
Boiler - Industrial Process	Industrial	36	15	12	2	10	75
Boiler - Space heating	Commercial	34	5	20	2	10	71
Outside Pipe Insulation	All	40	5	16	4	0	65
Boiler - Domestic Hot Water	Commercial	30	5	17	2	10	64
Boiler Controls	All	26	5	19	2	10	62
Energy Curtains	Greenhouse	32	15	10	3	0	60
Heat Recovery	All	22	15	8	3	10	58
Exhaust Fan Controls	Commercial	28	15	1	4	0	48
Heat Reflector Panels	All	1	20	14	10	0	45
Economizers - Conventional and condensing	All	18	15	7	4	0	44
Steam Trap	Industrial	14	1	15	2	10	42
Boiler Combustion Tune-Up	All	0	20	0	10	10	40
Infiltration Controls - Dock Seals, Air Doors	Industrial	4	15	18	2	0	39
IR Poly	Greenhouse	12	15	5	2	0	34
VFD retrofit on MUA	Commercial	1	20	3	10	0	34
Heat Exchanger	Commercial	16	15	1	2	0	34
Building Automation System	All	24	5	2	2	0	33
Ovens & Thermal Oxidizers	Industrial	1	20	1	10	0	32
Reverse Osmosis (RO) Water Conditioner	Industrial	1	20	1	10	0	32
Building Envelope	All	1	20	1	10	0	32
Recommissioning, Retro-Commissioning	All	10	15	1	5	0	31
Boiler Air Makeup (line)	Industrial	0	20	0	10	0	30
Boiler - Oxy-Fuel	Industrial	0	20	0	10	0	30
Boiler - Low Nox	Industrial	0	20	0	10	0	30
Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	All	6	15	6	3	0	30
Electric Loop Controllers	Commercial	0	20	0	10	0	30
PLCs	Industrial	0	20	0	10	0	30
Flame Supervision	Industrial	0	20	0	10	0	30
Ion Exchange Water Conditioner	Industrial	0	20	0	10	0	30
Windows	All	0	20	0	10	0	30
Furnaces	All	20	5	1	4	0	30
Combustion Tune-up	All	0	15	0	4	10	29
Roof/Ceiling insulation	Commercial	2	15	9	2	0	28
Make-Up Air	Commercial	8	5	4	5	0	22
Grain Dryer	Commercial	1	15	1	4	0	21
Building Optimization Program/RunSmart - Behavioral Savings Project	Commercial	0	15	0	5	0	20
Dessicant Cooling	Commercial	0	15	0	4	0	19
Turndown controls on Modulating Boiler	Commercial	0	15	0	4	0	19
Cooling Tower for HVAC	Commercial	0	15	0	2	0	17
Infrared Heaters	Commercial	0	15	0	2	0	17
Tank Exterior Insulation	All	1	5	1	4	0	11
Air Sealing	All	0	5	0	4	0	9
Steam Piping Leaks	Industrial	0	5	0	4	0	9
Steam Valve	Industrial	0	5	0	4	0	9

Based on Michaels' analysis of the program data and current referenced resources, Michaels Energy conducted further research on the following 20 measures.

- All other industrial equipment
- Boiler - Industrial Process
- Boiler - Space heating
- Outside Pipe Insulation
- Boiler - Domestic Hot Water
- Boiler Controls
- Energy Curtains
- Heat Recovery
- Exhaust Fan Controls
- Heat Reflector Panels
- Economizers - Conventional and condensing
- Steam Trap
- Infiltration Controls - Dock Seals, Air Doors
- IR Poly
- VFD retrofit on MUA
- Heat Exchanger
- Building Automation System
- Ovens & Thermal Oxidizers
- Reverse Osmosis (RO) Water Conditioner
- Building Envelope

One measure, boiler combustion tune-ups, was initially scored high enough to be selected in the top 20 measures. However, feedback from Enbridge indicated that they had not offered this measure for several years. Union also had no participation for combustion tune-ups in 2016. Therefore, boiler combustion tune-ups were not selected for further review.

The measures selected for review represent a significant portion of the savings from 2016. The 20 measures selected represent 85% of Union's 2016 custom program savings, and 96% of Enbridge's 2016 custom program savings.

1.2 | Secondary Literature Review

After selecting the measures for review, Michaels Energy completed a thorough literature review. The first step in the literature review was to determine if the measure life assumptions used by Union and Enbridge were consistent with industry standard practice. Michaels Energy systematically stepped through five different categories of research materials for each measure.

1. **Recent Evaluation Reports:** Recent evaluation reports of Enbridge or Union custom programs can provide recent research for projects completed right in Ontario. Most well-rounded custom program evaluations will address measure life for each project reviewed. They can also be great tools for finding provincial or regional data sources.
2. **Technical Reference Manuals:** Technical reference manuals (TRMs) contain significant amounts of detailed engineering data. Michaels Energy took the final list of researchable measures and scanned our known list of TRMS which contain those measures. Our team compiled a list of all TRMs found to include a given measure, as well as the measure life assumed in each TRM. A summary of the referenced TRMs can be found in Appendix B. In many cases, the technical assumptions used, including measure life, are sourced from

a specific research study. As part of our research, we tracked down the source document and ensured that the actual source was well reasoned and applicable to the measures found in Ontario.

3. **Measure Studies:** Beyond TRMs and Ontario evaluation reports, there are a plethora of other research studies completed for DSM programs across the United States and Canada every year. Michaels Energy used our wide knowledge base from our projects across both the United States and Canada to help uncover research relating to measure lives. Some of the referenced measure studies include those from the U.S. Department of Energy (DOE), National Resources Canada (NRCAN), California IOU Savings Retention Studies, Measure Life studies from the U.S., and data from the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE).
4. **Manufacturer Data:** Custom projects also contain a wide array of equipment that doesn't fit a typical category or isn't likely to be found in a TRM. There are not many TRMs that contain regenerative thermal oxidizers or steam turbines driven by wood pulp fired boilers. Manufacturers publish rated lifetimes for nearly all equipment. In cases such as those mentioned previously, they can sometimes be the only source of estimated measure life information. Michaels Energy examined manufacturer literature for air doors, loading dock door seals, boiler economizers, energy curtains, IR poly, and RO water filtration systems to supplement the existing energy efficiency literature.
5. **Michaels Energy Data:** Michaels Energy has an extensive library of previously calculated and evaluated custom projects. We mined our data and Ontario evaluation experience for Ontario specific insights and programmatic approaches to measure lives.

After completing the literature review, Michaels Energy examined the measure life data and determined variances between the utilities' custom measure life tables and industry norms. Noted differences were further examined to determine if they were justified. Some of the key factors considered were climate, installation practices, and commercial versus industrial participation. A complete benchmark table can be found in Appendix C.

Measures, where differences between the Ontario measure lives and industry seemed appropriate, are discussed under section 2.1.Michaels Energy did not recommend changes to measures lives which were consistent with industry values. However, all of these measures were considered for further research depending on life uncertainty and the contribution to lifetime savings.

Complementary to the benchmarking activity was also assessing the sources cited by the different jurisdictions. Understanding if a measure life was based on primary research, secondary research, or engineering judgment was necessary for understanding the uncertainty in measure life estimates.

2. Literature Review Findings

After completing the literature review, Michaels Energy aggregated the results to benchmark the measure lives used by Union and Enbridge. Variations between industry standard and current Union and Enbridge measure lives were used as a starting point for identifying any measure life changes and future research priorities.

During the examination of individual measures, Michaels Energy also assessed the basis of the cited measure life resources. This was identified as a key research priority during the early stages of this study. The source basis was used to inform the relative uncertainty surrounding each estimated measure life. Additionally, measure lives which were already based on primary data were considered lower priority candidates for Ontario specific research in the future.

2.1 | Measure Life Benchmarking

The measure lives used by Union and Enbridge were compared against the Ontario Technical Reference Manual, and an additional 20 TRMs from different states in the U.S. Technical Reference Manuals provide a significant repository of technical and engineering data, including estimates of measure life. Additionally, they often contain citations and references for other research and evaluation studies. Michaels Energy leveraged these cited resources during the literature review.

The first benchmarking step provided a high-level comparison to other jurisdictions and was used to help inform recommendations for future research specific to Ontario. A summary of the benchmarking results can be seen in Table 3. The average measure life shown is an unweighted average.

Table 3

Measure Life Benchmarking Comparison[5]

Measure	Custom Measure Life (UGL/EGD)	Average Researched Life
All other industrial equipment	20/20	18
Boiler - Industrial Process	20/20	20
Boiler - Space heating	20/25	22
Pipe Insulation	20/20	14
Boiler - Domestic Hot Water	20/25	20
Boiler Controls	20/15	14
Energy Curtains	10/10	13
Heat Recovery - Commercial	15/15	18
Heat Recovery - Industrial	20/15	17
Exhaust Fan Controls	15/ -	13
Heat Reflector Panels	15/15	25
Economizers - Conventional and condensing	20/ -	15
Steam Trap	6/6	6
Infiltration Controls - Dock Seals, Air Doors	15/15	10
IR Poly	5/5	5
VFD retrofit on MUA	10/ -	15
Heat Exchanger	17/ -	17
Building Automation System	20/ -	15
Ovens & Thermal Oxidizers	20/ -	18
Reverse Osmosis (RO) Water Conditioner	20/ -	20
Building Envelope	20/25	22

The benchmarking showed that the Ontario utilities use measure lives which are the same as industry for five measures, higher than average for 12 measures, and lower than average for four measures.

There are five different custom measure lives indicated in red in Table 3. In each of these cases, Union and Enbridge use a different value for the measure life. Three of those instances, space heating boilers, domestic hot water boilers, and buidling envelope are due to Union capping measure lives at 20 years.

The measures in Table 3 highlighted in green show those where the measure life claimed by the utilities differs by five years or more from the benchmarked results. Five years corresponds to a difference of at least 20 percent. In total, there are seven measure lives which differ. The

[5] Heat exchangers are displayed showing the average measure life of commercial (14 years) and industrial (20 years). Referenced sources did not separate these end uses.

remaining 13 measures show good agreement between the values used by Union and Enbridge and other parts of North America.

