ETOOLS BOILER TOOL VALIDATION STUDY

Ontario Energy Board

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1 EXECUTIVE SUMMARY

This report discusses the analysis completed during the study of Enbridge Gas Inc.'s (EGI) eTools energy modelling software. EGI has used eTools to estimate natural gas savings for many years. EGI uses eTools to estimate gas savings from the installation of energy-efficient boiler equipment offered through EGI's Custom Commercial Program and Affordable Multi-Family Housing Program. These programs, approved by the Ontario Energy Board (OEB) as part of EGI's broader natural gas demand side management (DSM) portfolio, offer customers incentives and guidance related to specific retrofits at their buildings which typically include efficiency upgrades to the boilers. Historically, commercial and multi-residential projects containing boiler system interventions have represented approximately 25% of annual custom program savings.

Gas consumption savings in eTools are estimated (ex ante) utilizing pre-period gas consumption and detailed engineering assumptions. The OEB has accepted these estimates as part of its evaluation process and subsequently, to calculate performance incentives and lost revenues.

The findings of this study will be used to provide guidance to the OEB on whether eTools can be relied on to estimate savings for projects completed through EGI's approved DSM programs and relied on by the OEB for use as part of future evaluation activities and ultimately as part of final verified natural gas savings results that are used to assess EGI's performance relative to OEB-approved metrics.

This study included two phases of analysis.

- Phase 1 used billing analysis to estimate natural gas savings (referred to as evaluated savings) by utilizing gas consumption of a facility before and after the installation of the efficiency measure, in this case, a boiler. This was compared to the estimate produced by EGI's eTools model. The Phase 1 analysis found that billing analysis savings were 64% to 68% of eTools estimates of savings. The realization rate figures for Phase 1 were preliminary results only with many known limitations that affected the analysis.
- Below is a description of how eTools estimates savings compared to the billing analysis conducted by DNV as part of this study:
  - eTools: Produces a forecast of gas savings from boiler system interventions using a calibrated engineering model that incorporates the usage at the site prior to the boiler system intervention, as well as anticipated configurations and settings for the new boiler systems. eTools makes several assumptions about the existing boiler system configuration, condition, use, and interaction with other systems in the facility. eTools also assumes that the new boiler will operate as intended, with no changes to settings after system commissioning.
  - Billing analysis: Uses actual natural gas consumption pre-intervention and post-intervention, it assumes that all observed changes in heating load at the site are due to the intervention, e.g., boiler system changes.
  - While neither method is perfect, billing analysis provides an empirical estimate of savings because it can leverage measured site usage from after the boiler system intervention.
- Phase 2 addressed several limitations in the Phase 1 analysis, including:
  - Using a consistent modern version of eTools for all sites and focusing on eTools savings estimates of advancement savings (existing consumption vs. efficient consumption) for an apples-to-apples comparison with billing analysis. The finding was that advancement savings estimated by the most recent version (e8-00) of eTools available during this study are 55% of the billing analysis estimates. However, advancement savings are not frequently used as reported program savings. Of the initial 456 projects for which Enbridge provided data to DNV only 85 projects (19%) utilized advancement savings for program savings and for these projects the advancement savings were only used for the remaining useful life of the existing equipment, not all of the lifetime savings. The balance of lifetime savings for advancement projects and non-advancement projects (81%) used standard savings (a counterfactual

industry standard system's consumption vs. efficient consumption) which are lower in magnitude than advancement savings, which is why the RR decreased from 64% in Phase 1 to 55% in this step of Phase 2.

- Explaining the differences in savings through simulating changes in assumptions in eTools that might produce estimates of savings more in line with billing analysis estimates. This investigation found that changing eTools' default assumption for existing boiler efficiency (73%) to values closer to market standard efficiencies (80.1% for space heating and 81.8% for domestic hot-water heating systems) and being more conservative with inputs to the efficient system control settings, increased the realization rate from 55% to 79%.
- Incorporating the findings from EGI's study of non-participant natural gas consumption trends (details in Section 3.11, the full study in APPENDIX A) into the billing analysis results increases the overall realization rate from 79% to 84%. The latter value is the one recommended for use in adjusting aggregate gross savings for commercial boiler projects that utilized eTools.
- Accounting for the possible double counting of changes to eTools boiler gross savings in this study and those in evaluation findings in the annual Custom Project Savings Verification (CPSV). The potential for double counting stems from adjustments to the system characteristics and control settings on the existing or efficient boilers during evaluations which are also captured in the billing data used in billing analysis. During the investigation, all eTools boiler projects (a total of 41) from previous evaluations were reviewed to identify the potential sources of double counting. The findings were that most changes to system characteristics and control settings from previous evaluations increased gross savings, and removing these adjustments decreased the aggregate eTools boiler gross savings realization rates from 102% (+/- 5%) to 97% (+/- 4%). Overall, the gross savings realization rates for previous evaluations with or without inclusion of adjustments potentially double counted are not statistically different from 100%.

Results of this study show that the savings from past and present eTools versions do not align with more empirical results from billing analysis. However, after key engineering assumptions are refined, eTools can provide an estimate of aggregate savings closer to those from billing analysis. Based on the analysis conducted in this study, the following recommendations are provided for the OEB's consideration:

1. Continue using eTools for implementation and evaluation. eTools is a sophisticated engineering-based estimation calculator that exceeds industry standard practice and generates local knowledge of implementation practices. There are no other boiler savings estimation models that are known to be more accurate, nor any known to be in development. Changing tools for evaluation will introduce additional uncertainty as to the causes of differences in verified vs. claimed savings. The continued use of this modelling software is akin to other simulation software which contain known performance gaps across all kinds in jurisdictions around the world. Despite these performance gaps, no jurisdiction has discarded their performance simulation software. EnergyPlus, 3E Plus, Integrated Engineering Software, etc. are all used to provide forecasted savings in buildings despite rarely being accurate for an individual building. DNV recommends the following changes to eTools to address the study's findings and provide a more accurate estimate of savings:

    a. eTools advancement projects should not utilize the current 73% thermal efficiency default value, rather site-specific values (supported by documentation) should be utilized. If documented site-specific values are not available, the efficiency values identified in this study, 80.1% for space heating and 81.8% for domestic hot-water heating, should be utilized by implementers and evaluators.
    b. Site-specific documentation verifying any anticipated controls or setpoint changes should be gathered by Enbridge after boiler system commissioning. If documentation verifying controls changes are unavailable, then the installed systems should be assumed to utilize the same controls and setpoints as the existing systems.

c. Version e8-00 of eTools was the latest version reviewed during this study and should be utilized by the evaluation team to assess any projects using eTools e8-00 or earlier.
d. Projects using a version of eTools more modern than e8-00 should use the modern version of eTools in evaluation. A "between version" calibration factor that takes the savings from version e8-00 relative to the new version should be employed to ensure that the changes from one version to another are accounted for without restricting the evaluation to using only version e8-00 prior to re-calibrating the billing analysis (see below in point 5). This calibration can be calculated using the sample plus the backup sample of projects in the evaluation (those that the evaluation requests files for as part of the typical evaluation process).

2. Future evaluations of eTools commercial boiler projects should continue in a manner consistent with Custom Project Savings Verification (CPSV) evaluations from 2015-2018 while updating the model to eTools version e8-00 or more modern. This means updating inputs to eTools based on site-specific data collected through evaluation activities.
3. After implementation of list items 1.a. and 1.b., the recommended realization rate from this study (84%), can be applied to evaluate aggregate eTools boiler gross savings. This recommended realization rate uses that described in 1a) above as well as incorporates the findings from EGI's study of non-participant natural gas consumption trends (APPENDIX A), explained in Section 3.11.
4. A correction factor for the double counting between evaluated gross savings and billing analysis should be utilized. As part of this study, it was found that based on past projects, the adjustment factor was 0.97. An alternative to using this factor is to re-estimate the correction factor based on the sample of projects evaluated in CPSV to apply to that year's CPSV results. The determination of which to use will be made by the evaluation team with input from the EAC and OEB. The primary factor in the decision will be the sample size of boilers evaluated.
5. eTools should be periodically calibrated via billing analysis to improve the accuracy of aggregate savings estimates. The precise cadence/timing of the calibration cannot be defined at this time in part because evaluation budget consideration necessarily have a role in determining the timing. Re-calibrating the billing analysis will be more about changes in use of eTools (defaults, assumptions and data entry choices) and less about the changes in the underlying calculations, which will be captured in the suggested "between version" calibration factor in 1d.
The OEB and EAC should consider the following key factors when determining whether a billing analysis calibration should be conducted:

a. Whether EGI's internal user guidelines for eTools have changed in a manner that materially impacts savings estimates produced. As informed by Enbridge's analysis of the impact of its user guideline changes to eTools. Materially in this case would be a change that is expected to change boiler savings by more than 5% in aggregate for boilers in the program. Note that 5% is a starting point to inform the EAC when it is time to start planning the next study.
b. If newer eTools versions are found to produce savings materially different from the versions evaluated in this study As informed by Enbridge's analysis of the impact of its updates to eTools and/or the calibration factors estimated in 1d above. If calibration factors in 1d exceed 10% it is of higher priority to conduct another calibration. 10% is a starting point, given that 1d is likely based on a relatively small sample, it is prudent to use a higher threshold than 5a.
c. If there is sufficient post-case heating data (minimum of two heating seasons) for the population of sites to be included in the billing analysis

Results from the two phases are reported separately in this report.

