2017-2018 Natural Gas Demand Side Management Custom Savings Verification

CUSTOM SAVINGS VERIFICATION FOR ONTARIO'S NATURAL GAS CUSTOM COMMERCIAL AND INDUSTRIAL DSM PROGRAMS

Ontario Energy Board

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SAFER, SMARTER, GREENER

Table of contents

1 INTRODUCTION

To encourage Enbridge Gas Distribution, Inc. (Enbridge) and Union Gas Limited (Union) to implement public benefits programs designed to reduce overall energy use, called conservation demand-side management (DSM) programs, the Ontario Energy Board (OEB) reimburses them for the cost of program implementation and provides an incentive, called the shareholder incentive, that reflects the utilities' performance against pre-determined targets. The OEB also compensates the utilities for the revenue lost as a result of the lower natural gas sales.

In the 2017 and 2018 calendar years, programs delivered by Enbridge and Union targeted all natural gas ratepayers, including residential, multifamily, low income, commercial, and industrial customers. This study is part of an overall conservation program cycle as shown in the following figure. This study is part of step 4.

Figure 1-1. Conservation Program Cycle

To verify the impacts of the Enbridge and Union DSM programs, the OEB sponsors studies to verify the energy savings achieved. Specifically, this study verifies the engineering calculations, inputs and assumptions that produce the utilities' claimed gas savings. The results of this study are combined with the results of two other studies[1] to produce verified net cumulative gas savings for the utilities' 2017 and 2018 C&I Custom and Custom Large Volume programs.

1.1 Findings

Key findings from the study include:

- Both utilities generally calculate sound claimed savings estimates, largely using engineering approaches. None of the three program overall realization rates were statistically different from 100%. Much of the variation in gross realization rates is driven by factors that the utilities only partially control, such as changes in operating conditions, changes in operating hours and changes in production levels. In some cases, the utility can control these types of discrepancies, but they can be difficult to anticipate when calculating savings before the project is installed.
- Both utilities could provide better supporting documentation of assumptions and inputs in their savings estimates and each could benefit from investing in a modern program tracking database with document storage capabilities

Additional recommendations are found in section 5.

[1] *2018 Natural Gas Demand Side Management Free Ridership Based Attribution Evaluation.* Prepared for The Ontario Energy Board by DNV GL, August 15, 2017.
CPSV Participant Spillover Results. Prepared for The Ontario Energy Board by DNV GL, May 23, 2018.

2 ENBRIDGE COMMERCIAL AND INDUSTRIAL CUSTOM PROGRAMS

Enbridge's custom DSM programs for commercial and industrial (C&I) customers encourage customers to reduce their natural gas consumption by recommending and incentivizing energy saving projects and actions.

These custom programs differ from the prescriptive programs by providing additional technical support for projects. They also provide financial incentives based on overall natural gas savings realized by the customer rather than a per-unit incentive.[2]

A subset of the projects in this program is part of the multi-residential segment. The custom project savings verification (CPSV) included custom projects from both the Market-Rate Multifamily (MR MF) and the low income multifamily (LI MF) subsets of the multi-residential segment.

All projects implemented as part of these programs and claimed in 2017-2018 are custom projects and are included in the scope of the CPSV study.

2.1 Gross Savings Realization Rate

The gross realization rate (GRR) represents the ratio of the savings verified by the evaluation to the savings claimed (or reported) by the utility, as shown in the following equation. A 90% GRR means the verified gross savings for the project or program were 90% of the claimed savings. Differences between claimed and verified savings for each project can arise for a number of reasons, usually related to differences in forecast assumptions, differences in underlying facts, or differences in calculation approaches or parameters.

$$gross\ realization\ rate = \frac{Evaluation\ verified\ savings}{Utility\ reported\ savings}$$

Table 2-1 shows the cumulative gross savings realization rate by customer segment for the Enbridge C&I Custom program. The table shows the gross realization rate, statistical precision at the 90% confidence interval, the program-claimed population cumulative cubic meters of natural gas (CCM) savings, and percent of program savings for each customer segment. The percent of program savings represents the relative contribution that each customer segment makes to the overall result.

Enbridge's custom program overall achieved a 111% gross realization rate. The customer segment gross realization rates varied from 95% to 121%. The largest segment was Industrial with 46% of the population energy savings. Relative precision for the program overall was 7% at 90% confidence.

[2] Enbridge's 2016 Annual Report provides a more detailed description of the program and can be found here: https://www.oeb.ca/sites/default/files/2016-EGDI-DSM-Annual-Report_20181117.pdf

Table 2-1. Cumulative gross savings realization rate for the Enbridge C&I Custom program

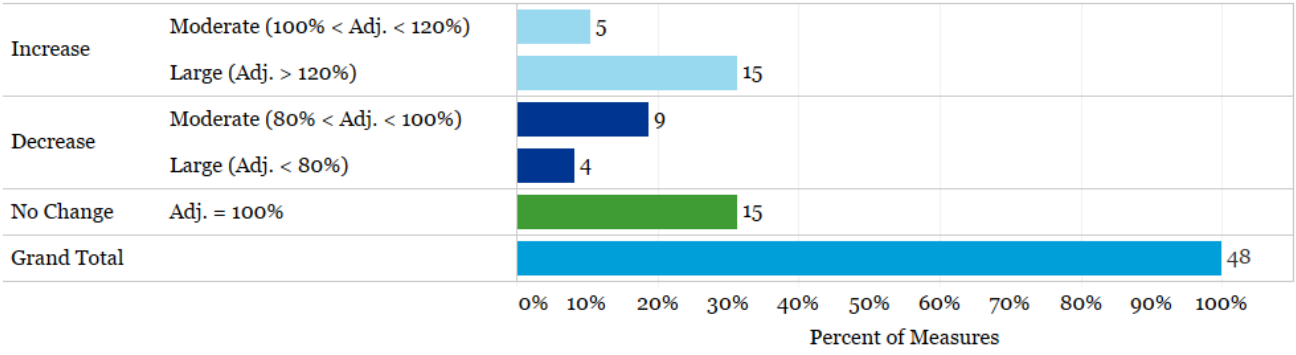
Segment	Gross Realization Rate	+/- at 90% Confidence	Population CCM Savings	Percent Population CCM Savings
Commercial	94.99%	9%	318,342,995	22%
Industrial	110.79%	8%	671,703,718	46%
LI & MR Multi-Residential	121.09%	16%	471,312,210	32%
Enbridge C&I Custom - Overall	110.51%	7%	1,461,358,923	100%

2.2 Discrepancy Summary

This section presents detailed results of the various project-level discrepancies between program claimed and evaluation verified savings. The verification found discrepancies in 69% of the projects reviewed.

Table 2-2 shows that 15 of the 48 measures had no adjustment from program claimed to evaluation verified savings, while 33 measures were adjusted based on verification findings. For custom savings verification, we consider verified savings that differ more than 20% from utility tracking savings to be a "large" discrepancy. Moderate adjustments within 20% of utility tracking savings are expected given the level of uncertainty in forecasting energy savings. Fourteen of the 33 adjusted measures had verified savings within 20% of utility tracked savings. Of the 19 measures with adjustments greater than 20%, 15 had adjustments increasing savings (adjustment greater than 120%) and four (4) had adjustments decreasing savings (adjustment less than 80%).

Table 2-2. Adjustment Summary – Enbridge C&I Custom



Four randomly selected measures with large adjustments are described below. They are included here in order to provide readers with examples of the types of discrepancies that can be identified through the CPSV process. The examples reference the site ID, which is also used in Figure 2-1 in this section and the appendix section 6.6.

- The sampled measure identified as ES159-2 was one of two measures at site ES159. The measure included steam trap jackets on several hundred steam traps. The realization rate for the measure was 76%. The verification *annual* savings are higher than the program savings because the verification site

visit found that the operating hours of the system on which the jackets were installed were greater than the program assumed. However, *cumulative (lifetime)* savings were lower due to an adjustment to the effective useful life (EUL) of the measure from 20 years to 14 years based on the updated measure life guide.

- The sampled measure identified as ET239-1 consisted of the replacement of seven steam traps. The program savings estimate was based on all seven traps being part of a seasonal space heating loop. The realization rate was 146%. The verification received the steam trap survey report and found that four of the seven traps were actually on a year-round steam loop, which increased the operating hours for those traps.
- The sampled measure identified as ET103-1 was Demand-Controlled Ventilation (DCV) controls on a laboratory ventilation system. The realization was 56%. The verification found that, after measure installation, the site had commissioned an airflow study. The study showed a significant reduction in outside airflow. In addition, supporting documentation for the program-assumed annual heating hours and outdoor air temperature could not be confirmed, so the verification re-calculated these inputs.
- The sampled measure identified as ES125-1 was the installation of two new boilers in a multi-residential housing building. The realization rate was 131%. The verification found differences from program claims for both the in situ (pre-existing) boiler system and the efficient system installed. For the in situ system, the differences were in the capacity, supply and return water temperatures, and controls in place. The measure was a replace on burnout, so these updates to the in situ system primarily impacted the estimate of heating load. The verification also found that the efficient system was installed in a lead-lag configuration, which was different from the program assumption.

Figure 2-1 plots the claimed cumulative savings and the realization rate for each measure in the sample. The plot is sorted with the smallest measure on the bottom and largest on the top. The left plot shows the relative size of each measure. The right plot shows the gross realization rate for each measure. In both plots, measures with light blue bars have a realization rate greater than 100% (verified savings greater than utility claimed savings). Measures with dark blue bars represent a gross realization rate less than 100% (verified savings lower than utility claimed savings). Measures with green bars represent a gross realization rate of 100%.

Figure 2-1. Sample Measure Realization Rates sorted by size – Enbridge C&I Custom Program

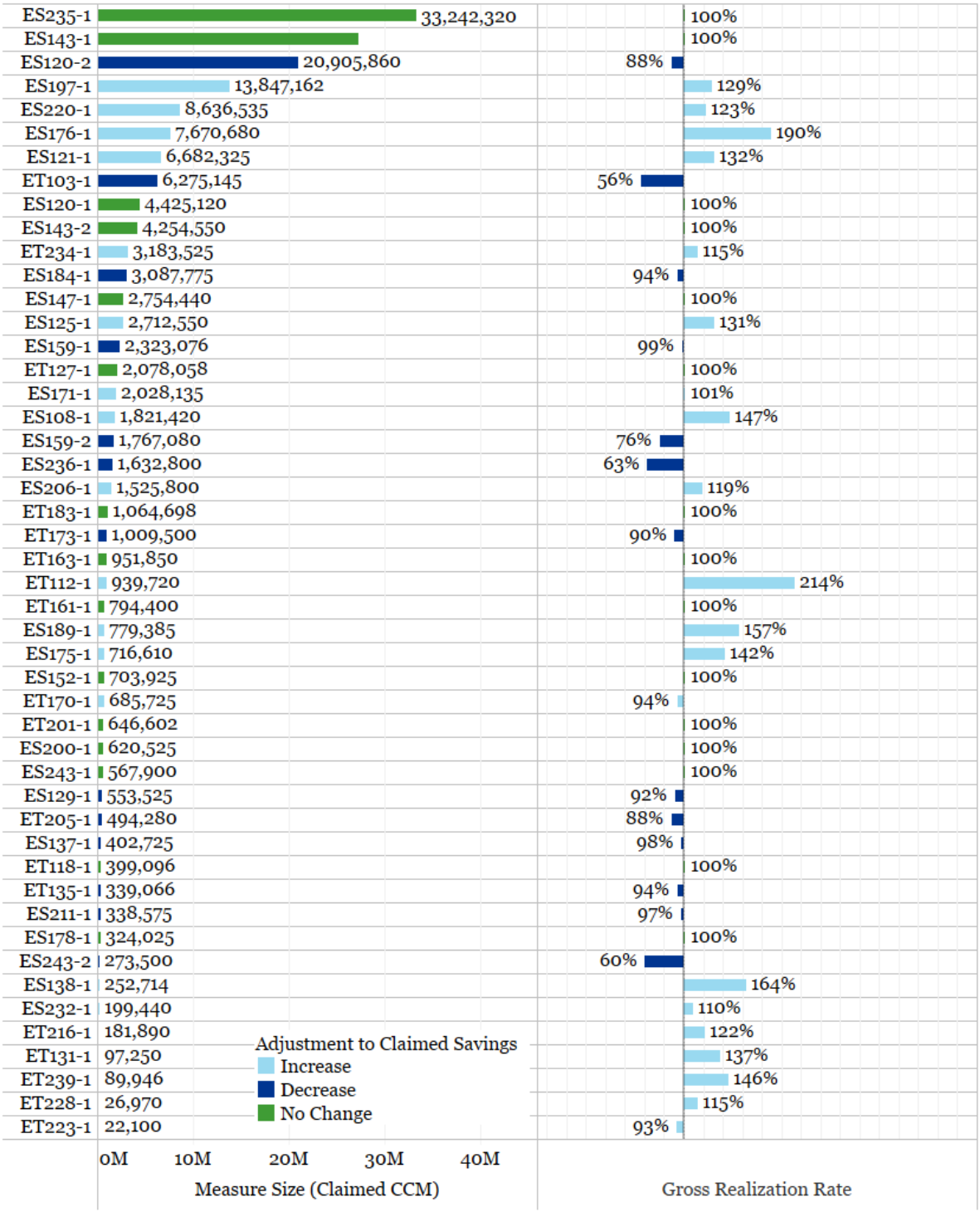
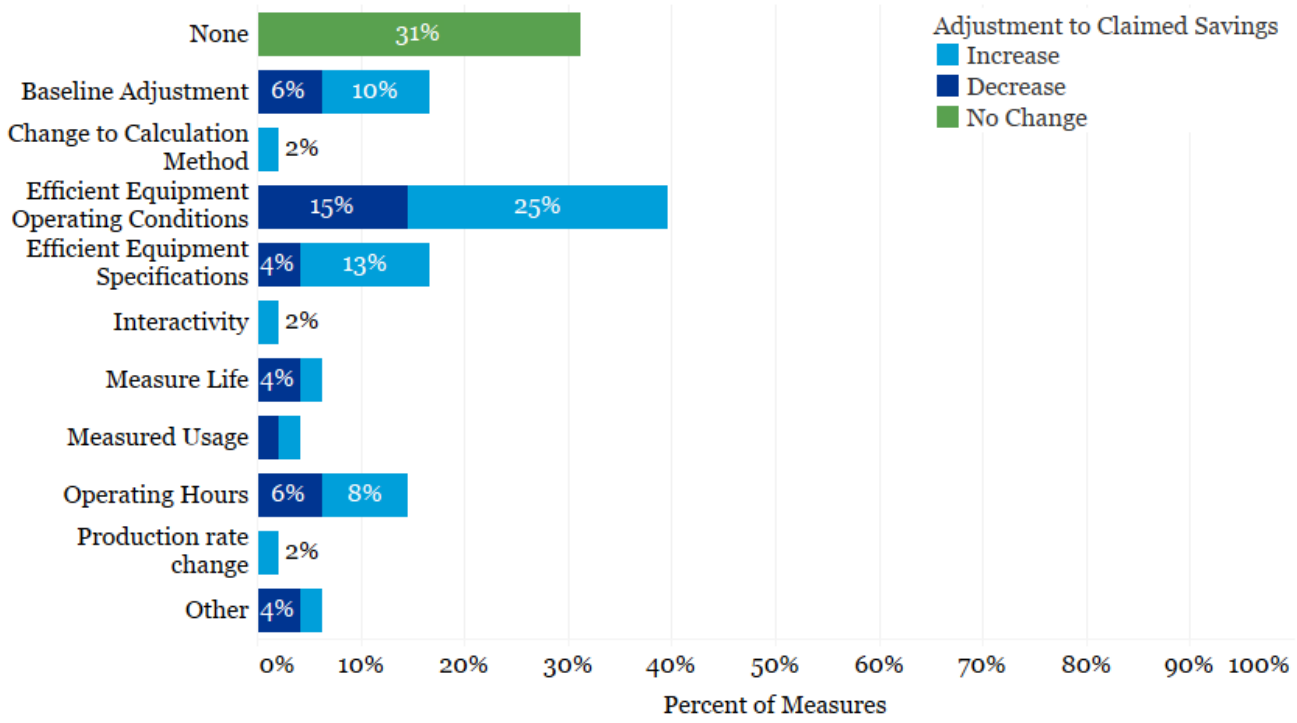


Figure 2-2 shows the types of discrepancies found by the verification. The verification found no discrepancies for 31% of sampled measures. Operating conditions were the only type of discrepancy found for more than 20% of measures. The utility can reduce this type of discrepancy by documenting projects more thoroughly with sources for the assumptions used and more complete descriptions of conditions found at the time of installation (see recommendations in section 5); however, this type of discrepancy is partially outside of utility control.