It is important to note that good agreement is not equivalent to correct. Even though 20 years is widely used as the measure life for industrial equipment, it does not mean that the *correct* measure life is 20 years. Michaels Energy considered the uncertainty associated with any particular measure life in addition to the agreement between industry averages when recommending measure life changes and further research. However, those measures with good agreement were not recommended for immediate changes.

The measures which were found to deviate from the industry average were:

- Outside Pipe Insulation
- Boiler Controls
- Heat Reflector Panels
- Economizers – Conventional and Condensing
- Infiltration Controls – Dock Door Seals, Air Doors
- VFD and Make-up Air Units
- Building Automation Systems

Michaels Energy completed further investigation of the seven measures where the measure life was found to differ from industry averages. Based on our previous experience evaluating custom measure projects in Ontario, Michaels Energy determined that out of the seven measures found to deviate, only economizers do so for justifiable reasons. The remaining six measures were considered for updates based on the literature. These six measures also constituted the short list of measures which were considered for recommended primary research.

Union currently claims a 20-year measure life for economizers. Boiler economizers were popular measures for industrial customers and greenhouses for Union during 2016. These customers tend to install larger boilers, with larger systems and are designed to operate longer hours throughout the year. Michaels Energy believes that a 20-year measure life is reasonable for the larger industrial installations commonly seen in Ontario. Economizers can also be installed on commercial buildings. Commercial installations would be expected to have a lower measure life of 15 years. Michaels Energy recommends that this measure be split into an industrial category with a 20 year life, and a commercial category with a 15 year life.

Enbridge currently uses the "Heat Recovery" measure for boiler stack economizers, which has a 15-year life. Enbridge has a similar mix of industrial versus commercial installations for boiler stack economizers and should consider adding an industrial boiler stack economizer classification with a 20-year measure life to be consistent[6].

2.2 | Source Basis

In order to inform the uncertainty associated with the assumed measure lives, the original source of the measure life must be understood. Where possible, Michaels Energy traced the evaluation reports, DOE Rulings, TRMs and other research reports back to the original sources for measure

[6] Michaels did not "audit" the utilities use of the custom measure life tables as part of this research. Instead, differences in how measure lives are applied are being identified for future improvements.

life. In most cases, this was a multi-step process of going from an original report to the cited source, and then again to a third common reference. Most of the referenced documents were found to base measure life estimates on literature reviews of other jurisdictions for the measures selected for investigation. A majority of the measure sources investigated used one of four different sources.

1. 2011 or 2015 ASHRAE Handbook, HVAC Applications. Chapter 37, Table 4 – Comparison of Service Life Estimates.
2. Database for Energy Efficiency Resources (DEER) Estimated Useful Life Tables.
3. Measure Life Report – Residential and Commercial/Industrial Lighting and HVAC Measures prepared by GDS Associates in June 2007.
4. Measure Life Study Report. Prepared for the Massachusetts Joint Utilities by ERS in 2005.

Michaels Energy has provided brief summaries of the key literature sources within this section for reference.

2.2.1 | ASHRAE Handbook

The ASHRAE Handbook Comparison of Service Life Estimates is a popular reference and was ultimately based on primary data collection. Prior to 2005, the measure life estimates provided in the HVAC Applications handbook were derived from an ASHRAE research project which took place in 1976[7].

However, beginning in 2005, an online database was started and seeded with information from 163 different commercial buildings[8]. The database contains standard information on each piece of equipment including major end-use, equipment type, equipment operating hours, building type, building location, building area, year and month installed, year and month removed, and the reason for removal. The database is open to being populated by engineers and facility owners who are replacing their equipment. The database contents can be openly downloaded from the ASHRAE website[9]. As of this report, there were more than 345 different buildings that have reported details on nearly 39,000 different pieces of equipment.

One notable concern with this dataset is that much of the data has not been updated since 2008. A majority of the measures indicate they were installed prior to 2005, and very few new entries have been added since that time. The information available from ASHRAE does not specify if work is being done to update the database regularly. However, this remains one of the most robust datasets of actual installed and replaced equipment data that is available publicly.

2.2.2 | California DEER Database

The California Database for Energy Efficiency Resources (DEER) is a commonly cited source for many energy efficiency related parameters, including measure life. The measure lives found in the DEER database were originally developed in 2000 for inclusion in the 2001 version of the DEER

[7] 2015 ASHARE Handbook, HVAC Applications. Chapter 37, page 2.
[8] Ibid.
[9] https://xp20.ashrae.org/publicdatabase/service_life.asp

database. Over the years there have been studies to update some of the measure lives included in DEER[10], but a majority of those updates focused on lighting technologies.

Many of the DEER measure lives were and still remain based on the data contained in California DSM Measurement Advisory Committee (CADMAC) Protocol F, available on the CALMAC website[11]. The most commonly cited source within this document appears to be engineering judgment. However, several of the measures in the DEER database have been updated or verified using primary data collection in California.

2.2.3 | GDS Measure Life Report

The Measure Life Report prepared by GDS in 2007 was the third common resource cited for measure life. The measure lives recommended from this study were the result of completing a literature review of recent measure life sources. The cited sources include the aforementioned DEER database and ERS measure life studies, as well as other research studies from the Northeast U.S. and California.

2.2.4 | ERS Measure Life Study

Similar to the GDS study, the measure life research completed by ERS in 2005 included a benchmarking component and a detailed literature review component. The benchmarking compared the measure lives used in Massachusetts to those used by 11 different utilities. Additionally, ERS completed an examination of the research done in the state of California.

During the early 2000's, the California utilities completed a number of retention studies. The retention studies attempted to measure the life of energy efficient equipment that had been installed through the programs up to 9 years prior. Retention studies use the known failure rates during the first years of a product, to estimate the median effective life. For example, the SDG&E Ninth year retention study completed in 2004 examined equipment that had been originally installed during the 1994 and 1995 program years.

These retention studies were based on surveys and site visit verification with customers who completed a wide range of measures. The sample sizes for some measures were very small (i.e., one customer). However, the full list of 16 different studies covers many popular measures, including some of the measures of interest for the Ontario gas utilities.

2.3 | Measure Life Primary Research

During the literature review, Michaels Energy was able to locate primary research related to four different custom measures included in this study. Included in the following sections are summaries of the data collection found.

[10] One such example is "Revised/updated EULs Based on Retention and Persistence Studies Results", prepared by SERA, Inc., July 9, 2005
[11] http://www.calmac.org/cadmac-protocols.asp

2.3.1 | Space Heating and Domestic Hot Water Boilers

The measure life for space heating and domestic hot water boilers from across the literature was found to reference one of three common sources.

1. 2011 or 2015 ASHRAE Handbook, HVAC Applications. Chapter 37, Table 4 – Comparison of Service Life Estimates.
2. Database for Energy Efficiency Resources (DEER) Estimated Useful Life Tables.
3. Measure Life Report – Residential and Commercial/Industrial Lighting and HVAC Measures prepared by GDS Associates in June 2007.

Out of the three key referenced sources, the ASHRAE Service Life Estimates were able to be traced back to the primary data.

The ASHRAE dataset was also used as the basis for the U.S. Department of Energy's (US DOE) most recent rule-making on commercial packaged boiler efficiency standards[12]. The US DOE mined the data to develop a probability distribution of the ages and estimated failure rates for commercial packaged boilers. Based on the data included in the ASHRAE database, the US DOE estimates that commercial boilers have a mean failure age[13] of 24.8 years.

Enbridge currently uses a 25-year measure life for space heating and domestic hot water boilers. Union uses a 20-year measure life; however, this is due to Union's policy of capping measure lives at 20 years[14]. Absent the cap, Michaels Energy believes that a 25-year measure life is most appropriate for space heating and domestic hot water boilers.

2.3.2 | Steam Traps

Currently, the Enbridge custom measure life table references an impact evaluation from Massachusetts as the source for the six-year steam trap measure life. The 2013 Prescriptive Gas Evaluation – Phase 1 Steam Trap Evaluation[15], conducted research in the following areas to assess measure life:

- Conduct in-depth industry and literature research on the steam trap measure with a focus on the measure lifetime assumption being used.
- Conduct and provide a summary of meetings with vendors/manufacturers most active with repair/replacement of steam traps in Massachusetts
- Collect actual Massachusetts gas customer facility data that supports steam trap lifetime conclusions

[12] TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT: COMMERCIAL PACKAGED BOILERS. December 9, 2016. file:///C:/Users/mtf/Downloads/00_CPB_ECS_FinalRule_TSD_Complete_2016-12-20.pdf

[13] The U.S. DOE uses the term "mean failure age" which Michaels Energy used for consistency. In reality, the ASHRAE data includes both equipment which had failed, and equipment which was replaced early for other reasons.

[14] Union Gas Custom Measure Life Table

[15] Massachusetts 2013 Prescriptive Gas Impact Evaluation Steam Trap Evaluation Phase 1: FINAL. DNV – GL. June 17, 2015. http://ma-eeac.org/wordpress/wp-content/uploads/MA-2013-Prescriptive-Gas-Impact-Evaluation-Steam-Trap-Evaluation-Phase-1.pdf

The data gathered by the study team indicated that most jurisdictions use measure lives that range between three and six years. Vendors interviewed as part of the research indicated that steam traps are capable of lasting for more than five years, but that water quality was a significant factor. The customer sites visited had annual steam trap failure rates between 10 and 20 percent, indicating a five to ten-year measure life.

The final conclusion of this report was that a six-year measure life was appropriate for steam traps. Enbridge and Union both utilize a six-year measure life for steam trap replacements. Thus, no changes are recommended for steam traps at this time.

2.3.3 | VFD on Make-Up Air Units

Variable frequency drive (VFD) measure life was commonly sourced from the DEER database. The original estimate for VFD measure life was based on engineering judgment. This was later validated using the retention studies completed by the California utilities.

A total of ten different VFD measures were examined across the retention studies, each with a reported measure life between 10 and 16 years, with confidence intervals of up to 10 years. The research was used to confirm a 15-year measure life for fan VFDs currently used in the DEER database.

2.3.4 | Building Automation Systems

Similar to VFDs, the California retention studies also examined building automation systems[16]. The DEER database estimate for building automation systems was originally based on engineering judgment; that was later validated with research findings.

A total of four different measures were studied in the various California retention studies. Three of those studies recommended a 15-year life, and one recommended a 14-year life. This ultimately confirmed the 15-year measure life used in DEER.