2 PHASE 1 OBJECTIVES AND APPROACH

2.1 Phase 1 Summary

Billing analysis is an industry-accepted empirical method of estimating ex post savings by utilizing gas consumption of a facility before and after the installation of the efficiency measure, in this case, a boiler. When the two methods (ex ante vs. ex post) are compared, the ratio of the ex post billing analysis results (evaluated results) to the ex ante results (e-Tools results) is called a realization rate (RR). Essentially, the RR represents the percentage of forecast efficiency savings that were found to be present when usage was measured through customer billing data. The purpose of Phase 1 was to produce RRs that provide insight into the accuracy of eTools as a basis for further investigation, not to produce a fully representative realization rate.

There are several ways to calculate the RR. In this analysis, DNV used three accepted methods, which showed RR results of 68%, 66%, and 64%. This means that the evaluated results were 64% to 68% of the eTools results. If described instead as an overestimation percentage, the three methods showed that eTools results were 47% to 56% higher than the evaluated results measured using a before and after billing analysis.[1] Table 2-1 the ratio-estimator RR (in the far-right column) is a ratio of the sum of savings for each approach. The other two RRs in the table (left columns) are calculated from regression lines through scatter plots of the two approaches (Figure 2-5 and Figure 2-6) based on savings, or savings as a percent of consumption. The three methods for determining RR weight customer facilities differently, but overall, provide consistent evidence that eTools savings are statistically greater than those found from the billing analysis conducted in Phase 1. This difference needs to be investigated further.

These RRs are conservative values because the billing analysis savings (in the numerator) are all advancement savings[2] (baseline is existing efficiency), whereas some eTools savings (in the denominator) are replacement savings utilizing a standard efficiency baseline greater than the existing efficiency, which decreases the denominator. If the two approaches were perfectly aligned, the resulting RR would be greater than one (>100%) making the difference in savings larger than indicated by these results.[3]

Table 2-1. Realization rates regression vs. quotient of sums

Population	Regression Trend RR		Ratio-Estimator RR
	Savings	% of Consumption	
Full analysis population	66%	64%	68%

The billing analysis method offers empirical results to compare against eTools' engineering estimate method. The billing analysis is a comparison of weather-normalized pre- and post-installation consumption that offers an estimate of advancement savings based on the consumption that occurred at the site. The primary risk to the billing analysis approach is the presence of non-routine events (NREs) that could undermine the assumption of steady-state pre- and post-installation operations separate from the energy efficiency measure's (EEM) implementation. NREs may cause significant changes (either positive or negative) in energy usage. Their impacts can also be small and impossible to identify within the distribution of energy savings estimates, but the presence of many NREs can bias billing analysis results in either direction.

[1] RR values have changed from those noted in the Phase 1 Study filed in EB-2021-0002, Undertaking J3.7 due to a change in the project start date field used in DNV's analysis. The Phase 1 Study reported values of 70%, 62%, and 64%, respectively. Details concerning this change are noted in Section 2.3.

[2] Advancement savings is the OEB term for savings calculated relative to existing efficiency at the site prior to measure installation. Replacement savings is the OEB term for savings calculated relative to the standard efficiency measure that would have been installed in the absence of the program measure.

[3] Even if all sites with negative savings are removed from the analysis, an action that ignores the natural variability of billing analysis results and injects upward bias into the results, these results stay well below one at 73%, 83%, and 91% respectively. These results should also be compared to an expected RR greater than one.

While addressing NREs directly is considered best practice in pre-post billing analysis, it is difficult to do so in a way that does not risk exchanging one source of potential bias for another.

A primary objective of this analysis was to explore if any potential sources of bias existed in eTools savings estimates. The analysis, in this first phase, was not designed to provide an exhaustive, fully-representative, RR. Rather, if the preliminary billing analysis results indicated either over or under-estimated savings, the site-level savings estimates could be used to explore potential sources of bias within the eTools calculator. In this preliminary stage, no attempt to address NREs was made. This means the resulting RR assumes NREs across the entire study population do not bias the result. Similarly, this result also assumes there are no underlying general trends, impacting natural gas usage, across time. That said, qualitative considerations were made as to the possibility that NRE-related bias could explain the preliminary RRs. Some considerations include:

- The billing analysis assumption that all resulting savings are from an advancement baseline could be a source of upward bias.
- eTools and the billing analysis both utilize outdated weather normals that substantially overestimate heating degree days (relative to current standard practice and expected future temperatures) producing an upward bias to both eTools savings and the billing analysis savings.

The analysis explored some potential drivers of low savings realization, such as intervention type, eTools version, audit sector, and pre-intervention consumption, but no obvious relationships were identified. The RR figures in this Phase 1 are preliminary results only. There are many known limitations, discussed in the memo body, to the comparison as it was done in Phase 1 that could make the actual performance of the e-Tools model better or worse than the preliminary numbers. Phase 2 is intended to address the identified limitations from Phase 1.

2.2 Phase 1 objectives and approach

The objectives of Phase 1 of the project were to:

- Estimate a RR for advancement period savings (existing equipment baseline) using a PRISM-based billing analysis for boilers installed through the EGI custom commercial, industrial, and multi-residential (including low-income) programs.
- Provide next steps to explore correlations between eTools project attributes and the alignment of eTools and billing analysis savings.
- Establish and maintain transparency throughout the project.
- Follow industry best practices.

The analysis approach included the 4 stages of data cleaning, weather-normalized savings calculation, site selection, and comparison of calculated savings with eTools modelled savings. Table 2-2 provides a summary of differences between the billing analysis and eTools approaches that could impact results.

Table 2-2. Summary of differences across billing analysis and eTools approaches

Area	Billing analysis	eTools	Comments
Data sufficiency	Two years pre- & post-implementation, actual reads only, minimum number of data points overall & in heating season	One year pre-implementation data, uses actual & estimated reads, selected from several years of consumption data based on good coefficient of determination	Best practice: Limiting to actual reads, 12 data points, and sufficient seasonal data to support heating trend.

Area	Billing analysis	eTools	Comments
Weather-normalizing regressions	Variable degree-day, separate for pre- & post-implementation	Fixed degree-day base	Variable degree-day offers the greatest flexibility to optimize data
Weather data	Calculate heating degree days (HDD) for specific days in each actual data bill period	HDD based on daily weather data	HDD for specific consumption days is essential to establish correlation
Weather normals	Required daily normals for variable DD modelling, so used actual weather year in last 10 with closest HDD to normals (had to be the coldest year to match the normal used by eTools)	Weather normals from 1970-2000 or 1980-2010 from Environment Canada.	Minimal effect on results. Also compared results based on fixed DD models using consistent normal. Historic weather normal are not representative of expected temperatures during EEM expected useful lives
Baseline efficiency in savings estimate	Existing efficiency (advancement savings)	Mix of existing & standard code (advancement & replacement savings)	Billing analysis results would be greater than eTools, all else being equal.
NREs	Not addressed. For this analysis, assumed not to bias result.	Could be present in pre-implementation data used to calibrate engineering estimate	NREs may explain some portion of the difference between evaluated savings & eTools savings but are extremely unlikely to explain most of the difference.

2.3 Data cleaning

Billing consumption data were first “rolled-up” to non-estimated reads. That is, estimated reads were combined with subsequent reads until an accurate reading for the combined billing period is confirmed with an “actual” read. For example, many sites offer monthly consumption reads but every other month had an estimated, not actual, value. The modelling process for the validation should reflect only “actual” reads rather than including reads that are themselves estimates from the utility with respect to when consumption took place. To have enough data for a robust model, the analysis included two full calendar years of pre- and post-installation data requiring a minimum number of data points as well as a minimum amount of data coverage during those two years. At the time of assessment, the eTools weather normalization procedure appears to use 12 months of data that are often a mix of actual and estimated billing data. Weather normalizing with too little actual data is a greater risk to the analysis than the possibility of including additional NREs by expanding windows to two full calendar years.

In the data cleaning step, DNV also established periods for calculating pre-intervention and post-intervention savings. For the original Phase 1 memo, data dated close to the project date variable in eTools–three months before the date and the next three to six months afterward[4]—were removed to account for lags in data entry or adjustments to the new equipment. Then the two years prior to this “exclusion period” were defined as the pre-intervention analysis period and the two years afterward as the post-intervention analysis period.