Figure 2-2. Savings discrepancies – Enbridge C&I Custom Program



3 UNION COMMERCIAL AND INDUSTRIAL CUSTOM PROGRAMS

Union's custom DSM programs for C&I customers encourage customers within this sector to reduce their natural gas consumption by recommending and incentivizing energy saving projects and actions.

These custom programs differ from the prescriptive programs by providing additional technical support for projects. They also provide financial incentives based on overall natural gas savings realized by the customer rather than a per-unit incentive.[3]

A subset of the projects in this program is part of the multifamily segment. The CPSV included custom projects from both the market-rate multifamily (MR MF) and the low income multifamily (LI MF) subsets of the multifamily segment.

All projects implemented as part of this program and claimed in 2017-2018 as custom projects are included in the scope of the CPSV study, including those from MR MF and LIMF segments.

3.1 Gross Savings Realization Rate

The GRR represents the ratio of the savings verified by the evaluation to the savings claimed (or reported) by the utility, as shown in the following equation. A 90% GRR means the verified gross savings for the project or program were 90% of the claimed savings. Differences between claimed and verified savings for each project can arise for a number of reasons, usually related to differences in forecast assumptions, differences in underlying facts, or differences in calculation approaches or parameters.

$$gross\ realization\ rate = \frac{Evaluation\ verified\ savings}{Utility\ reported\ savings}$$

Table 3-1 shows the cumulative gross savings realization rate by customer segment for the Union C&I Custom program. The table shows the gross realization rate, statistical precision at the 90% confidence interval, the program-claimed population CCM savings, and percent of program savings for each customer segment. The percent of program savings represents the relative contribution that each customer segment makes to the overall result.

[3] Union's 2016 Draft Annual Report provides a more detailed description of the program and can be found here: https://www.oeb.ca/sites/default/files/2016-Union-DSM-Annual-Report-20181130.pdf

Union's C&I programs overall achieved a 91% gross realization rate, which was also the value for each customer segment. The Agricultural and Industrial segments were combined into a single domain for reporting and verified savings estimation because the Agricultural segment did not meet the 15% absolute precision threshold (as described in the Scope of Work attached in the appendix section 6.5). Relative precision for the program overall was 11% at 90% confidence.

Table 3-1. Cumulative gross savings realization rate for the Union C&I Custom program

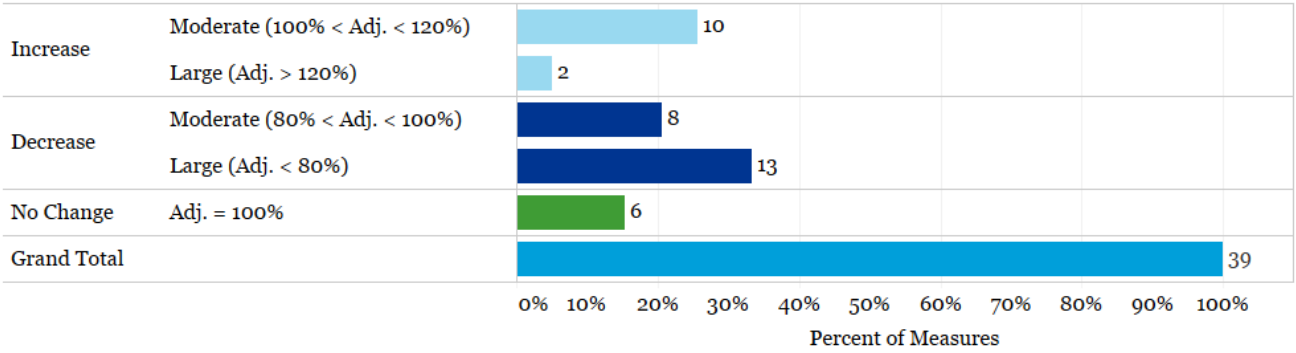
Segment	Gross Realization Rate	+/- at 90% Confidence	Population CCM Savings	Percent Population CCM Savings
Agricultural & Industrial	91.17%	13%	2,911,956,371	92%
Commercial & Multifamily	90.57%	6%	259,606,580	8%
Union C&I Custom - Overall	91.10%	11%	3,171,562,951	100%

3.2 Discrepancy Summary

This section presents detailed results of the various project-level discrepancies between program claimed and evaluation verified savings. The final realization rate for the program was close to 91%, but the verification found discrepancies for 85% of the measures reviewed.

Table 3-2 shows that 6 of the 39 measures had no adjustment from program claimed to evaluation verified savings, while 33 measures were adjusted based on verification findings. For custom savings verification, we consider verified savings that differ more than 20% from utility tracking savings to be a "large" discrepancy. Moderate adjustments within 20% of utility tracking savings are expected given the level of uncertainty in forecasting energy savings. Eighteen of the 33 adjusted measures had verified savings within 20% of utility tracked savings. Of the 15 measures with adjustments greater than 20%, 2 had adjustments increasing savings (adjustment greater than 120%) and 13 had adjustments decreasing savings (adjustment less than 80%).

Table 3-2. Adjustment Summary – Union C&I Custom



Four randomly selected measures with large adjustments are described below. They are included here in order to provide readers with examples of the types of discrepancies that can be identified through the CPSV

process. The examples reference the site ID, which is also used in Figure 2 in this section and the appendix section 6.6.

- The sampled measure at site US146 was a water to water pre-heat and recovery heat exchanger on a pasteurizing system. The realization rate for the measure was 44%. The verification updated key inputs to the savings calculation based on the site contact's reports. The updates included a reduction in annual operating days from the program-assumed 365 to the site contact's reported 267 days. Additional changes that reduced the savings estimate included those to system flow rate and three key operational water temperatures. The verification also increased the EUL for the system from 15 years to 17 years based on the updated custom measure life guide.
- The sampled measure at site US191 consisted of variable frequency drive (VFD) exhaust fans and automated control systems in the welding production area of a manufacturing facility. The realization rate for the measure was 74%. The verification found that the energy management system (EMS) was controlling 22 fans versus the 24 in the program estimate. The verification also made a correction to the calculation methodology used to estimate airflow.
- The sampled measure at site US217 installed an advanced climate control system in a greenhouse. The realization rate for the measure was 317%. The verification used the same calculation approach as the program, with updates to two inputs verified onsite that increased the savings estimate. The most significant change was the observed temperature setpoint which was found to be lower than assumed in the program estimate. An additional small increase in savings resulted from the newly installed controls system which increased the efficiency of the heating system
- The sampled measure at site UT168 added heat recovery to a rooftop heating, ventilation, and air conditioning (HVAC) unit. The measure realization rate was 73%. The program estimate of savings did not separate occupied and unoccupied hours in the bin analysis used to estimate savings. Based on information provided by the site contact, the verification was able to separate the hours. Since heating outside air is a significant portion of the heating load, accounting for lower thermostat settings during unoccupied hours produced a better estimate of savings.

Figure 2 plots the claimed cumulative savings and the realization rate for each measure in the sample. The plot is sorted with the smallest measure on the bottom and largest on the top. The left plot shows the relative size of each measure. The right plot shows the gross realization rate for each measure. In both plots, measures with light blue bars have a realization rate greater than 100% (verified savings greater than utility claimed savings). Measures with dark blue bars represent a gross realization rate less than 100% (verified savings lower than utility claimed savings). Measures with green bars represent a gross realization rate of 100%.

Figure 2. Sample Measure Realization Rates sorted by size – Union C&I Custom program

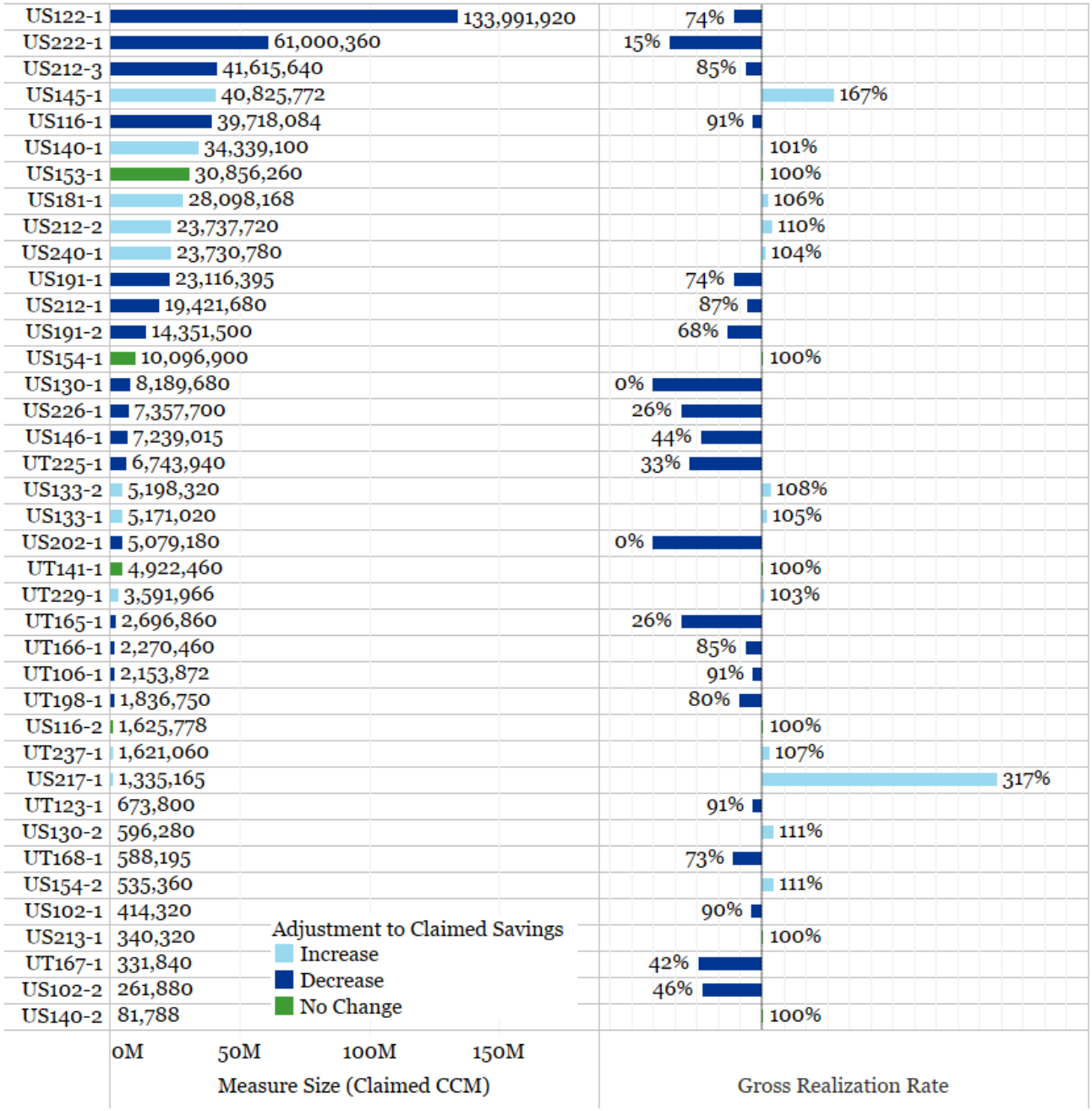


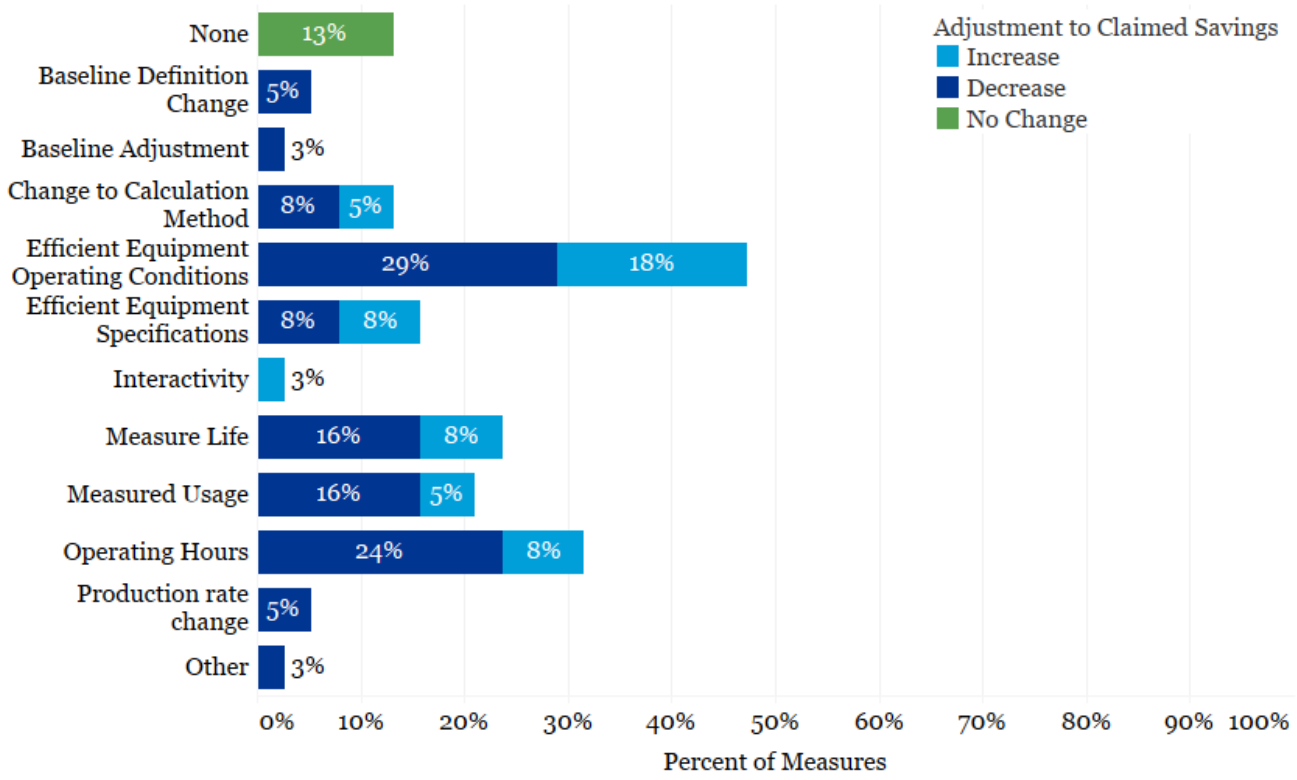
Figure 3-1 shows the types of discrepancies found by the verification. The verification found no discrepancies for 13% of sampled measures. The major categories of discrepancies between claimed savings and verified savings were different assumptions for operating conditions (47% of measures), operating hours (32%), measure life (24%), and differences in measured usage (21%).

The utility could reduce the frequency of operating condition discrepancies by improving its documentation, but changing operating conditions are partially outside the utility's control. The same is true for measured

usage and operating hours. In many cases, improving documentation and using pre-period measurements can mitigate these discrepancies, but there will be sites where operations change in unanticipated ways.