2.4 | Source Conclusions

Of the four most commonly referenced sources for measure lives, only the ASHRAE database is based solely on primary data collection. The other common sources are based on a combination of engineering judgment, benchmarking to other utilities, and examining primary-researched measures from other jurisdictions. Michaels Energy looked through each of the foundational sources to determine the most applicable basis for the industry average measure life. The results can be seen in Table 4. The green highlighted measures were retained from the benchmarking analysis to show again which measures differed from industry consensus.

[16] The CA studies use the energy management system name, but are effectively identical to building automation systems.

Table 4

Source Basis Summary

Measure	Researched Average Life	Source Basis
All other industrial equipment	18	Engineering Judgement
Boiler - Industrial Process	20	Engineering Judgement
Boiler - Space heating	22	Primary Data
Outside Pipe Insulation	14	Engineering Judgement
Boiler - Domestic Hot Water	20	Primary Data
Boiler Controls	14	Engineering Judgement
Energy Curtains	13	Engineering Judgement
Heat Recovery - Commercial	18	Engineering Judgement
Heat Recovery - Industrial	17	Engineering Judgement
Exhaust Fan Controls	13	Engineering Judgement
Heat Reflector Panels	25	Engineering Judgement
Economizers - Conventional and condensing	15	Engineering Judgement
Steam Trap	6	Primary Data
Infiltration Controls - Dock Seals, Air Doors	10	Engineering Judgement
IR Poly	5	Engineering Judgement
VFD retrofit on MUA	15	Primary Data
Heat Exchanger	17	Engineering Judgement
Building Automation System	15	Primary Data
Ovens & Thermal Oxidizers	18	Engineering Judgement
Reverse Osmosis (RO) Water Conditioner	20	Engineering Judgement
Building Envelope	22	Engineering Judgement

3. Recommendations and Future Research

Michaels Energy examined those measures which differed from industry standards and researched the source basis for the measures. Based on the deviation from industry consensus, applicability of the industry standard to Ontario, and the source basis of the measure life, Michaels Energy has developed several recommendations. The first set is focused on recommended changes to current measure lives. The second are priorities for future research in Ontario.

3.1.1 | Updates to Measure Lives

Michaels Energy was able to determine that a majority of the custom measure lives were sourced from a small number of literature sources. Each of these was more than 10 years old, and only a few measures were found to be based on primary research. Only one reference was based solely on primary data, the ASHRAE Handbook Comparison of Service Life Estimates.

Therefore, it must be acknowledged that the recommended changes to measure lives are based on the best available literature, program data, and Michaels' best engineering judgment.

3.1.1.1 | Boiler Controls

Boiler controls cover a wide range of measures including boiler reset, sequencing, and temperature lockout. Union Gas separates burner modifications, such as linkageless controls, into a separate category. Enbridge does not have a separate category for these types of modifications. However, Enbridge uses a lower 15-year measure life for boiler related controls. Additionally, Enbridge applies the 15 year controls life to other HVAC controls, such as demand controlled ventilation.

Excluding burner modifications, "soft" boiler controls such as reset and lockout are not expected to last as long as the boiler itself. These types of controls typically have lifetimes similar to other HVAC controls. Industry consensus for HVAC controls is 10-15 years. Lifetimes in this range are also what Michaels Energy uses for HVAC controls in our custom program implementation[17].

Therefore, Michaels Energy recommends using a 15-year measure life for boiler controls. This does not include burner modifications, which are currently assigned a separate measure life by Union. Enbridge could consider adding a separate category for burner modifications, which would use a 20-year life similar to Union.

3.1.1.2 | VFD for Make-Up Air Units

Variable frequency drives are popular measures within prescriptive and custom programs. Most of the reports reviewed indicate that a 15-year measure life for variable frequency drives is

[17] Michaels Energy provides custom rebate technical support for utility clients in the Midwest. We typically use 10-15 year measure lives for custom controls measures in this work.

appropriate. Currently, Union and Enbridge utilize a 10-year measure life for variable frequency drives.

The strong industry agreement is in line with Michaels Energy experience and engineering judgment as well. Additionally, the ultimate source used for the 15-year measure life was primary data collection from California. Therefore, Michaels Energy recommends that the measure life for variable frequency drives for make-up air units be increased to 15 years.

3.1.1.3 | Infiltration Controls – Dock Seals and Air Doors

Currently, a 15-year measure life is claimed for loading dock door seals and air doors. This is a reasonable assumption for mechanical equipment, such as air doors. However, loading dock door or ramp seals are large, heavy-duty foam gaskets that are, in some instances, exposed to weather. The two different types of equipment warrant different measure lives. Therefore, Michaels Energy recommends that these be split into two different measure lives.

The first would remain 15 years for air doors, air curtains, and fast closing doors. These mechanical pieces of equipment have the longer 15-year lifespan.

The loading dock door and ramp gasket measure life were indicated to be 10 years in the two cold weather sources that utilize this measure[18,19]. However, the measure life was determined based on engineering judgment and not any associated primary data.

Michaels Energy recommends that the lifetime for loading dock door and ramp seals be reduced to 10 years to be consistent with what is used in other cold-weather states. Manufacturers[20] typically assume a 1 year warranty period for these seals, which further indicates a shorter lifespan than normal mechanical equipment.

It is important to note that dock door seals are becoming a common occurrence in cold-weather warehouse applications. This measure could also be included in further research, either through vendor interviews or program participant interviews. Based on Michaels Energy past experience verifying savings for Union Gas' custom program, this measure has been regularly included in the program over the last five years. Due to the small lifetime savings, however, Michaels Energy did not include it as a suggested research priority.

3.1.2 | Future Research

Many of the measures examined are ultimately based on engineering judgment. Several of the measures reviewed showed the measure lives currently claimed in Ontario differed from the industry standards. In addition, a subset of those measures was either significant contributors to the overall lifetime savings claimed in 2016, or the measures themselves have high variability and uncertainty. Finally, even though the measure lives claimed by Union and Enbridge deviate from industry averages, the industry averages were not based on primary research. This adds considerable uncertainty to the industry average.

[18] MN Technical Reference Manual, page 302.
[19] Focus on Energy (WI) 2017 Technical Reference Manual.
[20] For example Chalfant and Rite Hite.

Due to the uncertainty, Michaels Energy is not recommending immediate updates to two of the measures; pipe insulation and building automation systems. These were two such measures where primary research should be considered a high priority. Michaels Energy recommends dedicated primary research for the types of applications installed in Ontario to be sure that lifetime values are appropriate.

3.1.2.1 | Pipe Insulation

Pipe insulation is the first, and Michaels Energy believes, the highest priority for additional research. Pipe insulation had the highest lifetime gas savings of all measures completed during 2016. The 20-year measure life claimed by Union and Enbridge is higher than the industry average of 14 years. The types of installations for pipe insulation include many indoor (commercial) and potential outdoor (industrial) applications as well.

The most popular sources referenced for measure life were the ASHRAE Handbook, which Union and Enbridge reference, and the GDS Measure Life study. The ASHRAE Handbook lists 20 years for "molded" insulation and 24 years for "blanket" insulation, while the GDS report has ranged from 10 years to 25 years depending on the source.

The degree of disagreement within the industry, new insulating products that are available, wide range of applications within Ontario, and large contribution to lifetime custom savings indicate that primary data collection is warranted. Ideally, future work could distinguish different expected lifetimes for commercial buildings (indoor HVAC) from industrial (indoor/outdoor hazardous environment) and exterior (exposed to weather or buried) insulation applications.

Prior to completing the primary research, Michaels recommends reducing the measure life for pipe insulation to 14 years. This is consistent with the industry average, and accounts for a portion of the insulation being installed outdoors or in hazardous environments where it is unlikely to last 20 years.

3.1.2.2 | Building Automation Systems

Building Automation Systems, also known as Energy Management Systems, are increasingly popular measures for customers. This can be seen in the 2016 program data as building automation systems were the 9th largest contributor to total lifetime savings.

Building automation systems can vary significantly in their setup and overall usage between commercial and industrial customers. Union Gas had both commercial, and greenhouse buildings install building automation systems during 2016. Additionally, industrial customers such as asphalt and concrete plants monitor energy usage in significantly different ways.

Many of the referenced reports suggest a 15-year measure life for building automation systems. This is in contrast to the measure life utilized by Union of 20 years. Enbridge claims a 15-year measure life for building automation systems processed through the program. The ASHRAE database has 97 different building controls systems that were installed and removed prior to 2007, with an average installed time of 21 years.

Outside of the ASHRAE database, the studies completed in California are out of date. Building automation systems have changed substantially since the mid-1990's when most of the studied

measures were installed. Additionally, much of the research was focused on commercial installations and not the industrial applications which can be seen in Ontario.

Therefore, even though some older primary data exists for building automation systems, the progress of the technology over the last 20 years, the variability of installations, and the popularity of building automation system projects suggests this measure warrants additional research.

Prior to completing the primary research, Michaels Energy recommends that a 15 year measure life be used. This is most consistent with the literature, and Michaels Energy believes is more consistent with our expected building automation system lifetimes.

3.1.2.3 | Other Measures

As noted in Section 2.4, many measure lives are ultimately based on engineering judgment. While there is some primary research into measure lives, most of it is based on technologies installed more than 20 years ago.

Michaels' research into measure life showed that there were additional measures which contributed significantly to lifetime savings in 2016, and were not based on primary research.

- Other Industrial Equipment
- Energy Curtains
- Exhaust Fan Controls
- Boiler Controls
- Heat Exchangers

While the measure life assumptions could be bolstered by primary research for those listed above, Michaels Energy does not believe they are high enough priority to warrant dedicated study. Instead, Michaels Energy believes that an on-going data collection effort, similar to ASHRAE's database, would be the most beneficial and cost-effective method for building a primary dataset.

Many custom projects already have documentation which provides details of the existing equipment age and location. The existing universe of custom projects or those which are completed in the future could be mined for information about all of the measures of interest for this study and more. The ASHRAE database currently contains information from 345 individual buildings. Just during 2016, the custom programs in Ontario completed 1,360 different custom projects. Assuming each project was at a different building, a dataset of similar scale to ASHRAE's specifically for Ontario could be built within several years.