[4] If the project date occurred in spring, a longer exclusion date was created to ensure that the post period contained two full heating seasons.

EGI later indicated that the eTools files themselves had a more accurate way to estimate when the boiler was installed than simply relying on the tracking data field that was used as part of the initial Phase 1 analysis. Initial reporting used the "project date" variable from the tracking data. In response to the new information provided by EGI, DNV updated its analysis, relying on installation information fields from the eTools project files directly to help improve the accuracy of boiler installation dates. The preferred field for installation year is the "replacement year" variables for each space heating and water heating boilers. As these fields do not contain values for all of the sites in the sample, when "replacement year" values are absent, the year of "project closing date" is used instead; when the year of the "project closing date" is also absent, the year of the "project date" field is used. Once the year of installation was determined, the exclusion period was defined as the entire potential heating period in the installation year, August through the following April. Consumption during the exclusion period is excluded from the dataset used in analysis.

This shift in project dates and derived exclusion periods affected which sites met DNV's criteria for data sufficiency. This change from the initial Phase 1 analysis is discussed in Section 2.6.

2.4 Weather-Normalized savings calculation

For each premise in the analysis, DNV fit a premise-specific degree-day regression model separately for the pre and post periods, modelling the heating energy consumption for each billing period as a function of the total number of heating degree days during that period, as shown below:

$$E_m = \mu + \beta_H H_m + \varepsilon_m$$

where:

E_m	=	Average consumption per day during interval *m*;
H_m	=	Specifically, $H_m(\tau_H)$, average daily heating degree-days at the base temperature(τ_H) during meter read interval m, based on daily average temperatures over those dates;
μ	=	Average daily baseload consumption estimated by the regression;
β_H	=	Heating coefficient estimated by the regression;
ε_m	=	Regression residual

To produce a model specific to the energy consumption dynamics of each site, a variable degree-day model was fit. This variable degree-day approach entails the following:

1. estimating each site-level regression and period for a range of heating degree-day bases
2. choosing an optimal model (with the best fit, as measured by the coefficient of determination R^2) from among all models.

With degree-days allowed to vary, the estimated heating degree-day base τ_H approximates the highest average daily outdoor temperature at which the heating system is needed. These base temperatures reflect both average thermostat setpoint and building dynamics such as insulation, internal, and solar heat gains.[5] The base temperatures for most sites

[5] The analysis allowed different optimal degree-day bases for pre- and post- periods. This is standard best practice. DNV also performed the analysis using the fixed degree day base consistent with eTools. The flexible degree-day base does not cause substantially different results but does produce slightly higher estimates of savings than the fixed degree day base.

shifted between pre and post periods, with an average decrease of approximately 2% in the base temperature used. There was no statistically significant aggregate trend associated with a shift in degree day basis and the difference between savings reported by eTools and those found by DNV's analysis. The sites with higher base temperatures used for post intervention analysis had lower savings reported by eTools at approximately the same proportional level as those found in DNV's evaluation.

For this model, DNV also decided to weight consumption data points differently in the model based on the number of days included in the billing period. Periods with very few days were given low weights because they are more likely to be noisy because of day-to-day anomalies. Data points that included many months of data were also down weighted, as they were more likely to include both days with and without heating, and so may not represent the assumed linear relationship of heating and gas usage. Data points with greater than 65 days of data were down weighted using the function:

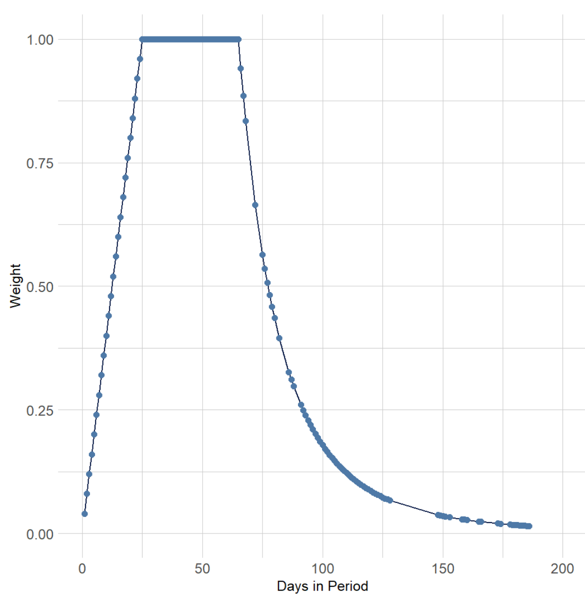
$$Weight = 65 - \left(\frac{65}{Number\ of\ Days}\right)^4$$

Datapoints with fewer than 25 days (Figure 2-1) were down weighted using the following function:

$$Weight = \frac{Numer\ of\ Days}{25}$$

This weighting schema was applied to data points representing different period lengths in the billing analysis model. This recognizes that a read with 5 days of data should not have the same weights as one with 30.[6] Points shown in Figure 2-1 represent data points in the model, but many points may be in the same spot. Most points fall in the weight =1 category. Fifteen points representing periods longer than 200 days are excluded.

Figure 2-1. Visual of weighting schema



[6] It is not uncommon to weight using count of days to account for the different amount of daily data in different length periods, especially when billing periods on are consistent monthly cycles. This analysis diverges from that here primarily due to the inclusion of longer read periods present in the billing data, which have less information to support heating trends. These periods are down-weighted rather than letting them get extra weight.

For each period, pre and post, DNV combined the coefficients of the fitted model with normal-year degree-days to calculate normalized annual consumption (NAC) for that period. That is, the fitted model was used to predict what the pre and post period energy usage would have been given weather from a given normal year.

The eTools models use normal degree day bases from either the years 1970-2000 or 1980-2010, which are not reflective of current weather trends. Therefore, billing analysis utilized a normalized weather base that is not representative of current weather but is aligned with eTools' weather data. Given the upward trend in temperatures, eTools should utilize weather normal values based on the 10 most recent years of data.

Additionally, EGI was only able to provide a fixed (18 °C) base temperature degree-day count, rather than actual normal temperature data for these periods. The billing analysis relies on a variable degree-day base and this analysis cannot use these degree-day counts. Instead, for each weather station to be used, DNV selected a year for which there were temperature data and whose degree day counts at an 18 °C base matched the historical normals well. Then the actual temperatures from these years were used as stand-ins for the historical normals to calculate normalized annual consumption and normalized savings.

For each site, the difference between pre- and post-program NAC values (∆NAC) represents the change in consumption under normal weather conditions. These are the billing analysis estimated savings, referred to as *evaluated savings*.

2.5 Site selection

The following criteria were used to identify the sites for this analysis:

Pre- and post-installation data. The billing analysis involves a comparison of gas usage before and after the boiler measure installation. DNV eliminated any sites without data in the “pre” period (the two years before the installation) or the “post” period (the two years after the installation). The site-level modelling approach also assumes that no other major events (aside from weather) caused changes in gas usage in either the pre or post periods, so sites with other non-boiler measures installed during the analysis period were also eliminated.

Data sufficiency. To be accurate, the modelling approach also requires sufficient data for each site in both the pre- and post-installation periods for a robust linear model. Because of this, sites that had fewer than 10 total data points in either the pre or post period were removed. Additionally, the PRISM approach flexibly chooses a temperature (degree day base) below which the boiler is active and energy use will increase as the temperature decreases. An accurate characterization of the relationship between consumption and heating degree days from an optimal degree day base is essential to the weather normalization process. Therefore, to estimate a robust model, there must also be sufficient data points in this range where energy use is increasing with temperature decrease. Any sites with fewer than six total data points in this temperature range, in either the pre or post periods, were also removed.

Data coverage. The models should capture enough of the pre- and post-period timeframes to accurately represent the site's operations during these periods. Sites without 80% of the days in the pre or post period represented in the data were removed. For example, this rule would remove a site whose data coverage was missing any more than about 5 months of the total 24 months of data targeted. These could be five key winter months which would make a model impossible to reasonably estimate.

Model fit criteria. In addition to having enough data for the models to fit, DNV also chose sites where the models fit well, and therefore are likely to accurately predict how energy use changes with the weather, allowing a good comparison of the pre and post conditions under a normalized weather situation. Using the site-level model discussed above, the adjusted R^2 measure of model goodness of fit was calculated to assess the relative accuracy of models with different degree-day bases.

The adjusted R^2 statistic varies from zero to one, with zero meaning the model does no better than an average, and one meaning the model explains all the variation in energy usage. Sites with a space heat or space and water heat intervention with an R^2 less than 0.8 were eliminated. Sites with a water heat intervention only tended to have lower R^2 values, so to include a large enough sample of these sites, sites with an R^2 less than 0.5 were eliminated.

This selection process left 475 total sites for analysis. A summary of a number of sites retained after each elimination step is shown in Table 2-3.