There wasn't a consistent single reason for measure life adjustments in this round of evaluation; however, two were more frequent. In some cases, the program claimed a standard EUL for measures where a site-specific value was more appropriate based on the customer report. In other cases, the measure life was updated to be consistent with the custom measure life guide.

Figure 3-1. Savings discrepancies - Union C&I Custom



4 UNION LARGE VOLUME

Union encourages the adoption of energy efficient equipment, technologies, and actions via its Large Volume program. In 2018, the Large Volume program was applicable to customers in Rate T2/Rate 100.

The program uses a direct access budget mechanism for the customer incentive budget process. This mechanism collects funds from each customer through rates. Customers must use these funds to identify and implement energy efficiency projects, or the funds become available for use by other customers in the same rate class. This "use it or lose it" approach ensures each customer has first access to the amount of incentive budget funded by their rates. The Large Volume program is the only "direct access" program offered in Ontario. [4]

Custom projects implemented as part of this program and claimed in 2017-2018 were included in the CPSV study. There was one (1) prescriptive project in the 2017 and 2018 Large Volume programs that is not included in CPSV.

4.1 Gross Savings Realization Rate

The GRR represents the ratio of the savings verified by the evaluation to the savings claimed (or reported) by the utility, as shown in the following equation. A 90% GRR means the verified gross savings for the project or program were 90% of the claimed savings. Differences between claimed and verified savings for each project can arise for a number of reasons, usually related to differences in forecast assumptions, differences in underlying facts, or differences in calculation approaches or parameters.

$$gross\ realization\ rate = \frac{Evaluation\ verified\ savings}{Utility\ reported\ savings}$$

Table 4-1 shows the cumulative gross savings realization rate for the Union Large Volume program. The table shows the gross realization rate, statistical precision at the 90% confidence interval, the program-claimed population CCM savings, and percent of program savings.

The Union Large Volume program overall had a 90% cumulative gross realization rate. The absolute precision (+/-) for the program was 13% at 90% confidence.

Table 4-1. Cumulative gross savings realization rate for the Union Large Volume program

Segment	Gross Realization Rate	+/- at 90% Confidence	Population CCM Savings	Percent Population CCM Savings
Union - Large Volume	90.46%	13%	1,552,094,997	100%

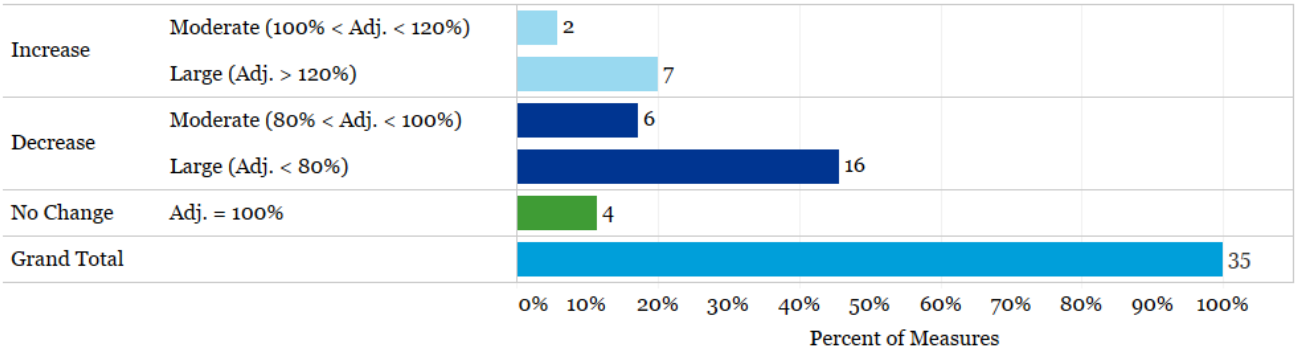
[4] Union's 2017 Draft Annual Report provides a more detailed description of the program and can be found here: https://www.oeb.ca/sites/default/files/UNION-2017-Draft-Annual-Report-20181130.pdf

4.2 Discrepancy Summary

This section presents detailed results of the various project-level discrepancies between program claimed and evaluation verified savings. The final realization rate for the program was 90% and the verification found discrepancies for 89% of the projects reviewed.

Table 4-2 shows that 4 out of 35 measures had no adjustment from program claimed to evaluation verified savings, while 31 measures were adjusted based on verification findings. For custom savings verification, we consider verified savings that differ more than 20% from utility tracking savings to be a "large" discrepancy. Moderate adjustments within 20% of utility tracking savings are expected given the level of uncertainty in forecasting energy savings. Eight of the 31 adjustments had verified savings within 20% of utility tracked savings. Of the 23 measures with adjustments greater than 20%, 7 had adjustments increasing savings (adjustments greater than 120%) and 16 had adjustments decreasing savings (adjustment less than 80%).

Table 4-2. Adjustment Summary – Union Large Volume



Four randomly selected measures with large adjustments are described below. They are included here in order to provide readers with examples of the types of discrepancies that can be identified through the CPSV process. The examples reference the site ID, which is also used in Figure 4-1 in this section and the appendix section 6.6.

- The sampled measure identified as US215-2 consisted of a recuperator replacement. The realization rate for the measure was 254%. The verification treated this measure and a reheat furnace operations optimization measure (US215-1) as one measure and estimated *annual* savings based on facility data in the common post-project period. This resulted in an overall decrease in *annual* savings. *Annual* savings were then allocated to the individual tracked measures based on the proportion of program savings claimed for each measure. For US215-2, *cumulative* savings increased due to a change to measure life consistent with the custom measure life guide for heat recovery.
- The sampled measure identified as US203-1 involved replacement of gas-fired unit heaters with high efficiency units. The realization rate for the measure was 2%. The verification learned that the replaced heaters were at the end of their life (they had been red tagged as no longer safe to operate). This changed the baseline from early replacement (in situ equipment) to replace on burnout (minimum viable replacement). The verification based the efficiency of the minimum viable replacement on ASHRAE 90.1 minimum efficiency for warm-air unit heaters, which was only slightly less efficient than those installed.
- The sampled measure identified as US214-3 replaced leaking valves in a heat recovery system. The realization rate for the measure was 46%. The verification updated the program claimed assumptions for

operating hours based on four years of production data that was fit to a typical meteorological year (TMY) weather pattern and used separate hours for each of the two systems on which the valves were installed. The EUL for the measure was also adjusted from 10 years in the program calculation to 6 years in the verification calculation as the site contact indicated that the facility puts high stress on the valves and they "hope" the valves last 5-7 years.

- The sampled measure identified as US192-3 was one of seven measures completed at this site through the Large Volume program during the evaluation period. The realization rate for the measure was 19%. The measure consisted of disassembly & removal of asphaltene and scale deposits on select heat exchanger surfaces in a preheat heat exchanger train. The verification used more extensive pre- and post-measure data than that used by the program, which reduced annual savings by 10%. The major reduction to cumulative savings resulted from a reduction in EUL from 14 years to 3 years based on the site contact's understanding of how often these heat exchangers undergo similar maintenance.

Figure 4-1 plots the claimed cumulative savings and the realization rate for each measure in the sample. The plot is sorted with the smallest measure on the bottom and largest on the top. The left plot shows the relative size of each measure. The right plot shows the gross realization rate for each measure. In both plots, measures with light blue bars have a realization rate greater than 100% (verified savings greater than utility claimed savings). Measures with dark blue bars represent a gross realization rate less than 100% (verified savings lower than utility claimed savings). Measures with green bars represent a gross realization rate of 100%.

Figure 4-1. Sample Measure Realization Rates sorted by size –Union Large Volume

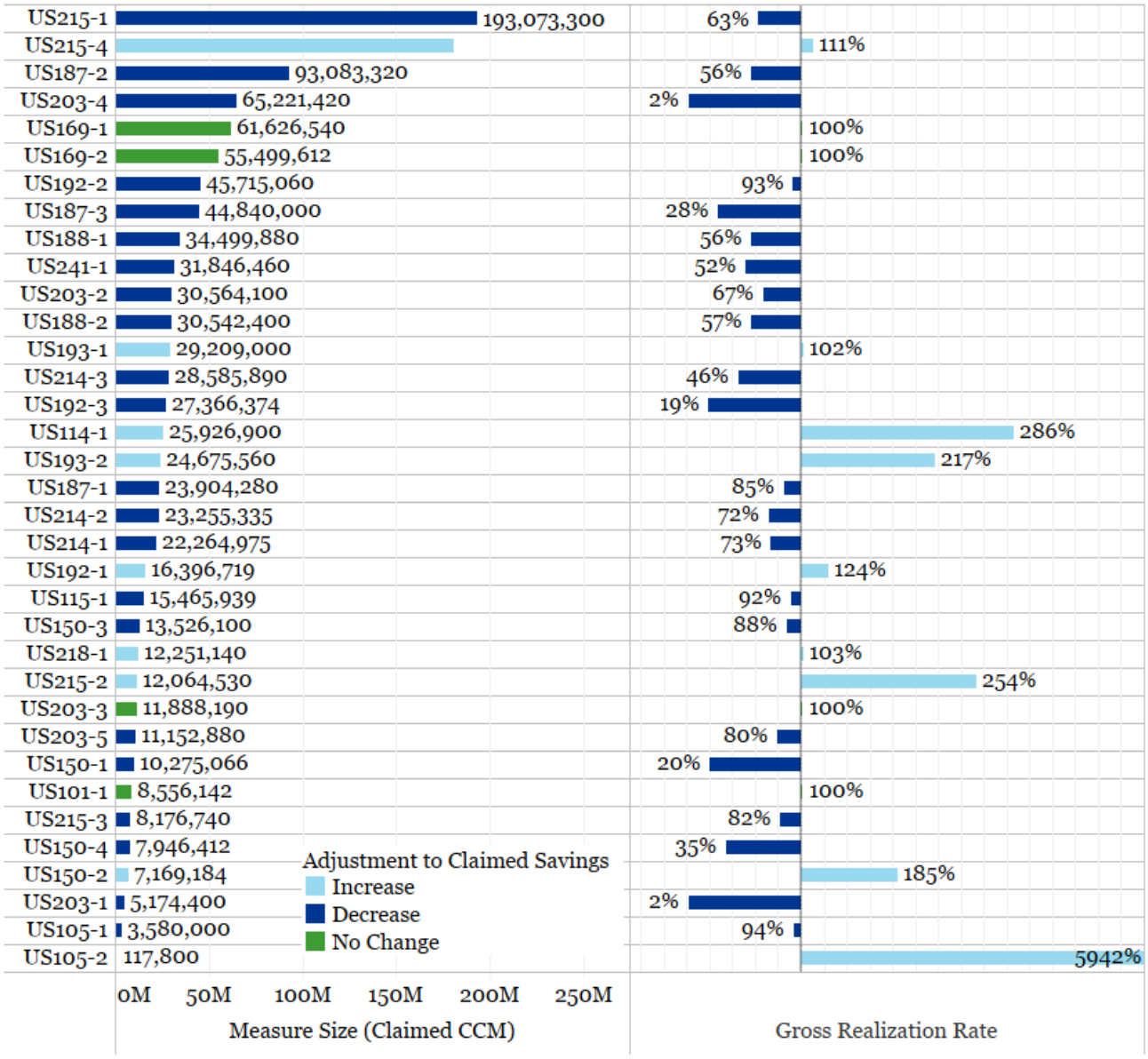
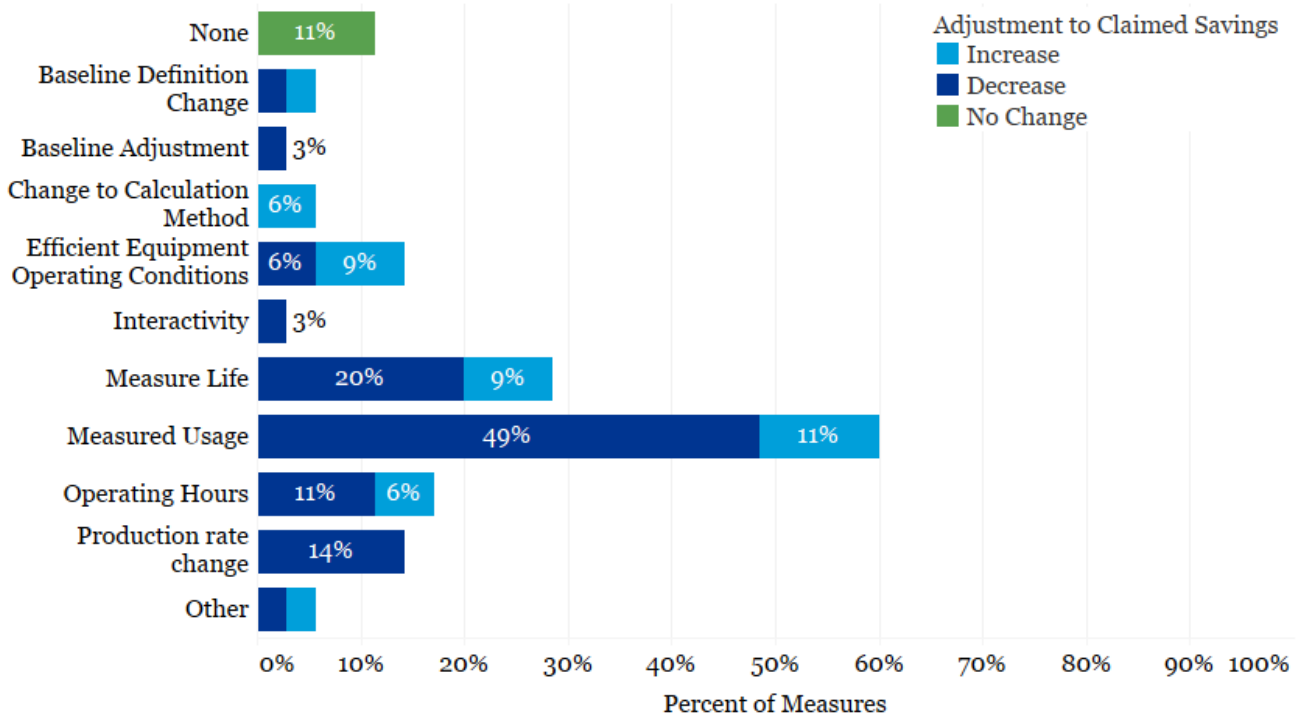


Figure 4-2 shows the types of discrepancies found by the verification. The verification found no discrepancies for 11% of sampled measures. The most common discrepancy between claimed savings and verified savings (60% of measures) was updates to measured energy usage data provided by customers to the verification team. Savings based on measured energy usage are expected to result in some discrepancy during verification because the verification has access to a longer time period of post-installation data than the implementation team. In several cases the implementation team was working with very limited post-installation period data to model savings, which increases the risk of a large adjustment in verification.

Measure life was the only other discrepancy type that occurred for more than 20% of measures. In most cases, measure lives were adjusted primarily for site specific conditions. The program can reduce these

adjustments by deviating from the measure life guide defaults where site-specific situations warrant. When determining the measure life to use, consider the age of the replaced equipment and the specifics of the environment in which the equipment will operate, and provide clear documentation of the reasoning for the measure life chosen, especially when it differs from the measure life guide.

Figure 4-2. Savings discrepancies - Union Large Volume



5 FINDINGS AND RECOMMENDATIONS

The tables in this section present the key findings and recommendations from the study. The tables show the party to whom the recommendation applies and the primary beneficial outcome of the recommendation. We classified outcomes into four categories: reduce costs, increase savings, increase (or maintain) customer satisfaction and decrease risk (multiple types of risk are in this category including risk of adjusted savings, risk to budgets or project schedules, and others). Details of the findings, recommendations and outcomes follow the tables.