3.1.3 | Recommended Measure Lives

Michaels Energy developed a full table of recommended measure life values for the 20 different technologies researched. This is a single table which is applicable to both Union and Enbridge. These measure life values should be updated once any Ontario specific primary research is completed.

Table 5

Recommended Measure Lives

Measure	Recommended Measure Life
All other industrial equipment	20
Boiler - Industrial Process	20
Boiler - Space heating	25
Pipe Insulation	14
Boiler - Domestic Hot Water	25
Boiler Controls	15
Energy Curtains	10
Heat Recovery - Commercial	15
Heat Recovery - Industrial	20
Exhaust Fan Controls	15
Heat Reflector Panels	15
Economizers - Conventional and condensing	20
Steam Trap	6
Infiltration Controls - Air Doors	15
Infiltration Controls - Dock Seals	10
IR Poly	5
VFD retrofit on MUA	15
Heat Exchanger	17
Building Automation System	15
Ovens & Thermal Oxidizers	20
Reverse Osmosis (RO) Water Conditioner	20
Building Envelope	25

Appendix A | Measure Selection Memo

Selection Methodology and Analysis

The methodology Michaels Energy used is consistent with the process outlined in our final work plan. We selected the measures for further study be examining the following criteria:

- **Measure Frequency:** The number of units claimed by Enbridge, Union, or both based on 2016 program data.
- **Measure Impacts:** Even if a measure has small numbers of individual projects completed each year, their natural gas impacts may be significant to the custom programs as a whole.
- **Age of Referenced Sources:** Older sources may still be valid, but the additional investigation will be completed to ensure any more recent sources confirm assumptions or suggest an alternate value.
- **The Basis of Referenced Sources:** Cited sources will be examined to determine if they are based on primary data, secondary data, a specific jurisdiction, or engineering assumption. Measures which are sourced from primary data will be less likely to be included, assuming other criteria mentioned here are also met.
- **Differences Between Utilities:** Technologies which have different measure lives for each of the two utilities. In some instances, this may be acceptable, for example, different types of customers who routinely utilize a particular measure.
- **Michaels Energy Experience:** As explained in our proposal, Michaels Energy has examined thousands of custom projects. Our research team has the depth of knowledge about measures and their associated measure lives. We'll leverage this experience to identify any measures which don't have measure lives consistent with our experience.

In order to determine which measures were selected for further research, Michaels Energy examined each of the characteristics listed above and assigned a point value to each measure. The higher the assigned points, the more likely the measure should be selected for inclusion and further review. For example, the most popular measure from 2016, space heating boilers, would receive 20 points, while measures which had no participation would be given 0 points.

Michaels Energy believes that measures which constitute a large portion of savings should receive a higher priority for review. Therefore, cumulative savings was given the most weight in our points system at 40. Source age was given the least with 10. The other characteristics were scored out of 20 points each.

Program Data Analysis

Michaels Energy received 2016 custom program data for Enbridge and Union. The program data did not contain the exact same measure descriptions as the utilities' custom measure life tables. Therefore, the program data needed to be mapped to the measure life tables.

The program data contained fields for end-use, building type, measure type, and technology type. These features were used to map each project in the program data to the appropriate measure classification from the custom measure life tables. An example of this mapping for 10

different measures is shown in Table 1. The columns for “Equipment Type” and “Technology” were taken from the program data, while the “Measure Classification” column is from the custom measure life tables.

Table 6
Example Measure Mapping

Utility	Equipment Type	Technology	Measure Classification	Count	Lifetime Savings
Enbridge	BAS	BAS	Building Automation System	1	7,431,645
Union	Building	Boiler - Space heating	Boiler - Space heating	1	384,100
Union	Building	Exhaust Fan Controls	Exhaust Fan Controls	1	4,530,660
Union	Building	New Construction	Unclassified	3	8,525,620
Enbridge	Building Envelope	Roof Insulation	Roof/Ceiling insulation	14	5,993,800

A full table containing all of the measure mappings can be found in Appendix B.

Measure types which were not listed in the most recent custom measure life tables were labeled with “Unclassified,” such as the Building – New Construction measure shown in Table 1. Michaels Energy carried the unclassified measure label throughout the analysis to provide context on its relative contribution to savings and measure counts. However, unclassified measures were not scored. Unclassified measures were evaluated for inclusion separately, as described in the last analysis section of this memo.

Measure Frequency

Measure frequency is simply the number of units installed during the 2016 program year. Table 2 shows the summary of the measure frequency seen in the 2016 program year for Union, Enbridge, and combined.

Table 7

Measure Frequency[21]

Measure Classification	Union Count	Enbridge Count	Total Count	Points
Boiler - Space heating	17	150	**167**	**20**
Boiler Controls	3	151	**154**	**19**
Infiltration Controls - Dock Seals, Air Doors	43	70	**113**	**18**
Boiler - Domestic Hot Water	26	77	**103**	**17**
Outside Pipe Insulation	61	42	**103**	**16**
Steam Trap	3	58	**61**	**15**
Heat Reflector Panels	0	59	**59**	**14**
Unclassified	49	10	**59**	-
All other industrial equipment	49	9	**58**	**13**
Boiler - Industrial Process	7	46	**53**	**12**
Prescriptive	0	46	**46**	**11**
Energy Curtains	35	10	**45**	**10**
Roof/Ceiling insulation	29	14	**43**	**9**
Heat Recovery	41	1	**42**	**8**
Economizers - Conventional and condensing	17	23	**40**	**7**
Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	23	5	**28**	**6**
IR Poly	23	1	**24**	**5**
Make-Up Air	13	11	**24**	**4**
VFD retrofit on MUA	1	23	**24**	**3**
Building Automation System	21	1	**22**	**2**
Building Envelope	8	9	**17**	**1**
Furnaces	14	1	**15**	**1**
Heat Exchanger	14	0	**14**	**1**
Tank Exterior Insulation	11	1	**12**	**1**
Exhaust Fan Controls	10	0	**10**	**1**
Grain Dryer	9	0	**9**	**1**
Ovens & Thermal Oxidizers	7	0	**7**	**1**
Recommissioning, Retro-Commissioning	4	0	**4**	**1**
Fire Supression	2	0	**2**	**1**
PLC	1	0	**1**	**1**
Reverse Osmosis (RO) Water Conditioner	1	0	**1**	**1**
Total	**541**	**818**	**1,359**	

Space heating boilers, boiler controls, and infiltration control measures rounded out the top three most common measures from 2016. All three were more popular, based on counts of measures, for Enbridge than Union.

[21] The "Prescriptive" classification is based on Enbridge's use of the Ontario TRM for measures life values consistent with the note provided on Enbridge's custom measure life table. "Where site specific information or a relevant prescriptive measure life is available to support an alternate measure life value for a specific custom project, Enbridge will use the alternate value for that custom project."

Measure Impacts

After examining measure frequency, Michaels Energy also examined the cumulative impacts resulting from each measure. Table 3 shows the cumulative cubic meters attributed to each measure classification from the 2016 program data for both utilities and in total. Similar to the frequency analysis, points were assigned based on rank. However, since there were not 40 different measures, points were dropped by two each time. Measures were also given at least one point if savings were claimed.

Table 8

Cumulative Measure Impacts

Measure Classification	Union Lifetime Savings (CCM)	Enbridge Lifetime Savings (CCM)	Lifetime Savings (CCM)	Points
Outside Pipe Insulation	529,356,770	23,635,200	**552,991,970**	**40**
All other industrial equipment	454,903,539	1,861,200	**456,764,739**	**38**
Boiler - Industrial Process	24,699,909	290,661,155	**315,361,064**	**36**
Boiler - Space heating	31,325,404	136,392,069	**167,717,473**	**34**
Energy Curtains	137,881,567	10,400,900	**148,282,467**	**32**
Boiler - Domestic Hot Water	78,498,112	69,391,975	**147,890,087**	**30**
Exhaust Fan Controls	119,155,605	0	**119,155,605**	**28**
Boiler Controls	4,994,860	109,805,190	**114,800,050**	**26**
Building Automation System	106,741,148	7,431,645	**114,172,793**	**24**
Heat Recovery	107,863,618	1,716,660	**109,580,278**	**22**
Furnaces	97,010,462	658,530	**97,668,992**	**20**
Unclassified	76,732,834	7,116,475	**83,849,309**	**-**
Economizers - Conventional and condensing	44,554,733	25,909,980	**70,464,713**	**18**
Heat Exchanger	63,393,112	0	**63,393,112**	**16**
Steam Trap	14,116,415	46,504,092	**60,620,507**	**14**
IR Poly	55,638,201	477,995	**56,116,196**	**12**
Recommissioning, Retro-Commissioning	48,679,220	0	**48,679,220**	**10**
Make-Up Air	27,421,693	7,054,755	**34,476,448**	**8**
Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	32,006,019	1,626,000	**33,632,019**	**6**
Infiltration Controls - Dock Seals, Air Doors	13,904,024	17,825,175	**31,729,199**	**4**
Roof/Ceiling insulation	20,079,180	5,993,800	**26,072,980**	**2**
Ovens & Thermal Oxidizers	24,265,940	0	**24,265,940**	**1**
VFD retrofit on MUA	572,210	20,711,100	**21,283,310**	**1**
Tank Exterior Insulation	14,913,510	15,285	**14,928,795**	**1**
Heat Reflector Panels	0	13,413,720	**13,413,720**	**1**
Building Envelope	1,388,500	8,370,025	**9,758,525**	**1**
Prescriptive	0	9,417,895	**9,417,895**	**1**
Grain Dryer	3,268,400	0	**3,268,400**	**1**
Fire Supression	1,704,540	0	**1,704,540**	**1**
PLC	527,955	0	**527,955**	**1**
Reverse Osmosis (RO) Water Conditioner	494,460	0	**494,460**	**1**
Total	**2,136,091,940**	**816,390,821**	**2,952,482,761**	

There are many measures which provide significant impacts and show up frequently. Pipe insulation, boilers, industrial equipment, energy curtains, are all popular and provide significant impacts. However, furnaces, exhaust fan controls, heat recovery, and heat exchangers provide large impacts even though they are less popular measures.

Age of Sources

The third parameter Michaels Energy examined was the age of the referenced sources from the custom measure life tables. Many of the referenced sources are less than 10 years old. The utilities have also indicated that as part of the annual custom program savings verification, their verification contractors complete a review of the custom measure lives for sampled projects.