Table 2-3. Removal of sites due to data insufficiency or model fit

Elimination Step	Sites Remaining
Removing those with other measures during analysis period, and those lacking data during the pre or post period	856
Removing those with fewer than 10 points in either the pre or post period	627
Removing those with fewer than 6 points in the temperature range where energy use varies, in either the pre or post period	623
Removing those with less than 80% of days present in either the pre or post period	564
Removing those with R^2 values less than 0.8 (Space Heat or Space and Water Heat) or 0.5 (Water Heat)	475
Total	**1,097**

Below is the distribution of R^2 values among the 564 sites with sufficient data.

Table 2-4. R^2 distribution of sites with sufficient data

R^2 bin	Number of Sites
Less than 0.5	27
0.5-0.7	36
0.7-0.8	49
0.8-0.9	121
Greater than 0.9	331

The numbers of sites remaining in different categories after the above filters are applied are shown in the Table 2-5.

Table 2-5. Filtered table of simple boiler installations and sites retained for analysis

<table>
<tr><th colspan="2" rowspan="2">Sector</th><th colspan="2">Type of Boilers (Installed in a Single Year)</th><th rowspan="2">Original Number of Accounts in Each Boiler Combination</th><th rowspan="2">Retained Number of Accounts in Each Boiler Combination</th></tr>
<tr><th>Space Heat</th><th>Water Heat</th></tr>
<tr><td colspan="2" rowspan="3">Commercial</td><td>✓</td><td></td><td>366</td><td>153</td></tr>
<tr><td>✓</td><td>✓</td><td>33</td><td>11</td></tr>
<tr><td></td><td>✓</td><td>41</td><td>12</td></tr>
<tr><td rowspan="9">Multi-Residential</td><td rowspan="3">Low Income</td><td>✓</td><td></td><td>30</td><td>22</td></tr>
<tr><td>✓</td><td>✓</td><td>50</td><td>27</td></tr>
<tr><td></td><td>✓</td><td>21</td><td>17</td></tr>
<tr><td rowspan="3">Market Rate</td><td>✓</td><td></td><td>303</td><td>144</td></tr>
<tr><td>✓</td><td>✓</td><td>148</td><td>61</td></tr>
<tr><td></td><td>✓</td><td>81</td><td>28</td></tr>
<tr><td rowspan="3">Total</td><td>✓</td><td></td><td>333</td><td>166</td></tr>
<tr><td>✓</td><td>✓</td><td>198</td><td>88</td></tr>
<tr><td></td><td>✓</td><td>102</td><td>45</td></tr>
<tr><td colspan="2" rowspan="3">Total</td><td>✓</td><td></td><td>699</td><td>319</td></tr>
<tr><td>✓</td><td>✓</td><td>231</td><td>99</td></tr>
<tr><td></td><td>✓</td><td>143</td><td>57</td></tr>
</table>

2.6 Comparison of eTools and Evaluated Savings (Billing Analysis)

DNV received data on 456 projects from EGI, as EGI was unable to find digitized data from approximately 20 projects. Upon receipt of this data, 8 sites had two associated projects and so were dropped, for a total of 440 sites and projects. Two sites where the mismatch between eTools and evaluated savings was a clear outlier compared to the other data were also removed for a final total of 438 sites.[7]

However, as noted in section 2.3, the “exclusion period” established by DNV shifted with the provision of additional information from EGI. As the site sufficiency metrics rely on the amount of billing data before and after the exclusion period, as well as the model results, which will also shift when a different time span is observed, several sites initially used in the Phase 1 analysis were excluded and no longer considered in the updated analysis. Table 2-6 is an attrition table showing how many sites fail to meet the sufficiency criteria after the new, more accurate exclusion period has been applied.

[7] Both dropped sites had very small percentage savings coming out of eTools. Both less than 1.5%. The calculation of difference in fraction savings over eTools saving got very big, one positive, one negative.

Table 2-6. Attrition table of sites used in Phase 1 with sufficiency metrics appropriately applied

Elimination step	Sites eliminated	Sites remaining
Sites used in Phase 1 memo	-	438
Removing those with less than 80% of days present in either the pre or post period	61	377
Removing those with R^2 values less than 0.8 (Space Heat or Space and Water Heat) or 0.5 (Water Heat)	17	360
Removing those with other measures during analysis period	2	358
Removing those with fewer than 10 points in either the pre or post period	2	356
Removing those lacking data during the pre or post period	1	355
Total	**83**	**355**

Following the updated exclusion period analysis, 18.9% (83) of sites used to produce results as part of Phase 1 fail to meet DNV's sufficiency criteria for analysis under the newly applied exclusion periods. The amended Phase 1 results relied on only the 355 sufficient sites shown in Table 2-6.

Most of the newly eliminated sites are due to insufficient days present in the pre or post period. Under DNV's understanding of installation dates and the resulting exclusion periods used in the Phase 1 analysis, project dates in the original dataset trended earlier than the actual reported installation year, which shifted the exclusion window into the past. With the correct, later installation date applied, many accounts lacked sufficient post-intervention data.

Once site sufficiency was established, DNV calculated several metrics to compare eTools-estimated to evaluated savings:

Difference in savings: The difference between each savings estimate in m^3

$$Evaluated\ Savings - Etools\ Savings$$

Difference in savings, as a percent of total usage:

$$\frac{(Evaluated\ Savings - Etools\ Savings)}{Evaluated\ Pre\ Usage}$$

Difference in percent saved:

$$\frac{Evaluated\ Savings}{Evaluated\ Pre\ Usage} - \frac{ETools\ Savings}{ETools\ Pre\ Usage}$$

DNV also calculated a RR, the ratio of total evaluated savings overall evaluated projects to eTools claimed savings for the same projects:

$$\frac{\sum Evaluated\ Savings}{\sum ETools\ Savings}$$

2.7 Phase 1 Results

The reported preliminary RR for the original Phase 1 analysis was 0.70. However, after applying the new project installation dates and modifying the exclusion periods and reducing the population of sites to only those meeting our stated sufficiency criteria given the new exclusion periods, the parallel RR was found to be 0.68. This means that at most only 68% of the savings calculated by eTools showed up in the evaluated savings for the selected sites. Possible explanations for this are explored in the following graphs.

There are multiple possible explanations for differences between the eTools estimates and the billing analysis estimates. The hypothesis (put forward in past CPSV recommendations) that motivated this study is that eTools is overestimating savings. The preliminary results are consistent with that hypothesis.

Also, it has been acknowledged from the beginning of the analysis, pre-post analyses of this sort can be sensitive to NREs or other external trends. While an engineering-based model will always estimate positive savings when provided with input showing an increase in efficiency, variations in consumption and unknown external factors can cause post-installation usage to be higher, or lower, than pre-installation usage even after accounting for weather. Aggregated across all sites, the external factors not accounted for in an engineering model could have a net effect of either more or less savings than initially projected. Finally, the limitations of this analysis approach could contribute to the differences. Specific reasons for potential differences in the evaluated versus eTools estimates that relate to the analysis approach may include:

- Different pre-periods being modelled
- The difference between variable and fixed degree day base models
- The normal-like years used in the evaluation model were not the exact same as the 1970-2000 normals used by eTools.

These analysis-related differences, as well as possible external trends and effects, are unlikely to fully explain the degree of difference in savings estimates leaving a reasonable presumption that eTools may consistently overestimate savings.

The black line in each of the figures below is a 45° line, showing where the data points would be if the two estimation techniques yielded the same results. If the x-axis estimate (DNV-evaluated results) is higher, points will fall below the black line. Similarly, if the y-axis estimate (EGI eTools results) is higher, points will fall above the black line. The blue line in the figures is a linear estimate of the relationship between the two.

In comparing the eTools versus evaluated energy consumption and savings, the analysis first looked at how total consumption values compare. Overall, they are very similar. Figure 2-2 shows that total evaluated pre-project consumption is an average of 2% higher than eTools estimates. The Phase 1 analysis found a difference of 3.75%. By improving the exclusion period definition logic to match measure installation dates more closely, DNV's estimate was closer to the reported eTools value than before.