Table 5-1. Energy savings and program performance recommendations

#	Energy Savings and Program Performance		Applies to			Primary Beneficial Outcome			
	Finding	Recommendation	Union	Enbridge	Evaluation	Reduce Costs	Increase Savings	Customer Satisfaction	Decrease Risk
1	Both utilities exhibit a strong commitment to accurate energy savings estimate	The utilities should continue in their commitment to accuracy.	✓	✓				✓	✓
2	The CPSV effort found realization rates for market segments that were between 90 and 125% and identified adjustments for most projects.	Continue performing custom savings verification on a regular basis.			✓				✓
3	Relative precision targets were not met for all programs, nor for all segments	Use error ratio assumptions from the results provided in this report in future evaluation years, possibly with more conservative bounding than performed this year.			✓	✓			✓
4	Some measures have difficult-to-define baseline technologies.	Establish a policy to define rules around energy savings calculation for fuel switching and district heating/cooling measures.	✓	✓	✓				✓

#	Energy Savings and Program Performance		Applies to			Primary Beneficial Outcome			
	Finding	Recommendation	Union	Enbridge	Evaluation	Reduce Costs	Increase Savings	Customer Satisfaction	Decrease Risk
5	Some measures in each utility program are routine maintenance, periodic repairs, or like for like replacements that are considered standard care in other jurisdictions.	Establish a clear policy regarding eligibility of maintenance repair and like for like replacement measures for the programs.	✓	✓	✓	✓			✓
6	Multiple heat sources and third-party purchases of heat require more documentation than typical measures	Document the gas demand in the pre-period that will be offset Document the volume of heat/steam/biogas available, the seasonality of supply and its alternative usage.	✓	✓					✓

Table 5-2. Verification process recommendations

#	Verification Process		Applies to			Primary Outcome			
	Finding	Recommendation	Union	Enbridge	Evaluation	Reduce Costs	Increase Savings	Customer Satisfaction	Decrease Risk
7	DNV GL was unable to obtain access to all the equipment at all the sites selected for verification.	Modify contracts to require participants to agree to comply with EM&V as part of the requirements for participation in the program.	✓	✓		✓			✓

Table 5-3. Documentation and Support recommendations

#	Documentation and Support		Applies to			Primary Outcome			
	Finding	Recommendation	Union	Enbridge	Evaluation	Reduce Costs	Increase Savings	Customer Satisfaction	Decrease Risk
8	Incremental improvement in project documentation by both utilities was again observed in the 2017-2018 CPSV. However, project documentation could still be improved.	Implement an electronic tracking system that archives all materials Include explicit sources for all inputs and assumptions in the project documentation. Store background studies and information sources with the project files and make them available to evaluators. Provide evaluators full access to customer data. Provide pre- and post-installation photos, where available. Institute a checklist as part of project closeout to ensure all relevant project documentation is assembled and ready for verification	✓	✓			✓		✓
9	Utility savings estimates based on annual energy consumption for industrial sites did not always include sufficient information documenting production.	Include site production totals in relevant years in the savings estimates based on annual energy consumption for industrial sites	✓	✓					✓
10	Enbridge Boilers use a 73% assumed thermal efficiency for in situ boilers that have been in place for more than 10 years.	Estimate boiler degradation from name plate efficiency to determine the baseline boiler efficiency rather than use a flat number	✓	✓					✓

#	Documentation and Support		Applies to			Primary Outcome			
	Finding	Recommendation	Union	Enbridge	Evaluation	Reduce Costs	Increase Savings	Customer Satisfaction	Decrease Risk
11	Pipe insulation is a significant source of savings for the Union programs. Documentation supporting the assumptions used in calculations, in situ conditions, and location of incentivized pipe insulation was not consistently provided.	Document baseline conditions of pipe insulation (and other measures) using photos and text descriptions to provide context. Explicitly tie the documentation of baseline condition to the heat loss assumption in the savings calculation. Documentation should clearly identify location of pipe insulation installed under the program, as well as associated equipment, especially in large facilities.	✓	✓					✓
12	Documentation did not always include explanation and supporting documentation for baseline types (ROB, ER) and remaining useful life (RUL).	Always provide a complete description of the base case. The description should reference included emails and photos to document in situ conditions and features that are carried over into the baseline system.		✓					✓
13	The utilities should use longer duration data in program savings estimates when possible.	Use longer duration data in program savings estimates. When time periods less than a year are used, utilities should document why the period used is applicable to a full year and why a full year was not able to be used.	✓	✓		✓			✓
14	In situ boiler name plate information, age and operating condition were not always recorded or described.	Document in situ boiler name plate information, age and operating condition for all projects where boiler efficiency affects savings.	✓	✓					✓

#	Documentation and Support		Applies to			Primary Outcome			
	Finding	Recommendation	Union	Enbridge	Evaluation	Reduce Costs	Increase Savings	Customer Satisfaction	Decrease Risk
15	At large sites with multiple spaces containing similar equipment, program documentation did not always identify which space or piece of equipment was affected by the project.	Include additional descriptions of spaces and equipment affected to differentiate among similar spaces and equipment at the site.	✓	✓					✓
16	Invoices were not always included with documentation, and sources for incremental costs were not always clear.	Ensure that incremental costs are supported by invoices or other documentation, especially for add-on and optimization measures where the total cost and incremental cost are likely to be the same.	✓	✓				✓	✓
17	Larger projects appeared to fall under the same documentation standards as smaller projects.	Increase the amount of documentation and source material for projects that have greater energy savings.	✓	✓					✓
18	Union's custom project summary workbook is a good approach to documentation. The workbook is not used in a consistent manner across all projects.	Consider providing more training or adding quality control steps to ensure the summary workbook front page is completed and stored in a consistent manner. Identify a common approach for common measures and, if applicable, document deviations and the reasons for the deviations in a clearly labelled field on the summary sheet.	✓			✓			✓
19	Enbridge Etools does not sufficiently document sources of inputs and assumptions.	Provide details used in Etools in the application along with supporting documentation.		✓		✓			✓

Table 5-4. Data management recommendations

#	Data Management		Applies to			Primary Outcome			
	Finding	Recommendation	Union	Enbridge	Evaluation	Reduce Costs	Increase Savings	Increase Customer Satisfaction	Decrease Risk
20A	Neither Union nor Enbridge currently track participating customer or participating vendor contact information in their program tracking database. Providing the information to the evaluation puts significant burden on utility staff.	Track contacts associated with projects in the program tracking database.	✓	✓		✓		✓	✓
20B		Strongly consider investing in relational program tracking databases.	✓	✓		✓	✓	✓	✓
20C		Continue to use improved structure for data integrity in the evaluator request for contact information for the 2019 savings verification and evaluation.			✓	✓		✓	
21	The extracts from the utility program tracking database do not include dates for key project milestones.	Track and provide to evaluators dates for key milestones in the project.	✓	✓		✓			✓
22	EUL and cumulative gross savings were not provided in a consistent manner in the Enbridge program tracking database extract	Include separate fields in the program tracking database for all components of gross and net cumulative and first year savings.	✓	✓			✓		✓

5.1 Energy Savings and Program Performance

1. **Finding:** Both utilities exhibit a strong commitment to accurate energy savings estimates. Each has made significant investments in developing calculation tools which model savings accurately. For example, Union's dock door seal calculator is well considered and designed, and Enbridge's Etools calculator is very thorough in attempting to model savings for key measures.

   Both utilities chose to retain engineers with a strong understanding of their customers' building and process systems and showed a commitment to finding accurate savings estimates. On several occasions,

both on the phone and in writing, the evaluation team suggested a value that would have increased savings in a way that the utility program engineer did not think was valid. When this happened, neither utility was shy in suggesting that we may want to make a more conservative choice.

Recommendation: The utilities should continue in their commitment to accuracy.

Outcome: Accurate energy savings.

2. **Finding:** The CPSV effort this year found realization rates between 90 and 125% for each market segment and identified adjustments for most projects. Across the programs, adjustments increased savings on for 41 measures and decreased savings on 56 measures. 57 measures had a large adjustment (verified savings more than 20% different from tracked), which was an increase from the 2016 verification.

   Recommendation: Continue performing custom savings verification on a regular basis. Even a study that results in an adjustment of near 100% is still valuable because the programs know that their savings estimates will be reviewed. Knowing a review will be conducted improves the quality of pre-verification estimates. The review itself also results in information that improves future program savings estimates.

   Outcome: Accurate energy savings.

3. **Finding:** Relative precision targets were met or close to met for each program. The sample design incorporated the final 2016 error ratios (ERs) and averaged them with the assumption used in the 2016 sample design. ERs were further bounded (minimum ER was 0.25, maximum 0.60) to limit the risk of over- or under- collecting data. Several segments did not achieve the precision targets sought. In some cases, the precision target was not met due to lack of data from very large measures in the sample, while in others the variability in the gross realization rate for projects was simply greater than the error ratio assumption that was used.

   Recommendation: In future years, continue the process used to develop error ratios assumptions from the results provided in this report, possibly with more conservative bounding (potentially increasing the maximum ER) to avoid under-collection of data for any segments.

   Outcome: Realistic estimates of error ratios result in an appropriate amount of data collected to meet targets.

4. **Finding:** Some measures (e.g., geothermal heat pumps, combined heat and power, and those that save district heating energy) have difficult-to-define baseline technologies. Multiple different baselines are possible for these projects, depending on how one looks at the scope of the project. Two challenging aspects include how non-gas energy changes and offsite gas use are considered in savings estimates.

   Recommendation: Consider establishing a policy to define rules around energy savings calculations and baselines for fuel switching and district heating/cooling measures.

   Outcome: Less risk of adjustment and a better alignment between provincial energy efficiency goals and program implementation.

5. **Finding:** Some measures in each utility program are routine maintenance, periodic repairs or like for like replacements that are considered standard care in other jurisdictions.

   Recommendation: Establish a clear policy regarding the eligibility of maintenance, repair and like for like replacement measures for the programs.

   Outcome: Reduced free ridership risk.

6. **Finding:** The technical estimates of potential savings from a measure need to match the achievable potential at the site. In 2017-2018, projects included measures that saved heat, but translating the heat savings into gas savings was challenging due to multiple heat sources and fuels. Other projects included the purchase of heat or landfill gas where the sufficiency and seasonality of supply affected the achievable gas savings. Also important in third-party purchase measures is to document whether and how the purchased product is and would be used in the absence of the purchase.

   Recommendation: In situations with multiple heat sources, document the gas demand that is affected by the measure in order to establish whether gas is saved in all periods. For measures where heat, steam or biogas is purchased from a third-party where it is a by-product, document the sufficiency, seasonality and baseline use of the product without the purchase.

   Outcome: Accurate energy savings.

5.2 Verification Processes

7. **Finding:** DNV GL was unable to obtain access to all the equipment at all the sites selected for verification. Both Enbridge and Union have several large projects with industrial companies, including food processing, refineries, and other industries. In several cases, the customer refused to provide the necessary trend data to allow a reasonable verification of the project. This means we were unable to do more than a reasonableness check on the savings.

   A review of the Enbridge contract shows that the customer is not required to provide the information that is necessary for EM&V. The most relevant sections are:

   - Item 6: Payment of the Incentive Payment is subject to the completion of a satisfactory site inspection of the improvements, including the installed equipment by an authorized representative of Enbridge.
   - Item 9: Upon request within eighteen months of the commissioning date of the Project, and with reasonable notice, the Customer agrees to provide authorized representatives of Enbridge with access to the Project, and with required information or data relating to the project for the purposes of the Application and these General Terms and Conditions.

   Neither of these are sufficient for EM&V.

   Recommendation: Modify contracts to require participants to agree to comply with EM&V as well as utility representatives as part of the requirements for participation in the program.

   Outcome: Reduced evaluation costs and risks. Participant non-compliance requires evaluators to request documentation for a large backup sample, and to survey and/or visit additional sites to obtain sufficient data for the evaluation. The process of contacting a site and getting a refusal costs time and

money, as does the substitution of an additional site to make up for the unobtained data. In some cases, there might not be additional sites to sample, in which case the evaluation estimates will have lower precision than they would with full compliance.

5.3 Documentation and support

8. **Finding:** Incremental improvement in project documentation by both utilities was again observed in the 2017-2018 CPSV. However, project documentation could still be improved. Specific issues included:

   - Project data or details missing
   - Insufficient measure-level details to fully describe what was installed
   - Descriptions that were difficult to understand
   - Use of black box tools
   - Hardcoded information in calculation spreadsheets
   - Undocumented assumptions
   - Input adjustments that approximate other effects, but are not explained
   - Insufficient access to customer data (by customers).
   - Adjustments to savings estimates for safety or influence that were not clearly marked, sourced, or carried out in a consistent fashion

   Recommendation: Improve data quality. Possible steps include:

   - Implement an electronic tracking system that archives all materials
   - Include explicit sources for all inputs and assumptions in the project documentation.
   - Store background studies and information sources with the project files and make them available to evaluators.
   - Provide evaluators with full access to customer data.
   - Provide pre- and post-installation photos, where available.
   - Institute a checklist as part of project closeout to ensure all relevant project documentation is assembled as ready for verification

   Outcome: Properly explaining and sourcing the savings calculation method and assumptions allows the evaluating engineer to more easily identify what needs to be verified. It also makes it easier to determine whether the methods and assumptions are reasonable and use program assumptions rather than seek documented values elsewhere.

9. **Finding:** Utility savings estimates based on annual energy consumption for industrial sites did not always include sufficient information to document production. The change in energy use pre- and post-measure is often sensitive to changes in production.

   Recommendation: Savings estimates based on annual energy consumption for industrial sites should include information from the site on the amount of production in the years used. If detailed production data are not available, the utilities should get percentage differences year to year (e.g.: if year 1=100%; is year 2 exactly the same or is it 95% or 110% of production the previous year).

   Outcome: Documenting production changes and using them in savings estimates will improve accuracy and reduce evaluation risk.

10. **Finding:** Enbridge boiler calculations use a 73% assumed thermal efficiency for in situ boilers that have been in place for more than 10 years. This value likely overstates energy savings with a baseline boiler that is 20 years or less in age. The value is based on a 2% de-rate of a 2007 combustion efficiency study that found an average combustion efficiency of 74.6% for 39 boilers aged 12-38 years (average 24.5). The study, which Enbridge provided to the evaluation team, did not attempt to tie the degraded combustion efficiency to the original rated efficiency of the boilers. The study is also now more than 10 years old, so its findings are likely out of date and should only at most apply to 20-year-old or more boilers. For 2017-2018, the evaluation used the 73% value since a better option was unavailable at the time.

    Recommendation: Use a degradation from name plate efficiency to determine the baseline boiler efficiency rather than use a flat number. The 2019 CPSV effort should include in the scope secondary research to determine a degradation factor or curve to be used for the 2019 CPSV and incorporated by the utilities for the 2020 program year until primary research is completed or a better approach is developed.

    Outcome: Improving this key assumption will improve savings estimates for a significant portion of savings in the Enbridge portfolio and the process would also be applicable to Union sites where baseline boiler efficiencies are required and not based on site tests of boiler performance.

11. **Finding:** Pipe insulation is a significant source of savings for the Union programs. Documentation supporting the assumptions used in the calculation and the condition of the existing pipe insulation (via photos and/or a description) was not consistently provided. In large facilities, it was often difficult to determine the location of the pipe insulation that was installed for the particular project being evaluated, especially if they had multiple similar incentivized projects installed through the facility.

    Recommendation: Document baseline conditions using photos and text descriptions to provide context. Tie the documentation of the baseline condition to the heat loss assumption in a clear way. Include maps, drawings and/or descriptions that clearly identify the location of the installed pipe insulation for each measure and its associated equipment, especially in large facilities.

    Outcome: Improving documentation of baseline conditions and clarity in calculations will reduce evaluation risk and improve consistency of approach among the Union engineering team.

12. **Finding:** Enbridge documentation did not always include an explanation and supporting documentation for baseline types (replace on burnout, early replacement) and remaining useful life (RUL). "See Etools for base case" is not sufficient: Etools[5] is not designed to provide context and sources to support the values included.

    Recommendation: Always complete the "Base Case Overview" with a detailed description of the base case. The description should reference included emails and photos to document in situ conditions and features that are carried over into the baseline system.