A summary of the ages of the referenced sources can be seen in Table 4. Measures with no cited source were given 10 points. Referenced sources 20 years old or more were also given 10 points, with points declining linearly down to zero if a source was published in 2018.

Table 9

Cited Source Age

Measure	Age	Points
Boiler Combustion Tune-Up	NA	10
Boiler Air Makeup (line)	NA	10
Boiler - Oxy-Fuel	NA	10
Boiler - Low Nox	NA	10
Heat Reflector Panels	NA	10
VFD retrofit on MUA	NA	10
Ovens & Thermal Oxidizers	NA	10
Electric Loop Controllers	NA	10
PLCs	NA	10
Flame Supervision	NA	10
Reverse Osmosis (RO) Water Conditioner	NA	10
Ion Exchange Water Conditioner	NA	10
All other industrial equipment	NA	10
Windows	NA	10
Building Envelope	NA	10
Building Optimization Program/RunSmart - Behavioral Savings Project	10	5
Make-Up Air	10	5
Recommissioning, Retro-Commissioning	10	5
Economizers - Conventional and condensing	7	4
Grain Dryer	8	4
Combustion Tune-up	8	4
Dessicant Cooling	7	4
Exhaust Fan Controls	8	4
Turndown controls on Modulating Boiler	8	4
Outside Pipe Insulation	7	4
Air Sealing	7	4
Tank Exterior Insulation	7	4
Steam Piping Leaks	7	4
Steam Valve	7	4
Furnaces	7	4
Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	6	3
Energy Curtains	6	3
Heat Recovery	6	3
Boiler - Industrial Process	4	2
Boiler - Space heating	3	2
Boiler - Domestic Hot Water	3	2
Boiler Controls	3	2
IR Poly	4	2
Building Automation System	3	2
Cooling Tower for HVAC	4	2
Infiltration Controls - Dock Seals, Air Doors	4	2
Heat Exchanger	4	2
Roof/Ceiling insulation	4	2
Steam Trap	3	2
Infrared Heaters	3	2

One important finding of this step is identifying measures where there is not a cited source. In some cases, such as industrial process improvements, this is expected. Measure lives for customer specific industrial equipment are not widely studied. Engineering judgment is the default for determining measure lives for industrial equipment.

Basis of Sources

Another characteristic Michaels Energy examined was the basis of the cited sources in the custom measure life tables. Both Enbridge and Union provided a list of cited sources within their custom measure life tables. These sources were examined to determine if they were based on primary data, a detailed literature review, a secondary source comparison, or engineering judgment.

It is important to note that this assessment does not provide any insight on the accuracy of the measure life that is currently used in the custom measure life tables. Measures may be based on engineering judgment, and still be correct. However, Michaels Energy would be more likely to select measures with measure lives based on engineering judgment to ensure that any available research is uncovered.

When assigning points for the source basis, Michaels Energy used four different classifications.

- **Primary Data (Primary)** – Based on studies that strove to collect primary data specifically on measure life. Sources in this category were given 1 point.
- **Detailed Data Review (Data)** – A literature review that focused on data collected from manufacturers and case studies of actual installations. Sources in this category were given 5 points.
- **Secondary Literature Comparison (Secondary)** – A literature review to ensure that the current measure life is consistent with other jurisdictions. These sources were given 15 points.
- **Engineering Judgment (Engineering)** – Assessment of the measure life based on engineering judgment and experience. Measures based on engineering judgment were also given 15 points.

Michaels Energy attempted to follow the source "trail" for each cited source from the custom measure life tables when making this assessment. For instance, the Massachusetts Prescriptive Steam Trap Evaluation, referenced by Enbridge, assessed measure life for steam traps. The research completed by this study focused on finding literature based on data from manufacturers of steam traps, in addition to customer steam trap surveys. Due to the use of primary data collection of actual steam trap turnover in facilities, this source was classified as using primary data.

Michaels Energy will complete this same type of digging during the next phase of this research as well. Our goal is to find credible, data-driven sources for validating or updating the lifetimes of the measures selected.

A summary of the assessment of the sources is shown in Table 5.

Table 10

Source Basis Review

Measure	Source Basis	Points
Boiler Combustion Tune-Up	Engineering	15
Boiler Air Makeup (line)	Engineering	15
Boiler - Oxy-Fuel	Engineering	15
Boiler - Low Nox	Engineering	15
Heat Reflector Panels	Engineering	15
VFD retrofit on MUA	Engineering	15
Ovens & Thermal Oxidizers	Engineering	15
Electric Loop Controllers	Engineering	15
PLCs	Engineering	15
Flame Supervision	Engineering	15
Reverse Osmosis (RO) Water Conditioner	Engineering	15
Ion Exchange Water Conditioner	Engineering	15
All other industrial equipment	Engineering	15
Windows	Engineering	15
Building Envelope	Engineering	15
Boiler - Industrial Process	Secondary	15
Building Optimization Program/RunSmart - Behavioral Savings Project	Secondary	15
IR Poly	Secondary	15
Grain Dryer	Secondary	15
Cooling Tower for HVAC	Secondary	15
Combustion Tune-up	Secondary	15
Dessicant Cooling	Secondary	15
Exhaust Fan Controls	Secondary	15
Infiltration Controls - Dock Seals, Air Doors	Secondary	15
Turndown controls on Modulating Boiler	Secondary	15
Heat Exchanger	Secondary	15
Roof/Ceiling insulation	Secondary	15
Recommissioning, Retro-Commissioning	Secondary	15
Infrared Heaters	Secondary	15
Boiler - Space heating	Data	5
Boiler - Domestic Hot Water	Data	5
Boiler Controls	Data	5
Economizers - Conventional and condensing	Data	5
Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	Data	5
Energy Curtains	Data	5
Building Automation System	Data	5
Heat Recovery	Data	5
Make-Up Air	Data	5
Outside Pipe Insulation	Data	5
Air Sealing	Data	5
Tank Exterior Insulation	Data	5
Steam Piping Leaks	Data	5
Steam Valve	Data	5
Furnaces	Data	5
Steam Trap	Primary	1

Differences Between Utilities

The final analysis step was to compare the measure lives used by the two utilities. Differences in lifetime for the same measure were flagged, and assigned points. Overall, many of the measure lives were the same between the utilities. However, there were several notable differences.

The first difference is that Union caps all of their measure lives at 20 years, while Enbridge does not. Union noted this cap in its custom measure life table for boiler measures. Enbridge uses a 25-year measure life for boiler related measures.

The second difference is in the combustion tune-up measure. Union uses a one-year measure life, while Enbridge uses a five year lifetime. Both of these estimates were based on engineering judgment, according to the measure life tables.

Additional differences between the utilities are shown below.

- Boiler Controls – Union 20, Enbridge 15
- Heat Recovery, Industrial – Union 20, Enbridge 15

Each measure where a difference was found was given an additional 10 points.

Unclassified Measures

Measures listed as unclassified were not able to be directly attributed to a measure life from the custom measure life table. However, Michaels Energy felt it was necessary to evaluate how significant of a contribution unclassified measures provided. Additionally, if there were some common measures, it may be possible to add measure lives to the custom measure table.

Table 6 shows all the unclassified measures based on their contribution to lifetime savings achieved in 2016. The "Rank" column shown is how the measures rank compared to all measures from 2016. Greenhouse Other, for example, contributed the 16th most savings in 2016.

Table 11

Summary of Unclassified Measures

Utility	Equipment Type	Technology	Measure Classification	Count	Lifetime Savings	Rank
Union	Greenhouse	Other	Unclassified	10	42,551,160	16
Union	Heat Recovery	Heat Exchanger - Clean	Unclassified	7	19,966,568	32
Union	Building	New Construction	Unclassified	3	8,525,620	50
Enbridge	Space Heating	5 Year Industrial	Unclassified	1	3,769,170	76
Union	HVAC	Destratification	Unclassified	23	2,689,905	86
Enbridge	Heating	Kitchen Ventilation	Unclassified	1	2,320,620	90
Union	Greenhouse	Multiple Measures	Unclassified	1	1,056,006	108
Union	Other	Other	Unclassified	1	875,060	112
Union	Controls	Other	Unclassified	1	416,540	129
Enbridge	Water Heating	10 Year Space	Unclassified	1	377,460	131
Enbridge	Cooking	10 Year Industrial	Unclassified	1	350,400	132
Union	Controls	Sensors	Unclassified	1	268,160	135
Union	HVAC	Setbacks	Unclassified	1	239,115	137
Enbridge	Water Heating	High Extraction Washer	Unclassified	4	200,360	140
Union	HVAC	HVAC Improvement	Unclassified	1	144,700	141
Enbridge	Water Heating	10 Year Water	Unclassified	1	51,830	145
Enbridge	Water Heating	Pool Heating	Unclassified	1	46,635	147

Greenhouse – Other, and Heat Exchanger Cleaning were the most significant unclassified measures during 2016. The other measures do not contribute significantly to the custom savings for either Union or Enbridge. In fact, the total contribution to savings for unclassified measures was 2.8% for the 2016 program year.

Based on the results of Table 6, Michaels Energy does not suggest including the unclassified measures in our review. Greenhouse – Other is likely combinations of several different measures. Many greenhouse measures are covered under other measure classifications already described. Heat Exchanger – Cleaning also does not contribute enough to the lifetime savings as a whole to warrant further investigation. Should these measures become more popular in the future, additional research could be undertaken at that time.

Measures Selected for Review

Based on Michaels' analysis of the program data and current referenced resources, Michaels Energy plans to conduct further research on the following 20 measures.

- All other industrial equipment
- Boiler - Industrial Process
- Boiler - Space heating
- Outside Pipe Insulation
- Boiler - Domestic Hot Water
- Boiler Controls
- Energy Curtains
- Heat Recovery
- Exhaust Fan Controls
- Heat Reflector Panels
- Economizers - Conventional and condensing
- Steam Trap
- Infiltration Controls - Dock Seals, Air Doors

- IR Poly
- VFD retrofit on MUA
- Heat Exchanger
- Building Automation System
- Ovens & Thermal Oxidizers
- Reverse Osmosis (RO) Water Conditioner
- Building Envelope

One measure, boiler combustion tune-ups was initially scored high enough to be selected in the top 20 measures. However, feedback from Enbridge indicated that they have not offered this measure for several years. Union also had no participation for combustion tune-ups in 2016. Therefore, boiler combustion tune-ups was not selected for further review.