Figure 2-2. Pre-project consumption

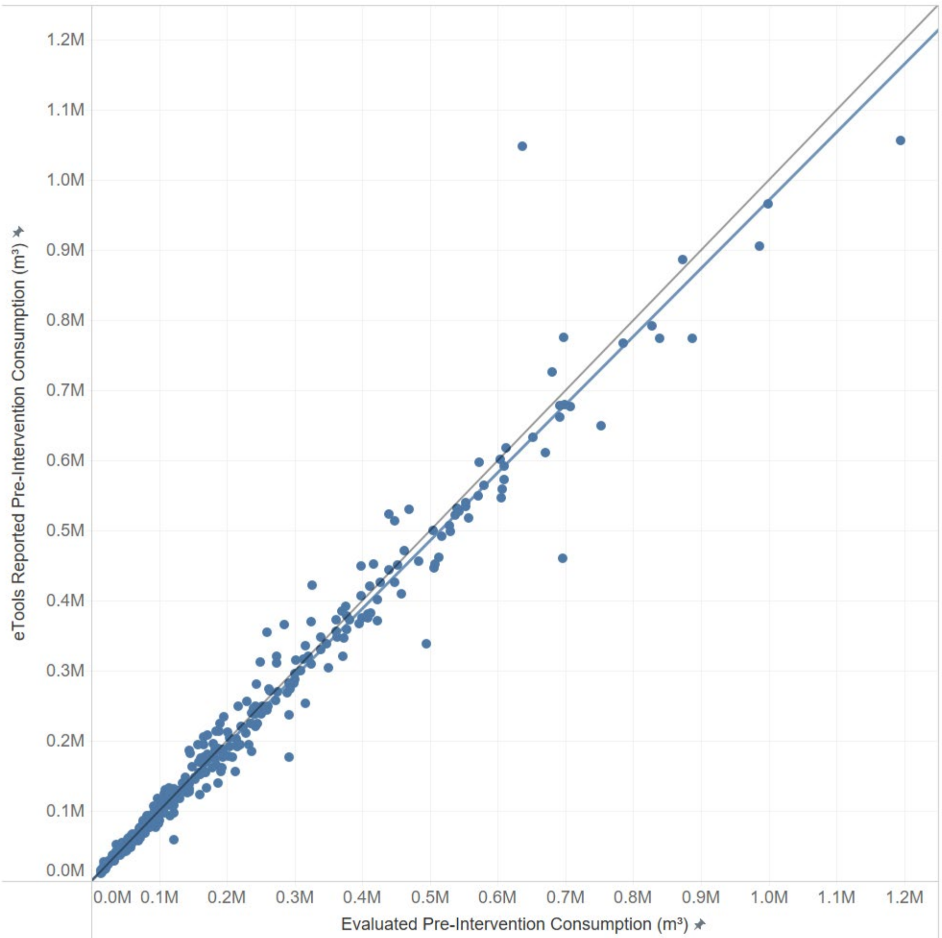
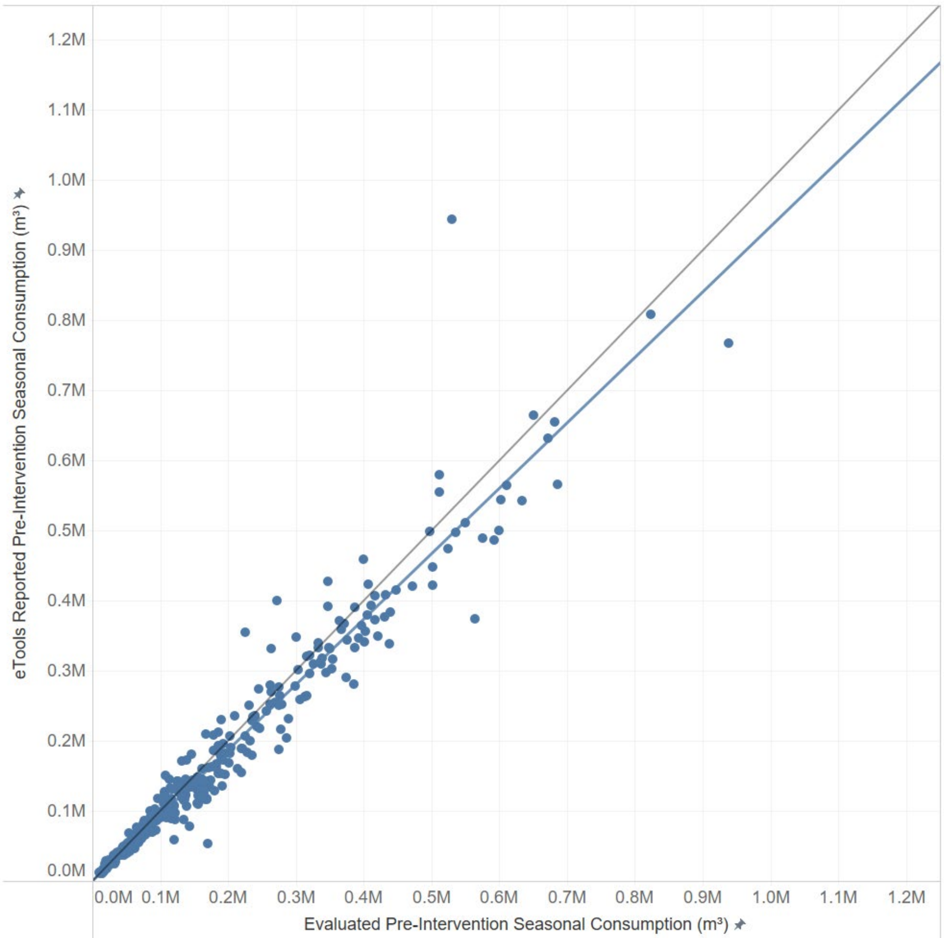


Figure 2-3 shows that the evaluated pre-project seasonal consumption is greater than eTools estimates by an average of 7.4%. The original Phase 1 analysis found a difference of 7.7%, however, utilizing more accurate project installation dates lead to smaller differences between reported eTools figures and evaluated figures than before.[8] Overall, these values show a high correlation between individual site-level estimates across the two methods, but the evaluation approach allocates a greater proportion of consumption to seasonal or weather-correlated consumption.

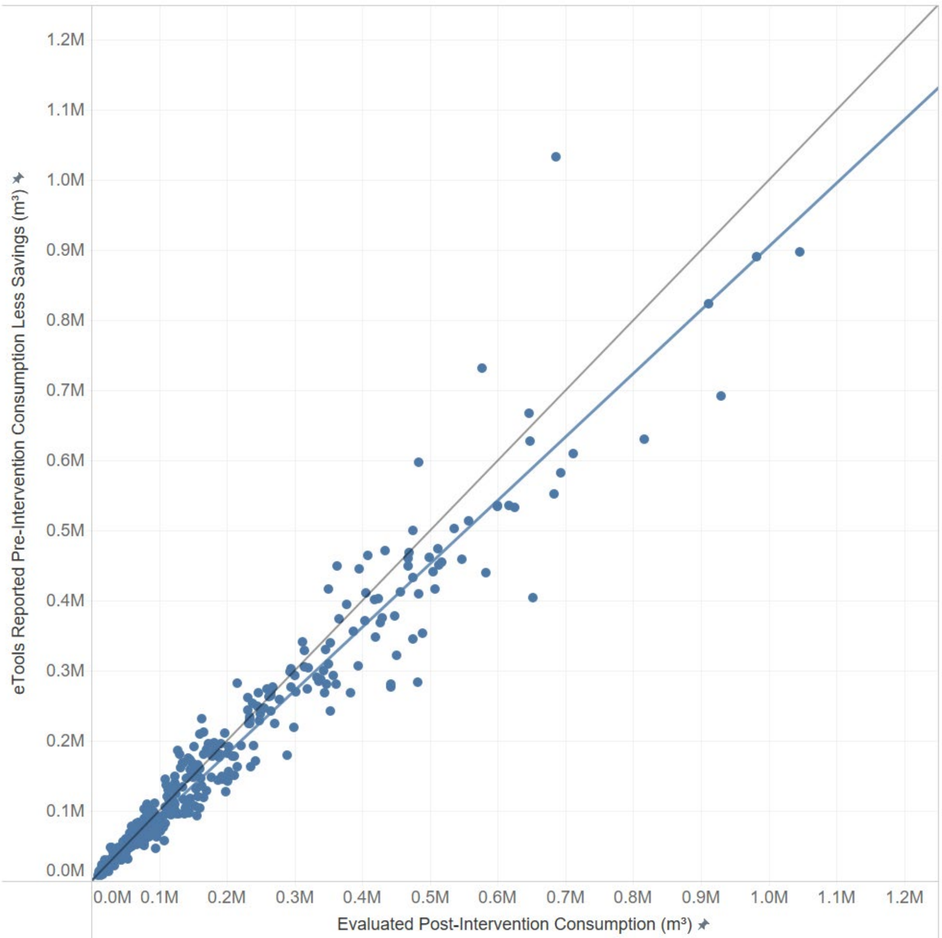
[8] This shift is also likely due to the shift in sample composition associated with the removal of sites no longer meeting sufficiency criteria for analysis. The sites removed from analysis trended towards having lower eTools pre-intervention seasonal consumption relative to billing analysis pre-intervention seasonal consumption.

Figure 2-3. Pre-project seasonal consumption



Because eTools does not provide post-period consumption, it was calculated by subtracting reported savings from a sum of seasonal and non-seasonal pre-period consumption. Figure 2-4 compares DNV's total evaluated post-period consumption using this metric and shows that evaluated estimates are 10.1% higher than eTools estimates, which follows from the lower overall evaluated savings estimates (Figure 2-5). The original Phase 1 analysis found 12.1% higher consumption.