[5] Etools is a suite of energy savings calculators that Enbridge has developed to document projects and provide savings estimates to contractors and customers.

Outcome: Improved descriptions and documentation will reduce evaluation risk and help Enbridge ensure that accurate information has been entered into Etools.

13. **Finding:** The duration of pre- and/or post-data (energy consumption, production output, raw material consumption, etc.) used by the utilities for savings estimates was too brief in several instances.

    Recommendation: The utilities should use data that encompasses a longer period of time in savings estimates when possible. When time periods less than a year are used, the utilities should document why the period used is applicable to a full year and why a full year was not able to be used.

    Outcome: Increased accuracy of savings estimates.

14. **Finding:** The utilities did not always gather boiler nameplate data for in situ systems. The age and operating condition were also not always recorded or described. This was a concern on boiler projects, but also for projects where boiler efficiency has an effect on savings, such as greenhouses, pipe insulation and heat recovery.

    Recommendation: In situ boiler name plate information, age and operating condition are all helpful for determining the designed performance and reasonable range of actual efficiency for the system as well as providing context to better RUL.

    Outcome: Improving documentation of the in situ boiler will reduce uncertainty in savings estimates and reduce evaluation risk.

15. **Finding:** At large sites with multiple spaces containing similar equipment, the utility documentation did not always identify which space or piece of equipment was affected by the project.

    Recommendation: Include additional descriptions of spaces and the equipment affected by the measure to differentiate among similar spaces and equipment at the site.

    Outcome: Reduced evaluation risk.

16. **Finding:** Invoices were not always included with measure documentation, and the sources for incremental costs were not always clear.

    Recommendation: Ensure that incremental costs are supported by invoices or other documentation, especially for add-on and optimization measures where the total cost and incremental cost are likely to be the same. Equipment replacement measures may require an additional standard efficiency quote to produce incremental cost.

    Outcome: Incremental cost is an important component of simple payback, which is often used to judge the economic benefit of energy efficiency projects. It is also an input to some benefit-cost tests.

17. **Finding:** Larger projects appeared to fall under the same documentation standards as smaller projects.

    Recommendation: Increase the amount of documentation and source material for projects that have greater energy savings.

Outcome: Projects that are better documented tend to have more accurate savings estimates and receive fewer evaluation adjustments than those that are less documented. Large projects have a greater effect on overall savings adjustment factors. Therefore, large projects with better documentation are more likely to result in program-level adjustment factors closer to 100%.

18. **Finding:** Union custom projects utilized a project application summary workbook that summarizes the key project inputs, calculations, and most details. In general, this is a good approach that facilitates internal review and evaluation. One challenge was that different projects used the workbook in different ways:

    - The notes section was sometimes used to identify and highlight specific unique approaches and features in projects, but not always.
    - Calculations internal to the summary page were consistent for most projects, but not all; additional factors were sometimes added.
    - Sub-methods critical to the calculation were sometimes contained in hidden sheets.
    - Safety and influence adjustments were inserted in different locations and not always explained.

    Recommendation: Consider providing more training or adding quality control steps to ensure the summary workbook front page is completed and stored in a consistent manner. Identify a common approach for common measures and, if necessary, document deviations and the reasons for the deviations in a clearly labelled field on the summary sheet.

    Outcome: A consistent summary workbook aids both internal and external quality assurance, quality control, and measurement and verification.

19. **Finding:** Enbridge Etools is used as both a calculation tool and as a communication tool with customers. While it appears to serve the needs of the program, this form of communication is difficult for the evaluation efforts.

    - Etools does not easily allow for assumptions to be sourced within the record.
    - Some Etools selections may be site-specific and some may be defaults; the calculator does not clearly distinguish.
    - Energy savings that are calculated outside of Etools are hard-entered in Etools but not always sourced.

    Recommendation: Use a consistent summary workbook. Provide details used in Etools in the application along with supporting documentation.

    Outcome: A consistent summary workbook aids both internal and external quality assurance, quality control, and measurement and verification.

5.4 Data management

20. **Finding:** Neither Union nor Enbridge currently track participating customer or participating vendor contact information in their program tracking database. Providing the information to the evaluation puts significant burden on utility staff.

Recommendation A: Track contacts associated with projects in the program tracking database. At a minimum, the program tracking database should include:

- Project site address
- Customer mailing address
- Primary customer contact name
- Primary customer contact phone
- Primary customer contact email
- Primary customer contact mailing address
- Addresses are best tracked as multiple fields including:
  - Street address line 1
  - Street address line 2
  - City
  - Province
  - Postal code

Phone number fields should include data validation to enforce a consistent format and avoid missing or extra digit errors. Phone extensions should be tracked in a field separate from the ten-digit phone number and be restricted to numeric data only.

The best practice is to maintain contacts in a table separate from specific project or customer data. This allows for a single contact to be connected to multiple accounts and/or projects as necessary without creating duplication. This structure also makes it easier to associate multiple contacts with a single project and decreases quality control costs.

Vendor contact information should also be tracked in the database, in the same table as the participating customer contact information. With a relational database, the contact ID from the table can be added to a project record in the role consistent with the contact's participation (such as vendor, decision maker, or technical expert) with a separate table that allows a single vendor contact to be associated with multiple projects.

Outcome A: Reduced burden on utility staff to seek contact information for projects, whether for internal or evaluation use. Reduced evaluation costs and improved sample design expectations.

Recommendation B: The utilities should strongly consider investing in relational program tracking databases. Relational program tracking databases and customer relationship management (CRM) systems allow for multiple contacts to be associated with a single account and/or project. The incremental cost of implementation is low if it is part of the initial database design, populated as projects are started, and updated once they are complete.

For the implementation team, a query-able one-stop shop for data provides a wealth of information that can improve delivery. For example, these databases can help programs understand how contractors work across projects, identify when projects have hit snags and need attention, and give the program team access to key customer context such as historical participation and different contacts that have worked with the program.

For evaluation, this allows programs to easily clarify aspects of projects during implementation and to provide accurate, timely, and usable contact information to evaluators and verifiers.

Outcome B: Improved customer satisfaction from better delivery, and a reduced burden on utility staff for tracking information. A relational database would also streamline aggregation of program data for scorecards and make providing data simpler for annual savings evaluation and verification.

Recommendation C: Continue to use the improved structure for data integrity in the evaluator request for contact information for the 2019 savings verification and evaluation.

Outcome C: Reduced evaluation costs due to less data cleaning and research to fill missing information. Improved data collection with less returned advance letters and more accurate connection between projects and contacts.

21. **Finding:** The extracts from the utility program tracking database do not include dates for key project milestones. Enbridge's data did not include any dates and Union's included only the "install date."

    Recommendation: Track and provide to evaluators dates for key milestones in the project. Dates for project start, installation, and those that define the program year provide useful context for interviewers that is not always easy to find in project documentation

    Outcome: Improved data collection through more informed interviewers and reduced evaluation costs through less need to search for dates in documentation.

22. **Finding:** EUL and annual gross savings in the Enbridge program tracking database extract total to the correct cumulative savings but are a work around for advanced (accelerated) projects. The data structure provides accurate cumulative savings but does not store and report the underlying dual-baseline annual saving estimates, or the actual claimed RUL and the EUL for each measure.

    Recommendation: Include separate fields in the program tracking database for:

    - EUL
    - RUL
    - gross first year annual savings
    - gross post-RUL annual savings
    - net to gross (NTG)
    - gross cumulative gross
    - net cumulative savings
    - net first year savings

    Outcome: Improved data integrity results in less evaluation risk and more accurate savings totals. Providing each of the key savings types and their components allows evaluation to confirm that the savings provided are internally consistent.

6 APPENDICES

6.1 Technical Introduction

This study provides verified savings ratios and verified gross savings totals from Enbridge's and Union's natural gas DSM programs delivered in 2017-2018. The projects included are shown in Table 6-1. In the CPSV study of 2017-2018 programs, custom Market-Rate Multi-Residential (Multifamily) and custom Low Income Multi-Residential projects are both included as a part of the Commercial program.

Table 6-1. CPSV by program

Program		2017-2018 CPSV
Union Custom	Large Volume	✓
	Commercial & Industrial	✓
Enbridge Custom	Commercial	✓
	Industrial	✓

6.1.1 Background

Enbridge and Union deliver energy efficiency programs under the Demand Side Management Framework for Natural Gas Distributors (2015-2020)[6] developed by the OEB. In April 2016, the OEB hired an Evaluation Contractor (EC) team led by DNV GL to develop an overall evaluation, measurement, and verification (EM&V) plan. The objectives of the plan were to:

- Assess portfolio impacts to determine annual savings results, shareholder incentive and lost revenue amounts, and future year targets.
- Assess the effectiveness of energy efficiency programs on their participants and/or market, including results on various scorecard items.
- Identify ways in which programs can be changed or refined to improve their performance.

Under the plan, the DNV GL team conducted a verification of gross savings for custom projects implemented as part of the 2017-2018 program year. This report is a result of that study.

An evaluation advisory committee (EAC) provides input and advice to the OEB on the evaluation and audit of DSM results. The EAC consists of representatives from Union and Enbridge as well as representatives from non-utility stakeholders, independent experts, staff from the Independent Electricity System Operator (IESO), and observers from the Environmental Commissioner of Ontario and the Ministry of Energy. The DNV GL team worked closely with the EAC throughout this study and received comment, advice, and input on methodology and results. We thank them for their involvement.

[6] EB-2014-0134

6.1.2 Methodology Summary

The results presented in this report are based on data collection from the following four primary sources, supplemented with secondary source information:

- Union and Enbridge tracking databases
- Union and Enbridge project documentation
- In-Depth Interviews with a sample of participating customers (vendors provided supplementary information for some sites)
- On-site visits to a sample of participating customer sites

The data collection with a sample of participating customers included site visits and telephone interviews supporting a detailed measurement and verification (M&V) analysis. Table 2 shows the targeted and completed data collection activities.

Table 6-2. Data collection activities*

Target Group	Activity	Targeted Measures	Completed Measures
Enbridge			
Participating Customers	M&V Site Visit (On-site)	45	30
	TSER Interview		18
Union			
Participating Customers	M&V Site Visit (On-site)	65	63
	TSER Interview		11
Overall			
Participating Customers	M&V Site Visit (On-site)	110	93
	TSER Interview		29

*This table reports the number of measures targeted and completed as measures were used to design the sample before customers and sites had been identified.

At a high level, the gross savings verification (CPSV) study employed the following methodology:

- **Review program data and documentation.** The evaluation started with a review of the program tracking data, which formed the basis of the sample, and an initial review of the program documentation. Once the sample was selected, additional documentation was provided by the programs to describe the energy efficiency measures and support the tracking savings estimates, also called the ex ante estimates.
- **Design and select the sample.** The tracking data was used to design and select a sample. Full documentation and contact information was requested for all sites within the sample.
- **Collect data.** Data was collected to verify the ex ante energy savings.
- **Analyze the results.** The collected data was used to verify the gross savings at each site.
- **Report the results.** The final step was to report the results.

Key features of the methodology include:

- The **sample design** employed a stratified random sample that targeted 10% relative precision with 90% confidence at the program level. Details of the sampling methods are presented in the scope of work embedded in appendix section 6.5. Final sample achievements are provided in appendix section 6.2.
- **Ratio estimation** was used to expand sample results to the population. The evaluation collected data on all sampled or backup projects that a customer contact could speak to rather than only the first selected. In our calculation of sampling error (+/-, confidence intervals, relative precision and error ratios), we used two-tailed 90-percent confidence limits and clusters defined by customers to appropriately estimate error when multiple units are collected from a single source. The approach used is described in the scope of work embedded in appendix section 6.5.
- The **gross savings verification** used a combination of on-site data collection and interviews to collect primary data. Calculation of lifetime gross savings used a dual baseline approach to more accurately estimate savings for early replacement measures. Detailed site reports for each of the sites visited or called were prepared by the DNV GL team and reviewed by the EAC.

6.1.2.1 Understanding Statistical Error

Statistical error is reported for all of the ratio results in this report. The studies were designed with sample designs targeting 10% relative precision with 90% confidence (90/10) based on the best available assumptions at the start of the evaluation. Table 6-3 describes each of the statistics provided in this report.

Table 6-3: Relevant statistics

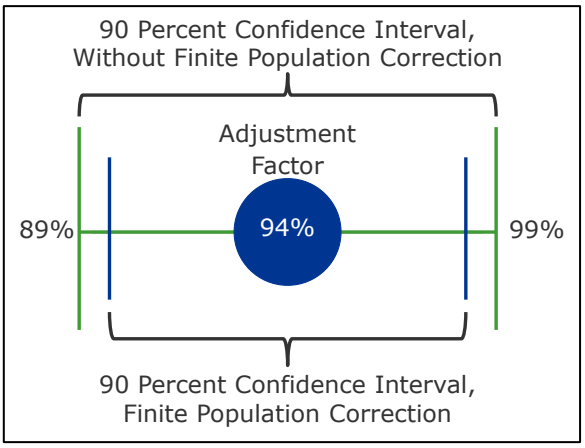
Term	Definition
Ratio/Adjustment factor	A point estimate of the evaluation findings expressed as a percent.
+/- or Absolute Precision	If the evaluation were repeated several times, selecting samples from the same population, 90%[7] of the time the ratio would be within this range
Confidence interval	The upper bound is defined by the ratio plus the absolute precision. The lower bound is defined by the ratio minus the absolute precision.
Relative Precision	The relative precision is calculated as the absolute precision divided by the ratio itself. By convention, relative precisions are the statistic that is targeted in sampling (i.e., 90/10 is a relative precision metric)
Finite population correction (FPC)	FPC is a factor that reduces the measured error of samples drawn from small populations (less than 300). FPC applies when the ratio is applied to the same population from which the sample was drawn.

Figure 6-1 shows an example of:

- the adjustment factor (ratio) as a blue point
- the 90% confidence interval *with finite population correction* (blue)
- the 90% confidence interval without finite population correction (green)

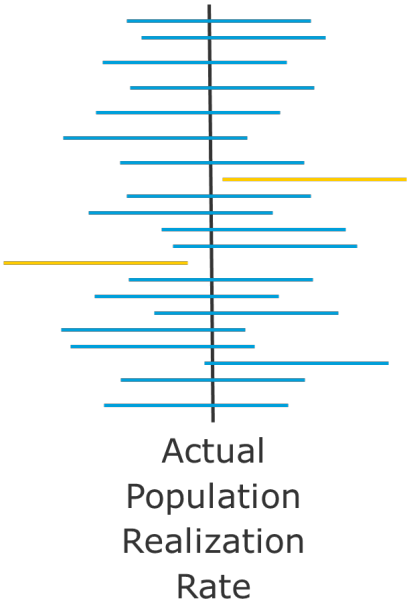
[7] 90% is the confidence limit that we are using.

Figure 6-1. Ratio diagram example



The plus/minus (±) error (%) indicated at the 90% confidence interval is the absolute difference between the estimated percentage and the upper or lower confidence bound. For example, in Figure 6-1, the ratio is 94% and the non-FPC 90% confidence interval is ± 5 percentage points (i.e., 94% ± 5%).[8] Another way of saying this is that there is a 90% probability that the actual ratio for the next year's program lies between 89 and 99%. Figure 6-2 demonstrates this concept by showing twenty hypothetical confidence intervals calculated from twenty different samples of the same population. Eighteen out of twenty (90%) include the true population ratio (overlap the black line representing the true ratio).

Figure 6-2. Ninety Percent Confidence Interval



Note: Each horizontal line represents a confidence interval, while the black vertical line is the actual population realization rate. Yellow confidence intervals do not include the actual ratio.

[8] The critical value for calculating the confidence interval ± for each adjustment factor is determined using Student's t-distribution and n-1 for the degrees of freedom, where n is the sample size. For 2-tailed estimates (ratios that could be above or below 100%) the appropriate t-stat used to calculate precision from the standard error is close to 1.645.