The measures selected for review represent a significant portion of the savings from 2016. The 20 measures selected represent 85% of Union's 2016 custom program savings, and 96% of Enbridge's 2016 custom program savings.

A full scoring summary for all of the measures in the measure life tables can be found in Appendix A.

Appendix A – Full Scoring Matrix

Measure	Sector	Measure Life	Frequency	Cummulative Savings	Source Age	Source Basis	Utility Differences	Total Points
All other industrial equipment	Industrial	20	13	38	10	20	0	81
Boiler - Industrial Process	Industrial	20	12	36	2	15	10	75
Boiler - Space heating	Commercial	20	20	34	2	5	10	71
Outside Pipe Insulation	Industrial	20	16	40	4	5	0	65
Boiler - Domestic Hot Water	Commercial	20	17	30	2	5	10	64
Boiler Controls	All	20	19	26	2	5	10	62
Energy Curtains	Greenhouse	10	10	32	3	15	0	60
Heat Recovery	Commercial	15	8	22	3	15	10	58
Exhaust Fan Controls	Commercial	15	1	28	4	15	0	48
Heat Reflector Panels	All	20	14	1	10	20	0	45
Economizers - Conventional and condensing	All	20	7	18	4	15	0	44
Steam Trap	Industrial	20	15	14	2	1	10	42
Boiler Combustion Tune-Up	All	1	0	0	10	20	10	40
Infiltration Controls - Dock Seals, Air Doors	Industrial	20	18	4	2	15	0	39
IR Poly	Greenhouse	5	5	12	2	15	0	34
VFD retrofit on MUA	Commercial	15	3	1	10	20	0	34
Heat Exchanger	Commercial	20	1	16	2	15	0	34
Building Automation System	All	20	2	24	2	5	0	33
Ovens & Thermal Oxidizers	Commercial	15	1	1	10	20	0	32
Reverse Osmosis (RO) Water Conditioner	Industrial	20	1	1	10	20	0	32
Building Envelope	All	25	1	1	10	20	0	32
Recommissioning, Retro-Commissioning	All	10	1	10	5	15	0	31
Boiler Air Makeup (line)	Industrial	20	0	0	10	20	0	30
Boiler - Oxy-Fuel	Industrial	20	0	0	10	20	0	30
Boiler - Low Nox	Industrial	20	0	0	10	20	0	30
Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	All	20	6	6	3	15	0	30
Electric Loop Controllers	Commercial	20	0	0	10	20	0	30
PLCs	Industrial	20	0	0	10	20	0	30
Flame Supervision	Industrial	20	0	0	10	20	0	30
Ion Exchange Water Conditioner	Industrial	20	0	0	10	20	0	30
Windows	All	6	0	0	10	20	0	30
Furnaces	All	20	1	20	4	5	0	30
Combustion Tune-up	All	1	0	0	4	15	10	29
Roof/Ceiling insulation	Commercial	14	9	2	2	15	0	28
Make-Up Air	Commercial	15	4	8	5	5	0	22
Grain Dryer	Commercial	20	1	1	4	15	0	21
Building Optimization Program/RunSmart - Behavioral Savings Project	Commercial	5	0	0	5	15	0	20
Dessicant Cooling	Commercial	15	0	0	4	15	0	19
Turndown controls on Modulating Boiler	Commercial	10	0	0	4	15	0	19
Cooling Tower for HVAC	Commercial	15	0	0	2	15	0	17
Infrared Heaters	Commercial	18	0	0	2	15	0	17
Tank Exterior Insulation	All	20	1	1	4	5	0	11
Air Sealing	All	20	0	0	4	5	0	9
Steam Piping Leaks	Industrial	20	0	0	4	5	0	9
Steam Valve	Industrial	20	0	0	4	5	0	9

Appendix B – Measure Mapping

Utility	Equipment Type	Technology	Measure Classification	Count	Lifetime Savings
Enbridge	BAS	BAS	Building Automation System	1	7,431,645
Union	Building	New Construction	Unclassified	3	8,525,620
Union	Building	Exhaust Fan Controls	Exhaust Fan Controls	1	4,530,660
Union	Building	Boiler - Space heating	Boiler - Space heating	1	384,100
Enbridge	Building Envelope	Roof Insulation	Roof/Ceiling insulation	14	5,993,800
Union	Controls	BAS	Building Automation System	5	65,184,400
Union	Controls	Linkageless	Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	12	12,847,240
Union	Controls	Burner	Boiler Controls	2	3,290,580
Union	Controls	Recommissioning, Retro-Commissioning	Recommissioning, Retro-Commissioning	1	2,441,000
Union	Controls	Boiler - linkageless	Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	1	2,437,860
Union	Controls	Boiler Controls	Boiler Controls	1	1,704,280
Union	Controls	VFD on MUA	VFD retrofit on MUA	1	572,210
Union	Controls	PLC	PLC	1	527,955
Union	Controls	Other	Unclassified	1	416,540
Union	Controls	Sensors	Unclassified	1	268,160
Enbridge	Cooking	10 Year Industrial	Unclassified	1	350,400
Union	Furnace	Furnace	Furnaces	9	75,237,657
Union	Furnace	Oven	Ovens & Thermal Oxidizers	4	20,958,580
Union	Furnace	Other	Furnaces	2	17,236,932
Union	Furnace	HE Grain Dryer	Grain Dryer	9	3,268,400
Union	Furnace	Burner	Furnaces	1	622,412
Enbridge	Generic	Furnace	Furnaces	1	658,530
Enbridge	Generic	Combustion Control	Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	1	93,480
Union	Greenhouse	Energy Curtain	Energy Curtains	35	137,881,567
Union	Greenhouse	Triple IR Poly Roof	IR Poly	21	54,939,836
Union	Greenhouse	Other	Unclassified	10	42,551,160
Union	Greenhouse	Hot Water Storage	Heat Recovery	9	27,460,173
Union	Greenhouse	Control System	Building Automation System	12	26,049,628
Union	Greenhouse	Pipe	Outside Pipe Insulation	4	25,628,900
Union	Greenhouse	Condensing Economizer	Economizers - Conventional and condensing	12	23,124,393
Union	Greenhouse	Boiler	Boiler - Space heating	14	22,537,234
Union	Greenhouse	Linkageless	Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	10	16,720,919
Union	Greenhouse	Building Automation System	Building Automation System	3	11,901,220
Union	Greenhouse	Boiler - Space heating	Boiler - Space heating	1	4,421,260
Union	Greenhouse	Economizer	Economizers - Conventional and condensing	1	4,421,260
Union	Greenhouse	Multiple Measures	Unclassified	1	1,056,006
Union	Greenhouse	Side Walls	IR Poly	2	698,365
Union	Greenhouse	Infiltration Controls - Dock Seals, Air Doors	Infiltration Controls - Dock Seals, Air Doors	1	35,720
Union	Heat Recovery	Heat Exchanger - Industrial	Heat Exchanger	10	43,252,480
Union	Heat Recovery	Condensate Return	Heat Recovery	6	30,382,210
Union	Heat Recovery	Heat Exchanger - Clean	Unclassified	7	19,966,568
Union	Heat Recovery	Other	Heat Recovery	3	13,702,300
Union	Heat Recovery	Compressor Air Recovery	Heat Recovery	12	13,020,420
Union	Heat Recovery	Economizer	Economizers - Conventional and condensing	2	10,972,580
Union	Heat Recovery	Hot Water Storage	Heat Recovery	1	6,356,920
Union	Heat Recovery	Condensing Economizer	Economizers - Conventional and condensing	1	5,820,460
Union	Heat Recovery	Glycol System	Heat Recovery	1	4,801,820
Union	Heat Recovery	Heat Recovery	Heat Recovery	3	2,151,975
Union	Heat Recovery	Preheating	Heat Recovery	1	2,069,160
Union	Heat Recovery	Pool	Heat Recovery	1	1,909,420
Union	Heat Recovery	Heat Transfer Improvement	Heat Exchanger	3	1,525,712
Union	Heat Recovery	Blowdown Recovery	Heat Recovery	1	909,060
Union	Heat Recovery	Recuperator	Heat Recovery	1	777,100
Union	Heat Recovery	Boiler	Heat Recovery	1	454,900
Enbridge	Heating	Boiler - Hydronic High Efficiency - Replacement	Boiler - Space heating	84	117,202,525
Enbridge	Heating	Pipe Insulation	Outside Pipe Insulation	39	20,907,200
Enbridge	Heating	VFD	VFD retrofit on MUA	23	20,711,100
Enbridge	Heating	Humidification	Boiler Controls	1	18,804,795
Enbridge	Heating	Reflective Panel	Heat Reflector Panels	59	13,413,720
Enbridge	Heating	DCV 15 yr	Boiler Controls	8	11,376,765
Enbridge	Heating	Building Envelope	Building Envelope	9	8,370,025
Enbridge	Heating	Dock Seals	Infiltration Controls - Dock Seals, Air Doors	38	8,247,330
Enbridge	Heating	Destratification	Prescriptive	33	6,900,960
Enbridge	Heating	Boiler - Hydronic Condensing - Advancement	Boiler - Space heating	21	5,563,844
Enbridge	Heating	Boiler - Hydronic High Efficiency - Advancement	Boiler - Space heating	10	5,110,258
Enbridge	Heating	Air Curtain	Infiltration Controls - Dock Seals, Air Doors	9	4,357,710
Enbridge	Heating	Envelope Infiltration	Infiltration Controls - Dock Seals, Air Doors	17	3,643,680
Enbridge	Heating	Steam Pipe Insulation	Outside Pipe Insulation	3	2,728,000
Enbridge	Heating	Kitchen Ventilation	Unclassified	1	2,320,620
Enbridge	Heating	Roof Top Unit	Boiler Controls	3	1,725,510
Enbridge	Heating	Steam Boiler Blowdown	Heat Recovery	1	1,716,660
Enbridge	Heating	DCV 10 yr	Prescriptive	3	1,326,610
Enbridge	Heating	High Speed Door	Infiltration Controls - Dock Seals, Air Doors	5	1,281,570
Enbridge	Heating	Thermostat - Programmable	Prescriptive	10	1,190,325
Enbridge	Heating	Boiler - Steam - Replacement	Boiler - Space heating	1	723,700
Enbridge	Heating	Linkageless Control	Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	2	527,655
Enbridge	Heating	Burner	Boiler - Space heating	1	500,892