Figure 2-4. Post-project consumption (note that eTools values are calculated)



It is important to note that the evaluated estimates include all observed consumption-related site changes, whether project-related or not, which include operational, behavioral, and other changes. In contrast, eTools calculates quantitative usage changes based on boiler efficiency, utilizing normalized whole-building gas consumption, and engineering assumptions.

Despite these differences in estimation technique, DNV would expect to see some correlation between the engineering estimates and the billing analysis estimates. Billing analysis measures consumption change between pre- and post-intervention periods. Therefore, the operating hypothesis is that a plurality of consumption changes identified via billing analysis is due to the program intervention, on average.

While Figure 2-5 and Figure 2-6 (displaying m^3 saved and fractional consumption saved) appear to show limited correlation between these estimates, a simple regression-based RR (e.g., forced through zero) produces estimates of 66% and 64% respectively, with greater than 90/10 precision. The original Phase 1 analysis found estimates of 62% and 64%.

The points below zero “Evaluated Fraction Saved” indicate that the billing analysis yielded negative savings, or increased gas consumption after the project was completed. eTools, by design, will not yield negative estimates. These sites represent less than 20% of the sites; major outliers will be discussed in the NRE analysis in Section 7.6.

Figure 2-5. Comparison of consumption saved (m^3) with 1:1 trend line

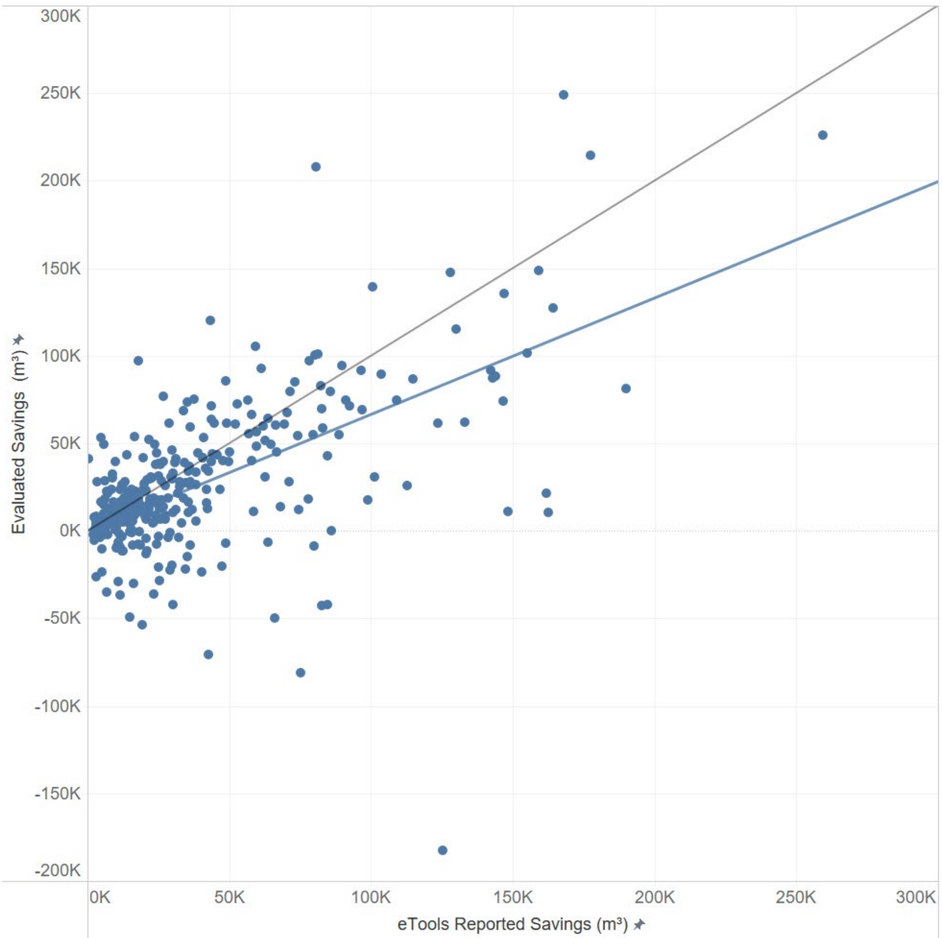


Figure 2-6. Comparison of fraction of consumption saved with 1:1 trend line

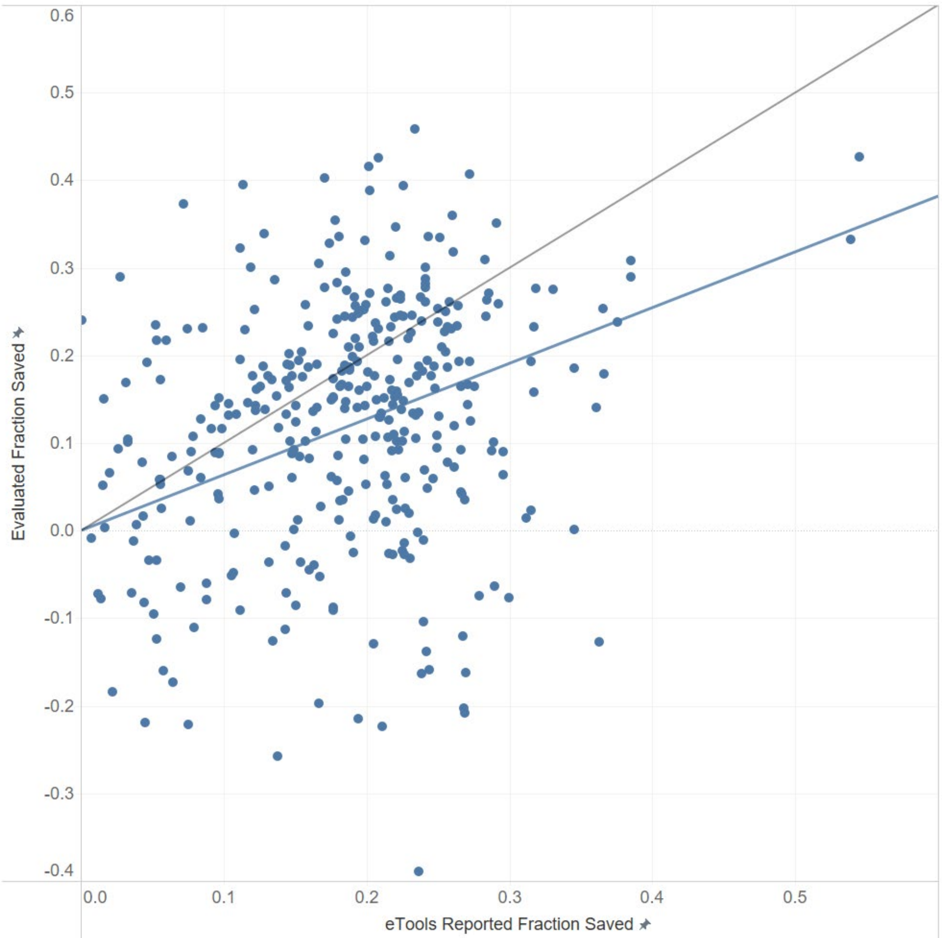
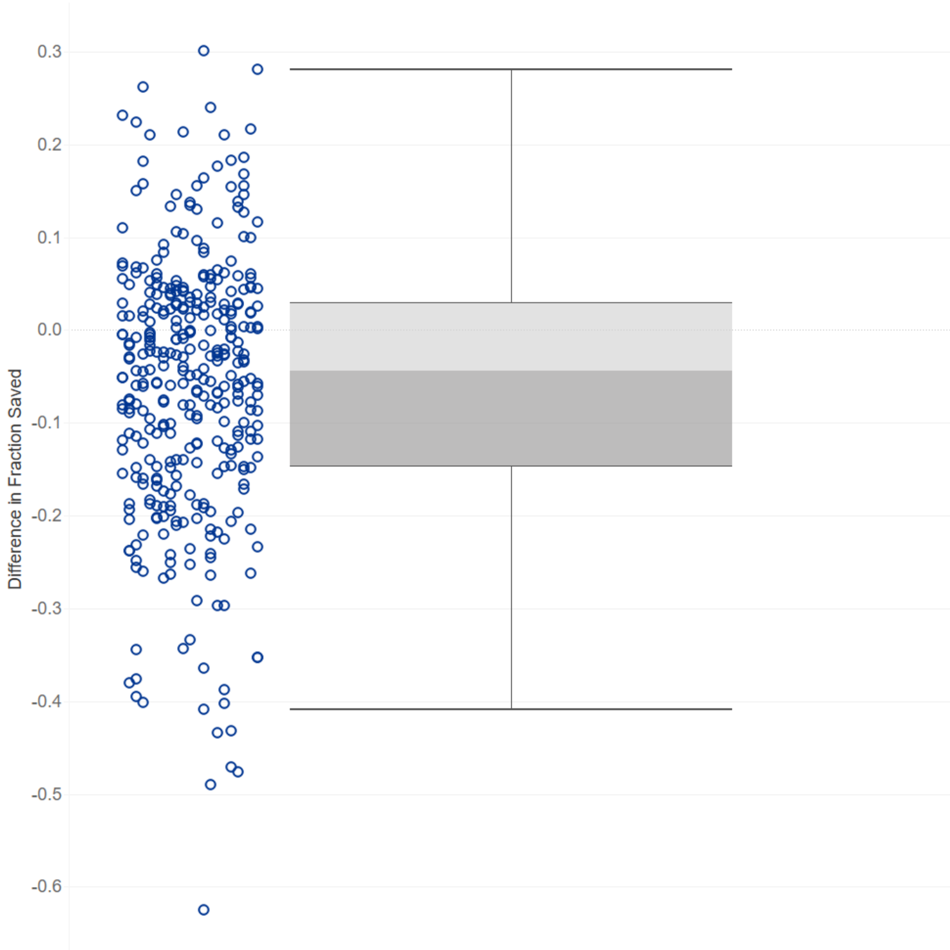