The relative precision of the ratio is calculated as 5%/94% =5.3%.

For low ratios, relative precisions may be quite high, even when the confidence interval around the ratio is quite narrow. Consider a ratio of 5% with the same 5% absolute precision as in the above example. While the absolute precisions are the same, the latter ratio (5%) has a relative precision of 5%/5% =100%. In absolute terms, we still are 90% confident the ratio is below 10%, despite the very high (100%) relative precision.

We report the relative precision in all cases at the 90% confidence level. That is, whether the relative precision is large or small, we have the same 90% confidence that the range defined by the point estimate +/- the absolute error captures the true unknown value. The "midpoint" estimate (the ratio) is the best (statistically most likely) estimate, while the confidence interval is calculated as an interval around that point. Thus, in all cases, we reported the best point estimate, with a symmetric 90% confidence interval (using the t-score for a 2-tailed 90% confidence interval).

6.2 Final Sample Achievement

The tables in this section show the achieved sample for each stratum in the sample designs. The tables are specific to each program and show the categorical stratification (segment) and size strata (larger numbers are bigger projects). Sampling was done at the measure level. The target column shows the number of units we attempted to complete. The complete column shows the number of measures randomly selected and completed. Cumulative savings (CCM) in the completed sample (completed CCM) and for the frame (total CCM) are also included. Note that in some cases measures beyond the target were completed. These completed measures were at sites with multiple measures in the sample.

6.2.1 Union C&I Custom: Summary of Participant Data Collection

Table 6-4 summarizes the participant data collection efforts for CPSV of the Union C&I Custom program. The table shows the portion of the program that:

- Completed on-site visits
- Completed telephone-supported engineering reviews (TSER)
- Did not respond to an evaluation attempt at contact, or refused verification
- Was not contacted by the evaluation team.[9]

The data collected is represented as the number of sites, the number of measures, and cumulative ex ante natural gas savings (ex ante CCM). The proportion of the program in each category is also represented in Table 6-5. In the table, size categories within segments (e.g. Industrial) are ordered with 1 being the smallest stratum within each segment. The study had a customer response rate of 65%, which is consistent with what DNV GL has seen in comparable studies in central North America.

[9] Sites or measures where contact was not attempted were either not selected for contact in sampling or in the backup sample or were not contacted due to strata quotas being met.

Table 6-4. Summary of CPSV data collection for the Union C&I Custom Program

Data Collection Category	Targeted	Completed		
	# Measures	# Sites	# Measures	Ex Ante CCM
Completed On-Site	39	19	28	568,326,085
Completed TSER		11	11	27,431,203
Attempted Contact, Not Completed		16	16	204,083,868
Not Attempted		450	904	2,371,721,795
Total		496	959	3,171,562,951

Table 6-5. CPSV Sample Achievement for Union CI&MF

Segment	Stratum	Max CCM	Target	Completed Measures	Frame Measures	Completed CCM	Total CCM
Agricultural	1	4,737,465	5	5	298	7,428,589	355,786,266
	2	25,068,700	4	4	50	27,705,255	515,023,490
	3	51,768,704	4	4	16	139,498,284	587,250,641
	4	98,247,900	1	0	1	0	98,247,900
Industrial	1	2,141,520	4	5	296	2,975,328	200,247,414
	2	5,996,460	4	3	75	9,929,912	266,047,381
	3	18,953,420	4	4	32	36,642,820	326,932,949
	4	54,888,000	4	5	12	142,230,535	367,428,050
	5	133,991,920	2	2	2	194,992,280	194,992,280
Commercial & MF	1	17,805,840	6	6	176	10,623,505	235,875,800
	2	23,730,780	1	1	1	23,730,780	23,730,780
Grand Total				39	959	595,757,288	3,171,562,951

6.2.2 Union Large Volume: Summary of Participant Data Collection

Table 6-6 summarizes the participant data collection efforts for CPSV of the Union Large Volume program. The table shows the portion of the program that:

- Completed on-site visits
- Did not respond to an evaluation attempt at contact, or refused verification
- Was not contacted by the evaluation team.[10]

The data collected is represented as the number of sites, the number of measures, and cumulative ex ante natural gas savings (ex ante CCM). The proportion of the program in each category is also represented in

Table 6-7. In the table, size categories are ordered with 1 being the smallest stratum. The study had a customer response rate of 72%, which is slightly higher what DNV GL has seen in comparable studies in central North America.

[10] Sites or measures where contact was not attempted were either not selected for contact in sampling or in the backup sample or were not contacted due to strata quotas being met.

Table 6-6. Summary of CPSV data collection for Union Large Volume

Data Collection Category	Targeted	Completed		
	# Measures	# Sites	# Measures	Ex Ante CCM
Completed On-Site	26	13	35	1,216,360,088
Attempted Contact, Not Completed		5	5	39,222,348
Not Attempted		19	48	296,512,561
Total		**37**	**88**	**1,552,094,997**

Table 6-7. CPSV Sample Achievement for Union Large Volume

Segment	Stratum	Max CCM	Target	Completed Measures	Frame Measures	Completed CCM	Total CCM
Large Volume	1	7,169,184	4	4	42	16,041,384	123,034,800
	2	12,064,530	4	7	15	70,059,960	156,405,427
	3	22,264,975	4	5	11	79,904,873	177,243,139
	4	29,209,000	4	7	7	182,923,339	182,923,339
	5	45,057,760	3	5	6	172,292,840	217,350,600
	6	61,626,540	3	3	3	162,841,212	162,841,212
	7	193,073,300	4	4	4	532,296,480	532,296,480
Grand Total				35	88	1,216,360,088	1,552,094,997

6.2.3 Enbridge C&I: Summary of Participant Data Collection

Table 6-8 summarizes the CPSV data collection efforts for the Enbridge C&I Custom program. The table shows the portion of the program that:

- Completed on-site visits
- Completed telephone supported engineering reviews (TSER)
- Did not respond to an evaluation attempt at contact, or refused verification
- Was not contacted by the evaluation team.[11]

The data collected is represented as the number of sites, the number of measures, and cumulative ex ante natural gas savings (ex ante CCM). The proportion of the program in each category is also represented in Table 6-9. In the table, size categories within segments (e.g. Industrial) are ordered with 1 being the smallest stratum within each segment. The study had a customer response rate of 66%, which is consistent with what DNV GL has seen in comparable studies in central North America.

[11] Sites or measures where contact was not attempted were not selected for contact in sampling or in the backup sample.

Table 6-8. Summary of CPSV data collection for Enbridge C&I Custom Program

Data Collection Category	Targeted	Completed		
	# Measures	# Sites	# Measures	Ex Ante CCM
Completed On-Site	45	26	30	152,282,237
Completed TSER		18	18	19,279,821
Attempted Contact, Not Completed		23	23	79,391,280
Not Attempted		1,321	1,834	1,210,405,585
Total		**1,388**	**1,905**	**1,461,358,923**

Table 6-9. CPSV Sample Achievement for Enbridge C&I Custom Program

Segment	Stratum	Max CCM	Target	Completed Measures	Frame Measures	Completed CCM	Total CCM
Commercial	1	487,050	5	5	507	1,268,457	79,357,624
	2	1,525,800	5	6	126	4,618,277	103,961,312
	3	7,893,920	4	5	48	14,264,779	126,387,524
	4	8,636,535	1	1	1	8,636,535	8,636,535
Industrial	1	2,709,350	5	5	234	1,534,800	162,681,383
	2	7,258,920	4	4	53	14,617,635	222,363,413
	3	27,231,760	4	4	19	69,655,462	253,416,602
	4	33,242,320	1	1	1	33,242,320	33,242,320
LI + MR Multi-Residential	1	427,650	4	4	559	860,650	88,021,628
	2	795,700	4	4	187	2,753,790	108,981,436
	3	1,632,800	4	5	113	5,598,568	123,260,418
	4	5,529,775	3	3	56	7,828,460	144,366,403
	5	6,682,325	1	1	1	6,682,325	6,682,325
Grand Total				48	1,905	171,562,058	1,461,358,923

6.3 Technical Policy Approaches

This appendix memorializes some of the more noteworthy topics that arose during the evaluation as part of Evaluation Advisory Committee (EAC) review of CPSV site reports. In some cases these decisions were made during the 2015 and 2016 CPSV (as noted in the text).

6.3.1 Measure categories and baseline selection

Table 6-10 shows the CPSV team's definitions of which baseline is appropriate for various situations. These are guidelines that apply to almost all projects. Some situations may require an exception, in which case the reasoning was described in the site report. In most cases where a code or market minimum baseline was an option, we used that rather than a customer specific baseline. This approach was used in order to maintain consistency of approach with the free ridership based attribution study, making the results applicable in conjunction with the results from this study.

Table 6-10. Measure categories and associated baselines

Measure Type	Gross Savings, based on remaining useful life from facility contact and documentation		Examples	Notes
	Early Replacement Baseline	Natural Replacement Baseline		
Replace on Burnout (ROB) and Existing Equipment More Efficient than Code or Where No Code Applies	NA	In Situ (use new equipment with the same size/rating and In Situ efficiency)	Unique measures where no code/Industry Standard Practice (ISP) exists; Drum Dryers	
Replace on Burnout (ROB) and Existing Equipment Less Efficient than Code	NA	Code/Standard Market Efficiency	Replacing a boiler which was no longer practical to operate	
New Construction (NC) / Capacity Expansion (CE)	NA	Code/Standard Market Efficiency or Minimum on Market/Customer Specific	New boiler for new space or system. Any new construction or natural gas load adding/increasing. Other recently constructed non-participating buildings onsite are a reasonable baseline	Minimum on market / customer specific applies where there is no enforced code
Retrofit Add On (REA)	In Situ	Code/Standard Market Efficiency or Minimum on Market/Customer-specific	Equipment controls; addition of boiler economizer; pipe/tank insulation	Minimum on market / customer specific applies where there is no enforced code
Early Replacement (ER) and Existing Equipment More Efficient than Code or Where No Code Applies	In Situ	In Situ (use new equipment with the same size/rating and In Situ efficiency)	Greenhouse components, such as a site with degraded double-layer polyethylene walls which then installs triple layer but uses single layer poly walls as the baseline (this is a regressive baseline) to estimate savings. Must use double layer (new not degraded) as the baseline in this case.	

Early Replacement (ER) and Existing Equipment Less Efficient than Code	In Situ	Code/Standard Market Efficiency or Minimum on Market/Customer Specific	Regenerative Thermal Oxidizer (RTO) – required to meet local air quality emissions requirements, that a recuperative or direct-fired oxidizer cannot achieve.	
Maintenance (Including Repair or Maintain to Code or Restoration to Prior Efficiency Level)	NA	In Situ	Re-tube boilers to rated efficiency levels; Repair or clean heat exchanger; Replace heat exchanger oil; Rewind motors; Repair or replace faulty/leaking valves, pipes, ductwork, etc.; Re-pipe condensate return lines.	
System Optimization (OPT)	NA	In Situ	Revamp Process Control Strategy; De-bottlenecking to increase production and m^3/widget; Modifying the sequence of processes.	

6.3.2 Estimated useful life

For most measures, we based EULs on those found in the Utility Measure Life Guide, when present and reasonable. Site contacts were asked about their expectations for the EUL of the measure installed. The simple decision matrix shown in Table 6-11 shows when the verification uses a site specific EUL instead of the measure life guide.

Table 6-11. EUL decision matrix

		Is there a measure specific (not other/process) EUL in the utility measure life guide?	
		Yes	**No**
Does site contact provide information that supports an EUL value determination?	**Yes**	Use utility measure life guide unless site contact has site specific reason for EUL value provided	Use site contact reported EUL
	No	Use utility measure life guide	Use utility measure life guide for other/process, ex ante EUL, or, in rare cases, secondary sources such as manufacturers or other studies

When EULs were not present in the Utility Measure Life Guide, and site contacts were not knowledgeable, we would base EULs on those used in other North American jurisdictions. In rare cases, manufacturer information may have been used to determine the applicable EUL for measures that were not found in a survey of EUL guides and TRMs.

6.3.2.1 Remaining useful life

The RUL of the existing equipment limited the EUL of the implemented measure for the following categories of measures:

- Retrofit Add-on (REA)
- System Optimization (OPT)

- Maintenance

RUL was determined based on the best available evidence. In some cases, the preponderance of evidence suggested that an REA measure was likely to be re-used with new equipment when the existing equipment was replaced. Evidence to support using an EUL rather than RUL for REA measures required that the re-use was both feasible (REA measure must be compatible with a wide range of substitute equipment) and likely (ISP was re-use for the application and/or site contact indicates that re-use was planned).

There are situations where the RUL of the existing measure is more than likely longer than the EUL of the REA measure. Pipe insulation is an example: in almost all cases we would expect existing pipes to outlast the insulation installed on them.

Site engineers and interviewers used a list of questions to help determine the RUL of existing equipment. Due to time constraints, project specifics and the site contact's willingness/ability to respond, not all questions were asked of all sites. In 2017-2018, we made this process more formalized as detailed below.

The following section provides the methodology we used for determining the applicable RULs. Question wording onsite and on telephone interviews did vary from the language used here as the questions were delivered in the context of the broader conversation about the implemented measures.

Framing Questions

These questions are intended to get the respondent thinking about their rebated equipment in the context of:

- Their broader facility or process
- Their typical maintenance and equipment replacement practices
- The performance of the equipment relative to their current needs

Interviewers ask these questions before moving to the measure-type-specific questions shown in the following sections.

- For all add-on measures, interviewers asked these questions of the host equipment, or the pre-existing energy using equipment that the add-on measure is making more efficient. Wording was informed by observed equipment condition.
- For add-on measures that replaced a pre-existing add-on, interviewers asked these questions referring to the pre-existing add-on in addition to and separate from the host equipment.
- For replacement measures, interviewers asked these questions referring to the condition of the replaced equipment at the time of replacement.
- Maintenance
  - frequency
  - costs relative to that anticipated for a new unit
  - costs over time (are they increasing or decreasing)
- Performance
  - Is/was it meeting needs?
  - Performing at its rated specification?
  - Degrading more or less quickly between maintenance/repairs?
- Any components whose failure would cause replacement of the equipment?
  - Which component is it?

- How much longer do you think it will last?

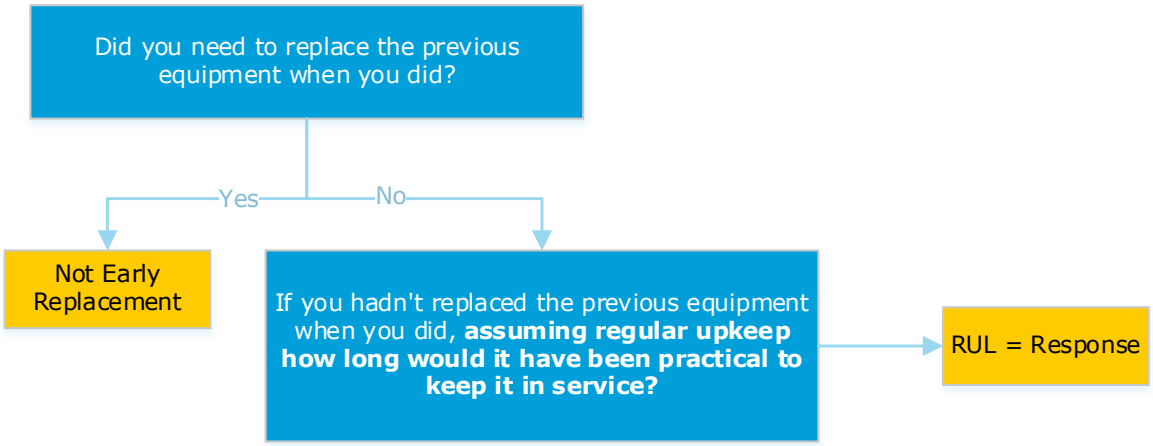
Equipment Replacement

The equipment replacement measure type refers to equipment that is installed in place of another piece of equipment being removed. In this case, the EUL of the installed equipment is split into two periods:

- **Early Replacement (ER) Period**: This is the period representing the RUL of the existing (replaced) equipment. During this period, the existing equipment is the baseline.
- **Non-ER Period:** The remaining EUL (after subtracting out the RUL) is referred to the non-ER period. During this period, the new standard efficiency baseline shall be used.