Utility	Equipment Type	Technology	Measure Classification	Count	Lifetime Savings
Union	HVAC	Exhausts	Exhaust Fan Controls	2	87,458,020
Union	HVAC	Recommissioning, Retro-Commissioning	Recommissioning, Retro-Commissioning	1	42,614,540
Union	HVAC	MUA	Make-Up Air	11	23,651,725
Union	HVAC	Exhaust Fan Controls	Exhaust Fan Controls	4	20,105,820
Union	HVAC	Heat Exchanger - Industrial	Heat Exchanger	1	18,614,920
Union	HVAC	Fume Hoods	Exhaust Fan Controls	2	6,804,305
Union	HVAC	Boiler - Space heating	Boiler - Space heating	1	3,982,810
Union	HVAC	ERV/HRV	Heat Recovery	1	3,868,160
Union	HVAC	Make-Up Air	Make-Up Air	2	3,769,968
Union	HVAC	BAS	Building Automation System	1	3,605,900
Union	HVAC	Destratification	Unclassified	23	2,689,905
Union	HVAC	Furnace	Furnaces	1	647,610
Union	HVAC	Exhaust Cascading	Exhaust Fan Controls	1	256,800
Union	HVAC	Setbacks	Unclassified	1	239,115
Union	HVAC	HVAC Improvement	Unclassified	1	144,700
Union	Infiltration	Dock Doors Seals	Infiltration Controls - Dock Seals, Air Doors	27	7,474,704
Union	Infiltration	Automatic Doors	Infiltration Controls - Dock Seals, Air Doors	14	5,331,520
Union	Infiltration	Air Curtain	Infiltration Controls - Dock Seals, Air Doors	1	1,062,080
Union	Infiltration	Roof	Building Envelope	1	108,140
Union	Infiltration	Wall	Building Envelope	1	49,420
Union	Insulation	Pipe	Outside Pipe Insulation	53	496,854,225
Union	Insulation	Roof	Roof/Ceiling insulation	29	20,079,180
Union	Insulation	Tank	Tank Exterior Insulation	8	13,475,840
Union	Insulation	Outside Pipe Insulation	Outside Pipe Insulation	2	5,412,880
Union	Insulation	tank exterior insulation	Tank Exterior Insulation	3	1,437,670
Union	Insulation	Refractory	Outside Pipe Insulation	1	1,224,645
Union	Insulation	Wall	Building Envelope	5	1,212,480
Union	Insulation	Fittings & Valves	Outside Pipe Insulation	1	236,120
Union	Insulation	Door	Building Envelope	1	18,460
Union	Other	Recommissioning, Retro-Commissioning	Recommissioning, Retro-Commissioning	2	3,623,680
Union	Other	Ovens & TO	Ovens & Thermal Oxidizers	2	2,513,880
Union	Other	Fire Supression	Fire Supression	2	1,704,540
Union	Other	Other	Unclassified	1	875,060
Enbridge	Process	Direct Contact Water Heater - Replacement	Boiler - Domestic Hot Water	1	2,883,325
Enbridge	Process Heating	Roof	All other industrial equipment	9	1,861,200
Union	Process Improvement	Other	All other industrial equipment	32	397,252,894
Union	Process Improvement	Line Speed Improvements	All other industrial equipment	4	16,159,160
Union	Process Improvement	Increased Yields	All other industrial equipment	3	15,711,820
Union	Process Improvement	Furnace Load Scheduling	All other industrial equipment	1	14,557,920
Union	Process Improvement	Idle Mode Minimization	All other industrial equipment	1	3,011,220
Union	Process Improvement	Integration	All other industrial equipment	1	2,156,600
Union	Process Improvement	Parasitic Load Reduction	All other industrial equipment	4	910,325
Union	Process Improvement	Dryer	Ovens & Thermal Oxidizers	1	793,480
Union	Process Improvement	Furnace	All other industrial equipment	1	289,080
Enbridge	Space Heating	Condensing Boiler	Boiler - Space heating	29	5,911,250
Enbridge	Space Heating	5 Year Industrial	Unclassified	1	3,769,170
Enbridge	Space Heating	High Efficiency Boiler	Boiler - Space heating	3	729,950
Enbridge	Space Heating	Air Doors	Infiltration Controls - Dock Seals, Air Doors	1	294,885
Union	Steam and Hot Water	Boiler	Boiler - Domestic Hot Water	20	55,029,572
Union	Steam and Hot Water	Other	Boiler - Industrial Process	7	24,699,909
Union	Steam and Hot Water	DHW Upgrade	Boiler - Domestic Hot Water	5	23,350,520
Union	Steam and Hot Water	Traps	Steam Trap	3	14,116,415
Union	Steam and Hot Water	all other industrial	All other industrial equipment	2	4,854,520
Union	Steam and Hot Water	Furnace	Furnaces	1	3,265,851
Union	Steam and Hot Water	Reverse Osmosis	Reverse Osmosis (RO) Water Conditioner	1	494,460
Union	Steam and Hot Water	Economizer	Economizers - Conventional and condensing	1	216,040
Union	Steam and Hot Water	Direct Contact Water Heater	Boiler - Domestic Hot Water	1	118,020
Enbridge	Steam Generation	Greenhouse Double Poly	IR Poly	1	477,995
Enbridge	Steam Generation	Insulation	Boiler - Industrial Process	1	38,535
Enbridge	Ventilation	Steam Trap	Steam Trap	58	46,504,092
Enbridge	Ventilation	Heat Recovery/Economizer	Economizers - Conventional and condensing	23	25,909,980
Enbridge	Ventilation	Air Handling Unit	Boiler Controls	8	4,918,455
Enbridge	Ventilation	Steam Linkageless Control	Boiler - Linkage-Less Controls, Modulating Motors, Mod Motors	2	1,004,865
Enbridge	Ventilation	Boiler - Hydronic High Efficiency	Boiler - Space heating	1	649,650
Enbridge	Water Heating	Industrial Equipment	Boiler - Industrial Process	45	290,622,620
Enbridge	Water Heating	Controls	Boiler Controls	131	72,979,665
Enbridge	Water Heating	Boiler - Hydronic Condensing - Replacement	Boiler - Domestic Hot Water	76	66,508,650
Enbridge	Water Heating	Greenhouse Curtains	Energy Curtains	10	10,400,900
Enbridge	Water Heating	Make Up Air Unit	Make-Up Air	11	7,054,755
Enbridge	Water Heating	10 Year Space	Unclassified	1	377,460
Enbridge	Water Heating	High Extraction Washer	Unclassified	4	200,360
Enbridge	Water Heating	10 Year Water	Unclassified	1	51,830
Enbridge	Water Heating	Pool Heating	Unclassified	1	46,635
Enbridge	Water Heating	Tank Insulation	Tank Exterior Insulation	1	15,285

Appendix B | Measure Level Research

Measure	Findings	Source
All other Industrial Equipment	Enbridge: 20 years for Industrial & Industrial Process Equipment	-
	Union: 20 years	
	Maine C&I: 15 years for new construction, 13 years for retrofit	1
	New Jersey: 10 years for custom industrial process measures, 18 years for custom non-process industrial measures	-
Boiler – Industrial Process	Enbridge: 20 years for industrial process boilers	-
	Union: 20 years for boilers greater than 2500 MBHp	38
	Arkansas: 20 years for all boilers	2
	DEER: 20 years	-
Boiler – Space Heating	Enbridge: 25 years	3
	Union: 20 years	44
	Arkansas: 20 years	2
	California: 20 years	2
	Connecticut: 15 years for condensing boilers, 20 years for non-condensing boilers	-
	Illinois: 20 years	4
	Indiana: 20 years, based on modeling and Ohio PUC Case No. 08-0833-GA-UNC	
	Maine Res: 20 years, citing	5
	Maine C&I: Varies from 24-35 years	6
	Massachusetts: 20 years – see noted source, EUL value adjusted for early replacement and replace on failure based on Cadmus' 2012 Net-to-Gross, Market Effects, and Equipment Replacement Timing report	7
	Mid-Atlantic: 20 years	8
	Minnesota: 20 years	2
	New Jersey: 20 years for small commercial and residential, 25 years for all others	-
	New Mexico: 25 years	9
	New York: 24 years for water tube hot water, 30 years for water tube steam, 25 years for fire tube hot water and fire tube steam, 35 years for hot water cast iron, 20 years for steam cast iron	10
	Rhode Island: 25 years	11

Measure	Findings	Source
	Vermont: 25 years	-
	Wisconsin: 20 years	-
	DEER: 20 years	-
Outside Pipe Insulation	Enbridge: 20 years, citing 2011 ASHRAE Handbook	3
	Illinois: 15 years, citing GDS Associates 2007 Measure Life Report	5
	Massachusetts: 15 years	11
	Minnesota: 13 years for residential HW pipe insulation in unconditioned spaces	2
	New York: 11 years for residential hot water with gas heating	12
	Rhode Island: 15 years	13
	Wisconsin: 10 years	14
Boiler – Domestic Hot Water	Enbridge: 25 years	3
	Union: 20 years	44
	Maine Res: 20 years for all boilers	5
	Massachusetts: 20 years	11
	Rhode Island: 15 years for indirect water heaters using a boiler	11
Boiler Controls	Enbridge: 15 years	-
	Union: 20 years	44
	Arkansas: 20 years for cutout & reset controls, citing	15
	Illinois: 20 years for space heating boiler lockout & reset controls, 16 years for linkageless controls, and 18 years for oxygen trim controls	16, 17
	Indiana: 10 years for oxygen trim controls for space heating boilers	-
	Maine C&I: 20 years for lockout & reset controls and 21 years for modulating controls, and 15 years for oxygen trim controls	18, 19
	Massachusetts: 15 years for lockout & reset controls	11
	Mid-Atlantic: 15 years for residential boiler reset controls	20
	Minnesota: 5 years for adding lockout, reset, or oxygen trim controls to an existing boiler, 15 years for fully modulating burners	21, 22
	New Jersey: 7 years for adding reset controls to a residential heating boiler	-
	New York: 15 years for boiler reset controls	-
	Rhode Island: 15 years for reset controls	23
	Vermont: 15 years for reset controls in multifamily housing units	-
	Wisconsin: 5 years for reset controls	24
	CALMAC: 15 years	12