Figure 2-7, similarly, shows the difference between these two fraction-saved numbers, i.e., Evaluated Fraction Saved less eTools Fraction Saved.[9] Thus, if the evaluated fraction saved is greater, this number will be greater than zero; if the evaluated fraction saved is smaller, this number will be less than zero. As expected, given previous results, most points are less than zero, indicating that the evaluation is finding lower savings than eTools, and the spread is large, indicating no consistent level of difference. The horizontal spread simply allows all points to be seen. These results are consistent with plots of pre- and post-installation consumption in Figure 2-2 and Figure 2-4. Pre- and post-installation consumption is 2% and 11% higher than eTools, respectively, driving a roughly 6 percentage point difference in savings.

The spread of difference in fractional savings is not statistically significantly different from that reported in the original Phase 1Phase 1 memo.

[9] The boxplot provides the median (solid line in middle of box), the 25th and 75th percentiles (the box) and 1.5 the inter-quartile range as whiskers. The horizontal dashed line represents the mean, while the dashed triangles delineate the standard deviation.

Figure 2-7. Spread of difference in fractional savings



The next series of graphs explore if some types of projects may show eTools savings closer to evaluated savings. In the original Phase 1 analysis, there was not a highly statistically significant correlation found between different intervention types and the difference in fraction of usage saved; that remains true, and there is no statistically significant difference between the spread of difference in savings by intervention type between the Phase 1 memo and these amended results.

Figure 2-8. Difference in savings by intervention type

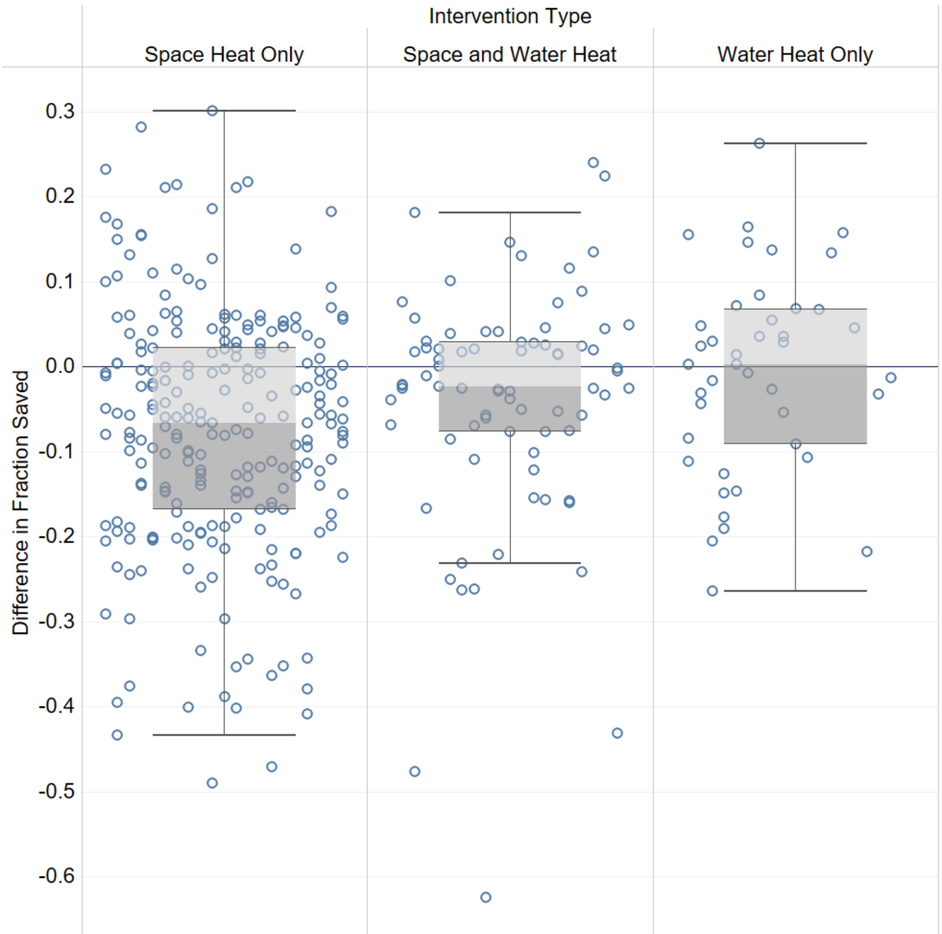
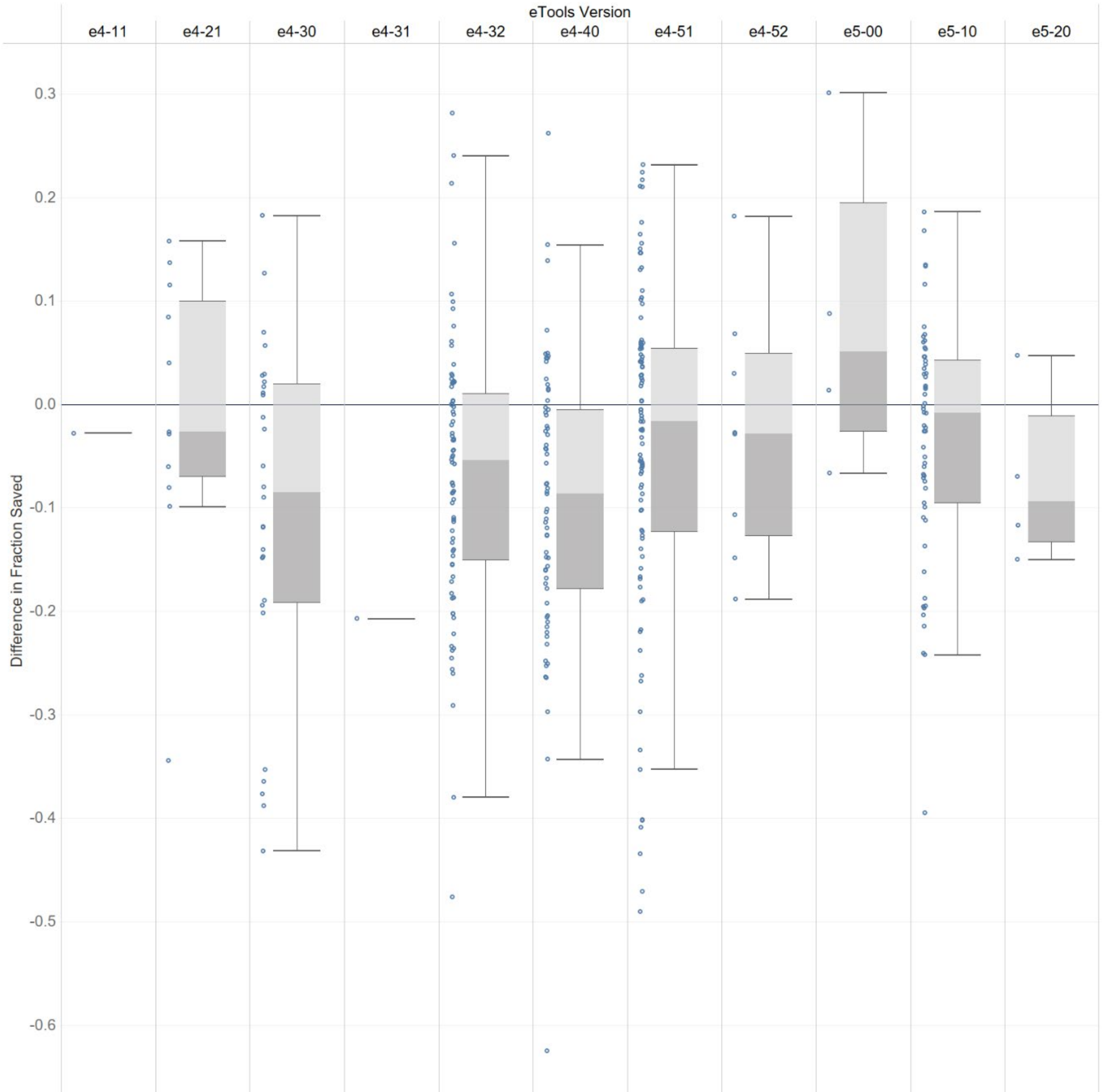


Figure 2-9 shows variation in the difference of fraction saved across eTools versions[10] found in the Phase 1 memo dataset. There is again no significant difference between these new results and those found in the previous Phase 1 analysis.