We determine the RUL for equipment replacement measures by asking the questions shown in Figure 6-3.

Figure 6-3. Equipment Replacement Data Collection Flow Chart



DNV GL ensured that the respondent understood that regular maintenance and upkeep should be assumed.

Note that the question does not refer to the program. The purpose was to understand how long the equipment would have stayed in service had it not been replaced at the time it was. This is different from a timing/acceleration question that might be found in a free ridership question sequence, in that the reasons for replacing now rather than later are not material in the gross context.

Put simply, for this gross-only evaluation, we do not care when a customer would have replaced their equipment without the program. Instead we are seeking to understand how much longer it would have been practical to keep the equipment in use.

Add-on Equipment

The add-on equipment measure type refers to equipment that is added to an existing system or piece of equipment to make it more efficient, such as a control or insulation. There are many potential periods within the EUL of the installed add-on equipment. These periods include:

- **ER Period 1**: The period where the existing add-on equipment (or none, if the existing equipment did not have any applicable add-on equipment) and existing host equipment could have continued operating in the same manner. During this period, the baseline would be the existing host equipment with the existing add-on (if any).

- **ER Period 2**: There could be a second ER period on rare occasions, for two reasons:
  - If the existing add-on equipment (if there was one) would have failed or been replaced, but the existing host equipment was still operating effectively. During this period, the baseline would be the existing host equipment with new standard efficiency add-on equipment.[12]
  - If the existing host equipment failed, but the existing add-on equipment could have been used with the new host equipment. During this period, the baseline would be the new host equipment (whatever the customer will most likely install) with the existing add-on equipment.
- **Non-ER Period**: The period after both the existing host equipment and the existing add-on (if any) would have failed or had to have been changed/replaced. During this period, the baseline is the new host equipment with a new standard efficiency add-on.[12]

These periods are represented visually in Figure 6-4. In this figure, the labels are defined as follows:

- **Exist. Add-on RUL > 0:** Existing add-on equipment was early replacement.
- **Exist. Host RUL > 0:** The add-on was installed on existing host equipment.
- **EUL of New Add-on > RUL of Exist. Host:** The host equipment will be replaced during the life of the new add-on
- **New Add-on Compatible with New Host:** The new add-on equipment is practical to reuse with whatever replaces the existing host equipment, as determined by the questions in Figure 6-3.

[12] Note that the "new std. eff. add-on" case may not include an add-on at all. For example, the standard efficiency case for many motors is not to use a motor drive but to allow the motor to run by itself. Sometimes customers even replace an existing VFD-driven motor with one that does not have a VFD.

Figure 6-4. Add-on Equipment Periods

Scenario					<----------New Add-on Equipment EUL---------->		
					Baseline is:		
#	Exist. Add-on RUL >0	Exist. Host RUL >0	EUL of New Add-on > RUL of Exist. Host	New Add-on Compatible with New Host.	ER Period 1	ER Period 2	Non ER Period
1	yes	yes	yes	yes	Exist. Host Pre-exist. Add-on	Exist. Host New Std. Eff. Add-on[12]	New Host New Std. Eff. Add-on[12]
2	yes	yes	yes	no	Exist. Host Pre-exist. Add-on[12]	Exist. Host New Std. Eff. Add-on[12]	No Savings
3	yes	yes	no	-	Exist. Host Pre-exist. Add-on (or none)	n/a	Exist. Host New Std. Eff. Add-on[12]
4	yes	no	-	yes	New Host Pre-exist. Add-on.	n/a	New Host New Std. Eff. Add-on[12]
5	no	yes	yes	yes	Exist. Host New Std. Eff. Add-on[12]	n/a	New Host New Std. Eff. Add-on[12]
6	no	yes	yes	no	Exist. Host New Std. Eff. Add-on[12]	n/a	No Savings
7	no	yes	no	-	n/a	n/a	Exist. Host New Std. Eff. Add-on[12]
8	no	no	-	yes	n/a	n/a	New Host New Std. Eff. Add-on[12]

Using the example of a boiler and a boiler controller, here is how these scenarios would work:

- Scenario 1:

  Customer had an existing boiler with an existing controller.
  Existing controller and boiler both had an RUL greater than zero.
  Boiler RUL was greater than the existing controller RUL.
  New controller EUL is greater than the existing boiler RUL.
  Controller would be compatible with a new boiler.

- Scenario 2

  Customer had an existing boiler with an existing controller.
  Existing controller and boiler both had an RUL greater than zero.
  Boiler RUL was greater than the existing controller RUL.
  New controller EUL is greater than the existing boiler RUL.
  Controller would not be compatible with a new boiler.

- Scenario 3

  Customer had an existing boiler with an existing controller.
  Existing controller and boiler both had an RUL greater than zero.
  Boiler RUL was greater than the existing controller RUL.
  New controller EUL is less than the existing boiler RUL.
  Controller would not be compatible with a new boiler.

- Scenario 4

  Customer had an existing controller which was re-installed on a new boiler.
  Existing controller had an RUL greater than zero.
  New boiler EUL is greater than the existing controller EUL

- Scenario 5

  Customer had an existing boiler with an RUL greater than zero.
  Existing controller had failed or did not exist.
  New controller EUL is greater than the existing boiler RUL.
  Controller would be compatible with a new boiler.

- Scenario 6

  Customer had an existing boiler with an RUL greater than zero.
  Existing controller had failed or did not exist.
  New controller EUL is greater than the existing boiler RUL.
  Controller would not be compatible with a new boiler.

- Scenario 7

  Customer had an existing boiler with an RUL greater than zero.
  Existing controller had failed or did not exist.
  New controller EUL is less than the existing boiler RUL.

- Scenario 8

  Customer installed a new controller on a new boiler.

Additional examples using other technologies:

- **Scenario 1:** A customer replaces damper driven speed control with a VFD on a make-up air (MUA) unit. The customer says that the VFD is easily removable and could easily be reused on a new MUA. The damper speed control had an RUL of 5 years, the MUA has an RUL of 10 years, and the VFD has an EUL of 15 years.

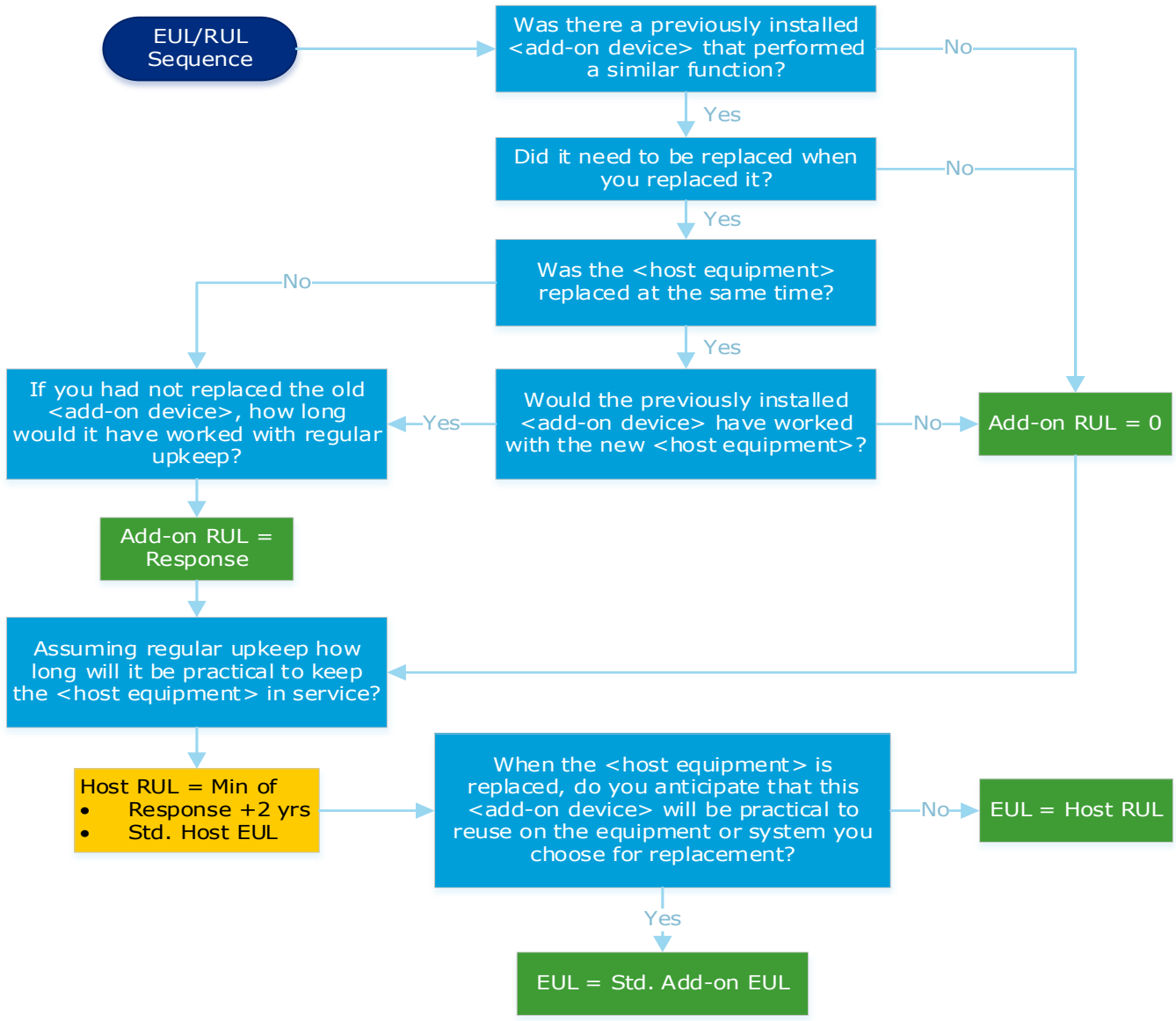
Period	Length (yrs.)	Baseline
ER Period 1	5	Exist. Host Exist. Add-on
ER Period 2	5	Exist. Host New Std. Eff. Add-on[12]
Non ER Period	5	New Host New Std. Eff. Add-on[12]

- **Scenario 2**: A customer adds a vendor-specific linkageless control to their existing steam boiler. The existing boiler did not have any similar controls. The customer says that the boiler has an RUL of 5 years. They do not like the existing system vendor, and so in a new system they would not find it practical to recycle the used vendor-specific linkageless control. The linkageless control has a standard EUL of 10 years, though in this case the EUL is limited to 5 years.

Period	Length (yrs.)	Baseline
Non ER Period	5	Exist. Host Exist. Add-on[12]

We determined the RUL and EUL for add-on measures by asking the questions shown in Figure 6-5. The purpose was to make sure that we got as much meaningful, accurate, and consistent information as possible from the customer, to minimize resorting to default guidelines.

Figure 6-5. Add-on Equipment Data Collection Flow Chart[13]



For customers who were hesitant to answer, we obtained approximate information by providing bracketed categories (e.g. "is it more or less than 10 years" … "is it more or less than 5 years") and incorporated any information available from the documentation or our own sources to help inform this value.

Summary

In the past, there was significant debate amongst the EAC on how to determine the length and nature of the EUL and RUL periods, particularly when the savings for one or more periods might have been zero.

[13] Note that we add 2 years to the final equipment life question response because the equipment was installed in 2017 or 2018 but we are asking about it in 2019.

For this reason, we chose to make explicit how we asked about these issues and collected the information necessary to reasonably quantify them. There were still situations where we had to follow default guidelines about items like RUL and whether equipment could be reused on new host equipment, though our approach reduced the number of times this was necessary.

6.3.3 Greenhouse baselines

For this round of CPSV, the evaluation team accepted most of the baseline assumptions used by the utilities, as applicable codes for commercial greenhouses do not provide specific guidance toward defining minimum efficiency levels for any of the equipment included in the utility programs. Further, Industry Standard Practice (ISP) for Ontario has not been studied. The baseline assumptions used by the utilities were generally closer to a "minimum available on the market" baseline rather than ISP. This approach was consistent with that used for the 2015 CPSV and NTG studies.

In accepting the program baseline for gross savings, the CPSV adjustment was smaller than it would have been with adjustment. The free ridership study asked about options that would have been installed in the absence of the program using the program baseline as the "full credit to the program" end of the scale. If ISP is more efficient than the program claimed baseline, this would theoretically result in more customers with higher free ridership relative to using an ISP based baseline. Mathematically, whether the "standard" baseline was set at minimum available or at an ISP level, the net savings would be the same or very similar as long as both the CPSV and FR projects work off of the same "standard."

Due to the number and size of these projects and the anticipated continued growth in greenhouse construction, we recommend scoping and undertaking a greenhouse baseline study in the future.

6.3.4 Union topics

Union specific topics that required significant decisions during the verification included evaluation approach to "influence factors," and steam traps.

Steam traps

The CPSV team used a six (6) year EUL for these measures, consistent with 2015 and 2016 CPSVs. The reasoning in 2015, which we carried forward in 2017-2018, is described below.

In previous project documentation, Union typically used seven (7) year EULs and Enbridge usually used six (6) year EULs. The CPSV team used a single EUL for both utilities, adopting a six (6) year EUL. The six-year value was based on a 2015 Massachusetts study and is also consistent with the California DEER database, Massachusetts evaluations and the Wisconsin Focus on Energy TRM. The Michigan MEMD (Michigan Efficient Measure Database) uses a five (5) year EUL.

Project documentation provided by Union to support a longer EUL for Union projects consisted of three reports from customers documenting their practices and survey results. Each of the three sites provided was a petrochemical plant.

The reports showed failure rates that could be consistent with 7, 11 and 13 years respectively.

Methodologically, "one divided by failure rate" is a way to estimate the EUL, but it assumes that all traps fail randomly. Many factors affect the life to the steam trap: temperature, pressure, flowrate, operating hours, quality of the installation of the steam trap, location of the steam trap in the system (e.g., near elbows and constrictions, or in a straight line of pipe, or somewhere near forklift traffic), presence of low concentrations

of chemicals in the steam and more. The steam traps replaced as part of a program are going to be more likely to be those with a higher rate of failure than those of the facility as a whole.

DNV GL also reviewed the project files sent for the 2015 CSPV sample. While most of the project files did not report the number of traps surveyed, the evaluation team found two others in the 2015 project files that did (the two largest, one petrochemical and one other manufacturing). The failure rates in those sites were consistent with 4.3 and 8.1 years, but it was not clear how often they conducted surveys, so these could have been multi-year failures (longer implied EUL with a "one divided by failure rate" method).

Five large customers do not necessarily represent the program population, and the steam traps replaced by the program are likely to fail at a rate greater than those not replaced. The evaluation team does not have enough evidence to support a longer steam trap EUL for Union and used 6 years as the EUL, consistent with the current best available research (the Massachusetts study).[14]

Union used three general approaches to calculate savings from steam traps. Most of the projects fell into approaches 1 and 2, with only a few projects using approach 3.

1. Standard: A calculation tool took inputs provided by vendors and applied them to a simplified version of the Spirax Sarco equation, then applied a derating factor. This is similar to the approach used by many vendors.
2. Chemical and Refinery: A calculation tool which used four different equations depending on pressure and steam trap type, including choked and non-choked versions of both the Napier equation and ANSI standard equation. This was generally applied to large chemical and refinery plants with thermodynamic traps.
3. Ad-Hoc: This approach represented a variety of methods which took different outputs (which were likely to have been based on different assumptions from simple vendor calculations) without specifically stating assumptions and converted steam loss to natural gas savings.