Measure	Findings	Source
Energy Curtains	Union: 10 years	45
	Connecticut: 15 years for air curtains	-
	Illinois: 15 years for industrial air curtains	25
Heat Recovery	Union: 15 years for Commercial, 20 years for Industrial	45
	Connecticut: 15 years for domestic hot water heat recovery, 14 years for HVAC plate/heat pump and rotary type HVAC heat recovery systems, heat recovery from refrigeration systems has EUL of 10 years for retrofit and 13 years for lost opportunity (no source specified for lost opportunity EUL)	12
	Minnesota: 20 years for residential drainpipe heat exchanger	26
	New Jersey: 24 years for commercial heat exchangers, 20 years for industrial heat exchangers	-
	Vermont: 10 years for dairy farm milk cooling system heat recovery, 25 years for drain water heat recovery	-
	Wisconsin: 15 years for refrigeration heat recovery in dairy applications	-
	DEER: 10 years for heat recovery from a central refrigeration system, 14 years for heat recovery from a compressed air system	-
Exhaust Fan Controls	Union: 15 years for Kitchen DCV	28
	Arkansas: 15 years for Kitchen DCV	28
	California: 15 years for kitchen exhaust hood DCV	30
	Connecticut: 10 years for process equipment interlock for exhaust fans with machine operations	5
	Delaware: 15 years for HVAC VFD applications, including exhaust fans	31
	Illinois: 15 years for kitchen DCV	32
	Maine C&I: 13 years for HVAC VFDs, including exhaust fans	1, 5
	Massachusetts: 15 years for retrofit HVAC VFDs, including exhaust fans, 13 years for lost opportunity (no source for lost opportunity EUL)	1
	Minnesota: 15 years for kitchen DCV, 15 years for parking garage exhaust fan CO control	33, 34
	Rhode Island: 15 years for HVAC VSDs, including exhaust fans	1
	Wisconsin: 5 years for parking garage ventilation controls	-
Heat Reflector Panels	Enbridge: 25 years for residential, 15 years for commercial/industrial	35
	Union: 15 years	-

Measure	Findings	Source
Economizers: Conventional and Condensing	Connecticut: 7 years for retrofit HVAC air or water-side economizer, 10 years for lost opportunity, 10 years for dual-enthalpy economizer controls	5
	Union: 20 years	45
	Delaware: 10 years for dual-enthalpy economizers	8
	Illinois: 5 years for HVAC economizer repair or optimization, 15 years for refrigeration economizer, 15 years for boiler stack economizer	28, 36, 8
	Indiana: 10 years for dual-enthalpy HVAC economizer	2
	Maine C&I: 20 years for boiler stack economizer	11
	Massachusetts: 10 years for dual-enthalpy HVAC economizer lost opportunity applications, 7 years for retrofit applications	1, 5
	Mid-Atlantic: 10 years for dual-enthalpy HVAC economizer for commercial facilities	8
	Minnesota: 10 years for C&I unitary equipment economizers	5
	New York: 10 years for dual-enthalpy economizers for C&I facilities	12
	Rhode Island: 10 years for dual-enthalpy economizers for C&I facilities	1
	Vermont: 14 years for dual-enthalpy economizers, 15 years for refrigeration economizers	-
	Wisconsin: 10 years for adding economizing to an existing RTU	2
	DEER: 15 years for water-side economizer	-
Steam Traps	Union: 7 years	45
	Enbridge: 6 years	38
	Arkansas: 5 years	15
	California: 6 years	29
	Illinois: 6 years	37
	Massachusetts: 6 years for process steam traps	5
	Minnesota: 6 years	2
	New York: 6 years	28
	Rhode Island: 6 years	38
	Wisconsin: 6 years	-
	DEER: 6 years	
Infiltration Controls – Dock Seals, Air Doors	Union: 15 years	28
	Enbridge: 15 years for Air Doors	5
	Minnesota: 10 years for C&I loading dock door and pit seals	-

Measure	Findings	Source
	Wisconsin: 10 years for new or replacement dock door seals or dock pit/ramp external seals	-
IR Poly	Union: 5 years	28
	Enbridge: 5 years for double poly greenhouses	-
	DEER: 5 years for IR film for greenhouses	-
VFD Retrofit on MUA	Union: 10 years	-
	Ontario: 20 years	40
	California: 15 years	2
	Connecticut: 15 years	41
	Illinois: 15 years	36
	Indiana: 15 years	2
	Maine C&I: 13 years	1, 5
	Massachusetts: 15 years for lost opportunity, 13 years for retrofit	1
	Mid-Atlantic: 15 years	31
	Minnesota: 15 years	2
	New Mexico: 15 years	36
	New York: 15 years	28
	Rhode Island: 15 years	1
	Texas: 15 years	28
	Vermont: 15 years	-
	Wisconsin: 15 years	8
	DEER: 15 years	-
Heat Exchanger	Ontario: 14 years for ERVs	42
	Union: 14 years for commercial, 20 years for industrial	28
	Connecticut: 14 years for rotary and plate-type heat recovery systems	2
	Illinois: 15 years for ERVs	43
	Minnesota: 15 years	43
	New Jersey: 20 years for industrial heat exchangers	-
	Rhode Island: 20 years	11
	Wisconsin: 15 years for well water/milk heat exchangers	21
	DEER: 14 years for air-to-air heat exchangers	-
	Union Gas: 20 years	44, 45
	Arkansas: 15 years for individual boiler and fan controls	15

Measure	Findings	Source
Building Automation System	Connecticut: 15 years for lost opportunity applications, 10 years for retrofit applications	5
	Illinois: 10 years for building sensors	46
	Indiana: 15 years	-
	Maine C&I: 10 years	47
	Massachusetts: 15 years for lost opportunity applications, 10 years for retrofit applications	1
	New Jersey: 15 years	-
	Rhode Island: 15 years	7, 23
	DEER: 15 years	-
Ovens & Thermal Oxidizers	Union: 20 years	-
	Wisconsin: 15 years for Industrial Ovens	-
Reverse Osmosis (RO) Water Conditioner	Union: 20 years	-
Building Envelope	Ontario: 25 years	-
	Enbridge: 25 years	-
	Union: 20 years for ceiling/roof insulation	28
	Arkansas: 20 years	2
	California: 10 years for reflective window film	2
	Connecticut: 20 years for insulation, 15 years for cool roof, 10 years for window insulation and films, 15 years for new windows	2
	Delaware: 25 years	5
	Illinois: 20 years	2, 5
	Indiana: 15 years	2
	Maine C&I: 25 years	5
	New York: 15 years for cool roof, 10 years for window films, 20 years for window glazing, 30 years for opaque shell insulation	12, 28, 27
	Rhode Island: 25 years	21
	Texas: 15 years for cool roof, 10 years for solar screens, 11 years for residential air infiltration reduction, 25 years for insulation and windows	48, 49
	Vermont: 15 years	-
	Wisconsin: 20 years for air sealing, 25 years for attic or wall insulation, 20 years for attic insulation with air sealing	5

Measure	Findings	Source
	DEER: 20 years for insulation and high-performance windows, 11 years for low-income weatherization, 15 years for cool roof, 10 years for solar screens	-

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Appendix C | Measure Life Data

Measure	Ontario TRM	Enbridge	Union	Arkansas	California	Connecticut	Delaware	Illinois	Indiana	Maine	Maine C/I	Massachuse	Mid-Atlantic	Minnesota	New Jersey	New Mexico	New York	Rhode Island	Texas	Vermont	Wisconsin	CALMAC	Michaels
All other industrial equipment	20	20	20								15				14								20
Boiler - Industrial Process	20	25	20	20																		20	20
Boiler - Space heating	25	25	20	20		15		20	20	20	30	20	20	20	20	25	25	25		25	20	20	25
Outside Pipe Insulation	20	20	20			10		15				15						15			10		14
Boiler - Domestic Hot Water	25	25	20							20		20						15					25
Boiler Controls	15	15	20	20				20	10		20	15		5			15	15		15	5	15	15
Energy Curtains	10	10	10			15		15															10
Heat Recovery - Commercial	14	15	15			14		15						15	24			20		25	15	14	15
Heat Recovery - Industrial	14	15	20			14		15						15	20			20		25	15	14	20
Exhaust Fan Controls	15		15	15	15	10	15	15			13	15		15				15			5		15
Heat Reflector Panels	25	15	15																				15

Measure	Ontario TRM	Enbridge	Union	Arkansas	California	Connecticut	Delaware	Illinois	Indiana	Maine	Maine C/I	Massachuse	Mid-Atlantic	Minnesota	New Jersey	New Mexico	New York	Rhode Island	Texas	Vermont	Wisconsin	CALMAC	Michaels
Economizers - Conventional and condensing			20			10	10	15	10		20	10	10	10			10	10		10	10	15	20
Steam Trap		6	7	5	6			6				6		6			6	6			6	6	6
Infiltration Controls - Dock Seals, Air Doors		15	15											10							10		10, 15
IR Poly		5	5																			5	5
VFD retrofit on MUA	20		10	15	15	15		15	15		13	15	15	15	15	15	15	15	15	15	15	15	15
Heat Exchanger (Plate-Plate or Tube-Tube) - Commercial			14			14												20			15		17
Heat Exchanger (Plate-Plate or Tube-Tube) - Industrial			20			14									20								17
Heat Exchanger (Air-Air) - Commercial	14	14	14			14		15			20			15								14	17
Heat Exchanger (Air-Air) - Industrial	14		20			14		15			20			15	20							14	17
Building Automation System	20		20	15		15			15		10	15			15			15				15	15
Ovens & Thermal Oxidizers	20		20																		15		20

Measure	Ontario TRM	Enbridge	Union	Arkansas	California	Connecticut	Delaware	Illinois	Indiana	Maine	Maine C/I	Massachuse	Mid-Atlantic	Minnesota	New Jersey	New Mexico	New York	Rhode Island	Texas	Vermont	Wisconsin	CALMAC	Michaels
Reverse Osmosis (RO) Water Conditioner	20		20																				20
Building Envelope	25	25	20	20		20	25	20	15		25						25	25		15		20	25