For this round of evaluation, we accepted Union's methodology for Approaches 1 and 2, retaining their savings estimates unless we learned something from the site contact about the pressure, leak rate, or other condition that differed from the ex ante assumption/documentation. Where site information differed from the documentation, the methodology used to estimate ex post savings was determined on a case-by-case basis. For Approach 3, we planned to recalculate savings using a formula from the Illinois TRM, which generally produces savings estimates similar to the results from the Enbridge and Union Approach 1 methods. Approach 3 was, in the end, not used.

In the future, we propose that Union document and provide the orifice sizes used to check the vendor calculations. We also propose that Union provide all documentation, including charts, tables, and vendor documentation where needed, to evaluate Approach 2 sites. Union should also provide Excel calculators with live formulas rather than hardcoded values when the values were determined based on a formula or table as opposed to a chart or curve. If the chart or curve was the source, Union should provide a copy of the source material.

[14] Massachusetts 2013 Prescriptive Gas impact Evaluation. Prepared by DNV GL for Massachusetts Gas Program Administrators and Massachusetts Energy Advisory Council, June 2015.

Some options for increasing the evaluation rigour for steam traps, might entail one or more of the following:

- Attempting to independently gather orifice sizes and maximum flow capacity charts by reaching out to vendors to develop a database which would allow us to independently verify calculations
- Purchasing a license for steam trap auditing software allowing for independent verification
- Developing an assessment of measure life using DNV GL's ultrasonic leak detector to assess failure rate at participating sites.

Boiler Measure Lives

In the 2016 CPSV and continuing in 2017-2018, we harmonized the boiler measure lives for the two utilities. Previously, Union used 20 years for boilers, while Enbridge used 25 years. DNV GL senior engineers were asked which was more reasonable and consensus was that 25 years is a reasonable estimate of measure life for most large boiler applications.

6.3.5 Enbridge topics

Enbridge specific topics that required significant decisions during the verification included an evaluation approach to boilers and steam traps.

Boilers

For the 2017-2018 evaluation of the Enbridge programs, the DNV GL team accepted the Etools calculation method along with the inputs used by Enbridge, except in cases where we were able to verify with site contacts a different condition than what was shown in the documentation. This approach was consistent with 2015 and 2016.

For the future evaluations, the evaluation team will:

- Look for more existing evidence from Enbridge (including emails from the customers, photographs, inspection reports, cut sheets, invoices, and conversation notes) to explain why site-specific inputs were used
- Request that Enbridge explicitly state for domestic hot water (DHW) boiler replacements in buildings with storage tanks whether the existing tank was replaced as part of the boiler replacement, and whether the existing tank was insulated.
- Recommend that the DHW tank insulation be included as a separate measure from boiler replacement.
- Consider additional research and reporting that includes:
  - Pursuing a detailed review of the ASHRAE 155P research
  - Pursuing a review of the Etools calculator which digs into the underlying assumptions and formulas
  - Writing a detailed memo which summarizes the results of these reviews

One benefit to pursuing these activities would be greater clarity around the remaining calculation uncertainties and a better understanding of their effect. Another would be the identification of areas where the calculation rigour can be cost-effectively increased through further research.

During the evaluation, we noted that Enbridge's approach to boiler implementation appeared to take more of the boiler system into account than prescriptive and custom programs implemented elsewhere. This may be motivated by the savings estimation approach that Etools takes and provides justification for on average higher savings estimates from Etools than prescriptive boiler savings estimates elsewhere.

Due to the unique approach to market and calculation that Enbridge takes, future CPSV efforts should consider using an empirical measurement approach to directly estimate usage and/or savings for boilers. Empirical measurement could take the form of billing analysis or an on-site metering study which either measures natural gas directly or measures proxy values (such as flue gas temperature, water flow, or combustion fan electrical usage). On-site metering studies are becoming more cost effective as end-use natural gas metering expertise and the accuracy of meters to measure proxy variables continue to increase. An empirical sample-based study would not prevent Enbridge from using a custom calculation approach but would help to calibrate the custom calculation and may provide value to the ASHRAE committee attempting to quantify seasonal efficiency. A billing analysis approach to estimate savings for multifamily and/or commercial boiler replacements may yield reasonable statistical significance due to the large numbers of boilers installed by Enbridge and the fact that boiler usage represents the large majority of gas usage in most buildings.

Steam traps

For this round of evaluation, consistent with 2015 and 2016, the evaluation team accepted Enbridge's approach and savings estimates for steam trap evaluations unless we learned something from the site contact about the pressure, leak rate, or other condition that differed from the ex ante assumption/documentation. Where site contacts provided different information to the verifier than that included in the ex ante documentation, the approach used to estimate ex post savings was determined on a case by case basis (depending on what was different).

For their steam trap savings estimates, Enbridge used an internal database of vendor-provided orifice sizes to check the calculations done by vendors. Based on a review of the formulas used by each vendor, calculations with a sample of pressures and leak rates used by each vendor, and a comparison to Spirax Sarco (whose calculation approach is generally recognized as superior by independent industry experts), Enbridge determines an vendor-specific average derating factor which is applied to the steam losses reported by each vendor. These derating factors are used to convert vendor savings estimates to ex ante program estimates.

The estimates that each contractor's approach produces can vary widely depending on orifice size, leak rate, pressure, and whether condensate is returned or not, so we deviated from Enbridge's method where applicable based on site-specific information.

The Enbridge estimates appeared accurate for a group of projects averaged together. The evaluation checked these estimates using an alternative calculation method (based on the Illinois TRM approach) and achieved a similar total savings, though site specific estimates varied widely.

In the future, the evaluation team will consider requesting that Enbridge document the orifice sizes they used to check the calculations done by vendor for the evaluated site and independently confirm the calculated savings. We will also consider increasing the rigour for steam traps, which could entail one or more of the following options:

- Attempting to independently gather orifice sizes by reaching out to vendors to develop a database
- Purchasing a license for steam trap auditing software
- Assessing the measure life using DNV GL's ultrasonic leak detector to assess failure rate at participating sites.

6.4 Additional Results

First year savings are used in the annual verification report to calculate lost revenue for the utilities. The gross adjustment factors for first year savings for the 2017-2018 program years are provided here.

Table 6-12. First-year gross savings realization rate for the Enbridge C&I Custom program

Segment	Gross Realization Rate	+/- at 90% Confidence	Sampled Measures	Population Measures	Percent Population CCM Savings
Commercial	100.42%	7%	17	682	23%
Industrial	106.91%	6%	14	307	50%
LI & MR Multi-Residential	121.85%	15%	17	916	27%
Enbridge C&I Custom - Overall	108.83%	5%	48	1,905	100%

Table 6-13. First-year gross savings realization rate for the Union C&I Custom program

Segment	Gross Realization Rate	+/- at 90% Confidence	Sampled Measures	Population Measures	Percent Population CCM Savings
Agricultural & Industrial	90.47%	12%	32	782	93%
Commercial & Multifamily	95.04%	6%	7	177	7%
Union C&I Custom - Overall	90.94%	11%	39	959	100%

Table 6-14. First-year gross savings realization rate for the Union Large Volume program

Domain	Gross Realization Rate	+/- at 90% Confidence	Sampled Measures	Population Measures	Percent Population CCM Savings
Union - Large Volume	85.21%	7%	35	88	100%

Table 6-15 through Table 6-17 provide identical results to those in the body of the report, but with additional information.

Table 6-15. Cumulative gross RRs for the Enbridge C&I Custom program, additional Statistics

Segment	Gross Realization Rate	+/- at 90% Confidence	Sampled Measures	Population Measures	Percent Population CCM Savings
Commercial	94.99%	9%	17	682	22%
Industrial	110.79%	8%	14	307	46%
LI & MR Multi-Residential	121.09%	16%	17	916	32%
Enbridge C&I Custom - Overall	110.51%	7%	48	1,905	100%

Table 6-16. Cumulative gross RRs for the Union C&I Custom program, additional domains

Segment	Gross Realization Rate	+/- at 90% Confidence	Sampled Measures	Population Measures	Percent Population CCM Savings
Agricultural & Industrial	91.17%	13%	32	782	92%
Commercial & Multifamily	90.57%	6%	7	177	8%
Union C&I Custom - Overall	91.10%	11%	39	959	100%

Table 6-17. Cumulative gross RRs for the Union C&I Custom program, additional domains

Segment	Gross Realization Rate	+/- at 90% Confidence	Sampled Measures	Population Measures	Percent Population CCM Savings
Union - Large Volume	90.46%	13%	35	88	100%

6.5 Key Documents

The site verification template which will be used for reporting verified results for each site to the OEB and EAC is found below.

CPSV_Site_Report template

The Scope of Work and sample design memo for the CPSV study are embedded below.

Scope of Work

CPSV Sample Design

6.6 Site Level Savings Results

This appendix provides the verification results for each measure in the sample. For each measure, the utility's tracking savings, the verification's verified savings and the realization rate are provided.

Table 6-18. Site level verification results – Enbridge C&I Custom program

Segment	Measure Type	Measure ID	Gross Realization Rate	Utility Tracking CCM	Verified CCM
Commercial	Heating	ES129-1	92%	553,525	507,650
		ES152-1	100%	703,925	703,925
		ES159-2	76%	1,767,080	1,348,284
		ES178-1	100%	324,025	324,025
		ES200-1	100%	620,525	620,525
		ES206-1	119%	1,525,800	1,817,275
		ES220-1	123%	8,636,535	10,618,695
		ES243-1	100%	567,900	567,900
		ET103-1	56%	6,275,145	3,493,470
		ET118-1	100%	399,096	399,096
		ET127-1	100%	2,078,058	2,078,058
		ET201-1	100%	646,602	646,602
		ET216-1	122%	181,890	222,315
		ET239-1	146%	89,946	130,920
	Other Commercial	ES108-1	147%	1,821,420	2,670,510
		ES159-1	99%	2,323,076	2,289,476
		ES243-2	60%	273,500	164,100
Industrial	Heating	ES143-1	100%	27,231,760	27,231,760
		ES175-1	142%	716,610	1,014,060
		ET228-1	115%	26,970	31,000
	Other Industrial	ES120-1	100%	4,425,120	4,425,120
		ES138-1	164%	252,714	415,464
		ES143-2	100%	4,254,550	4,254,550
		ES197-1	129%	13,847,162	17,898,972
		ET135-1	94%	339,066	320,390
		ET234-1	115%	3,183,525	3,663,850
	Process	ES120-2	88%	20,905,860	18,293,708
		ES147-1	100%	2,754,440	2,754,440
		ES176-1	190%	7,670,680	14,603,780
		ES232-1	110%	199,440	219,640
		ES235-1	100%	33,242,320	33,242,320
LI & MR Multiresidential	Heating	ES121-1	132%	6,682,325	8,817,425
		ES125-1	131%	2,712,550	3,550,400
		ES137-1	98%	402,725	396,350
		ES184-1	94%	3,087,775	2,913,200
		ES211-1	97%	338,575	329,100
		ES236-1	63%	1,632,800	1,022,200
		ET183-1	100%	1,064,698	1,064,713
	Other Multi-Family	ES171-1	101%	2,028,135	2,040,735
		ES189-1	157%	779,385	1,224,630
		ET112-1	214%	939,720	2,011,110
		ET131-1	137%	97,250	132,950
		ET161-1	100%	794,400	794,400
		ET163-1	100%	951,850	951,850
		ET170-1	261%	685,725	1,789,650
		ET173-1	90%	1,009,500	909,025
		ET205-1	88%	494,280	436,905
		ET223-1	619%	22,100	136,825
Grand Total				171,562,058	185,493,348

Table 6-19. Site level verification results – Union C&I Custom program

Segment	Measure Type	Measure ID	Gross Realization Rate	Utility Tracking CCM	Verified CCM
Agriculture	Greenhouse - Heating or Water System	US116-2	100%	1,625,778	1,625,778
		US133-1	105%	5,171,020	5,428,280
		US146-1	44%	7,239,015	3,168,562
		US153-1	100%	30,856,260	30,856,260
		US217-1	317%	1,335,165	4,231,920
		UT229-1	103%	3,591,966	3,687,110
	Greenhouse - New Build	US116-1	91%	39,718,084	36,076,306
		US145-1	167%	40,825,772	68,065,536
		US181-1	106%	28,098,168	29,856,723
	Greenhouse - Other	US133-2	108%	5,198,320	5,611,080
		US154-1	100%	10,096,900	10,096,900
		US154-2	111%	535,360	592,520
		US213-1	100%	340,320	340,320
Commercial & Multi-Family	Commercial & Multi-Family	US240-1	104%	23,730,780	24,585,400
		UT123-1	91%	673,800	615,920
		UT141-1	100%	4,922,460	4,922,460
		UT166-1	85%	2,270,460	1,934,400
		UT167-1	42%	331,840	139,440
		UT168-1	73%	588,195	429,090
		UT198-1	80%	1,836,750	1,474,905
Industrial	HVAC	US102-1	90%	414,320	373,360
		US102-2	46%	261,880	119,580
		US130-1	0%	8,189,680	0
		US130-2	111%	596,280	663,980
		US191-1	74%	23,116,395	17,126,010
		US191-2	68%	14,351,500	9,749,505
		UT165-1	26%	2,696,860	708,080
		UT237-1	107%	1,621,060	1,742,550
	Other Industrial	US122-1	74%	133,991,920	99,025,900
		US140-1	101%	34,339,100	34,646,200
		US202-1	0%	5,079,180	0
		US212-1	87%	19,421,680	16,892,740
		US212-2	110%	23,737,720	26,017,580
		US212-3	85%	41,615,640	35,373,640
		US222-1	15%	61,000,360	8,875,820
		US226-1	26%	7,357,700	1,882,996
	Steam or Hot Water System	US140-2	100%	81,788	81,788
		UT106-1	91%	2,153,872	1,951,516
		UT225-1	33%	6,743,940	2,247,980
Grand Total				595,757,288	491,218,135

Table 6-20. Site level verification results – Union Custom Large Volume program

Segment	Measure Type	Measure ID	Gross Realization Rate	Utility Tracking CCM	Verified CCM
Large Volume	Large Volume	US101-1	100%	8,556,142	8,556,142
		US105-1	94%	3,580,000	3,355,720
		US105-2	5942%	117,800	6,999,504
		US114-1	286%	25,926,900	74,094,080
		US115-1	92%	15,465,939	14,235,531
		US150-1	20%	10,275,066	2,095,064
		US150-2	185%	7,169,184	13,288,836
		US150-3	88%	13,526,100	11,912,194
		US150-4	35%	7,946,412	2,786,157
		US169-1	100%	61,626,540	61,626,540
		US169-2	100%	55,499,612	55,499,612
		US187-1	85%	23,904,280	20,343,720
		US187-2	56%	93,083,320	52,349,520
		US187-3	28%	44,840,000	12,531,720
		US188-1	56%	34,499,880	19,338,020
		US188-2	57%	30,542,400	17,364,580
		US192-1	124%	16,396,719	20,261,130
		US192-2	93%	45,715,060	42,563,020
		US192-3	19%	27,366,374	5,278,998
		US193-1	102%	29,209,000	29,899,240
		US193-2	217%	24,675,560	53,622,740
		US203-1	2%	5,174,400	104,780
		US203-2	67%	30,564,100	20,485,660
		US203-3	100%	11,888,190	11,888,190
		US203-4	2%	65,221,420	1,307,876
		US203-5	80%	11,152,880	8,900,500
		US214-1	73%	22,264,975	16,325,095
		US214-2	72%	23,255,335	16,842,580
		US214-3	46%	28,585,890	13,284,666
		US215-1	63%	193,073,300	122,461,260
		US215-2	254%	12,064,530	30,608,840
		US215-3	82%	8,176,740	6,745,240
		US215-4	111%	180,918,440	201,116,740
		US218-1	126%	12,251,140	15,433,220
		US241-1	52%	31,846,460	16,594,880
Grand Total				1,216,360,088	1,010,101,595

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.