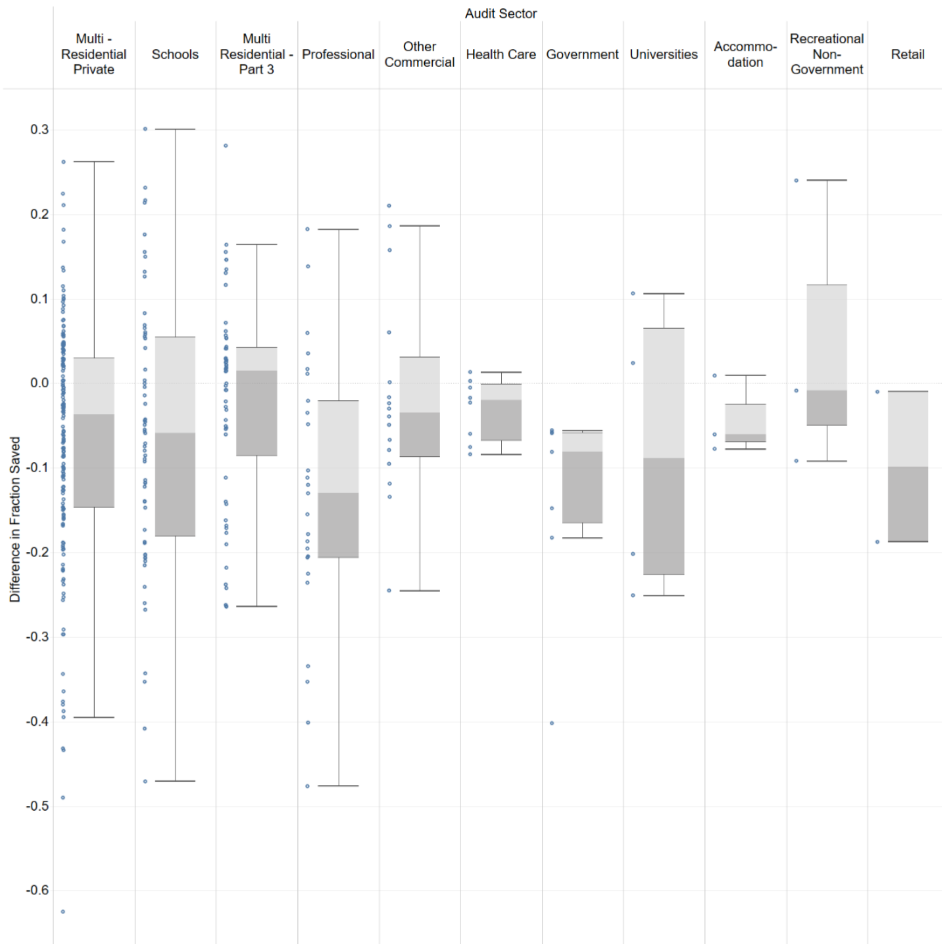
[10] Each eTools version is an update to the modelling software in the form of updates to calculation formulas, default assumptions, weather data, addition of energy saving measures, or bug fixes.

Figure 2-9. Difference in savings by eTools version



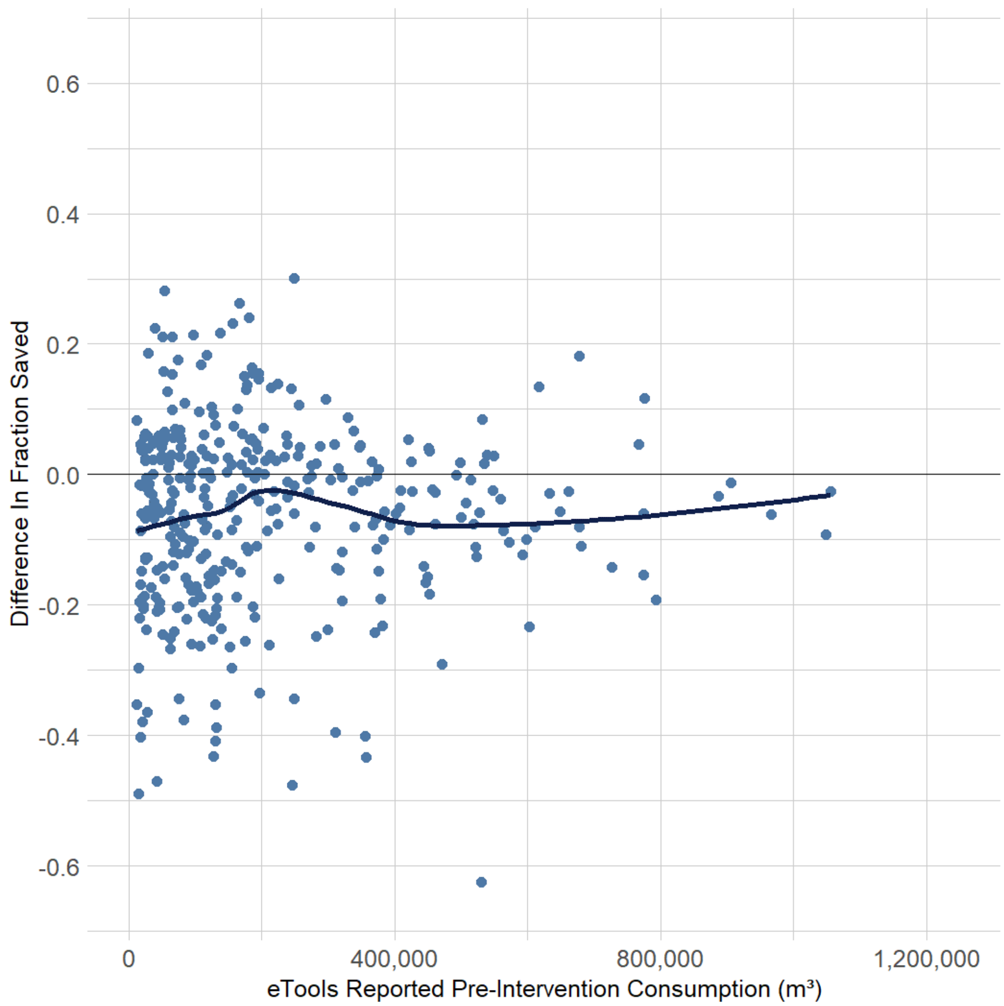
In Figure 2-10, we examine the difference in savings across Audit Sectors. In the original Phase 1 analysis, DNV found that a few Audit Sector categories appeared to perform better, on average: Multi-Residential Part 3, Other Commercial, and Health Care. With the shift in project installation dates, Multi-Residential Part 3 is the only remaining Audit Sector category where eTools savings estimates perform better, on average, than the evaluated savings from DNV’s billing analysis; and even in that case, with such a wide spread over zero, it is not an especially significant difference.

Figure 2-10. Difference in savings by audit sector



The LOESS trend line in Figure 2-11 relates the difference in fraction saved for a given site with the eTools reported consumption of that site. The original Phase 1 analysis found a tenuous connection that sites with the greatest pre-program consumption performed worse, on average, than more moderately sized sites. With improved exclusion dates applied, the LOESS trendline shows that for accounts with low and moderately high sized sites, the difference in fraction saved diminishes as site size increases. However, for sites in the middle of the distribution, there is an association with increased pre-intervention consumption and worse model performance. Generally, the relationship shows a trend towards a lower magnitude of difference in fraction saved as site size increases, but a linear regression applied to the data fails to find a statistically significant trend.

Figure 2-11. Difference in Savings by pre-intervention consumption



2.8 Phase 1 Conclusions

The comparison of eTools savings estimates with billing analysis results provides an opportunity to assess the accuracy of eTools. The billing analysis results are a purely empirical change in consumption from the existing technology period to the post-program technology period, controlling for weather. The updated Phase 1 analysis accounts for new information about project intervention dates and filters down to a subset of the sites analyzed in Phase 1 based on their data sufficiency metrics using the newly defined exclusion periods. The findings from Phase 1 of the evaluation are:

- Overall, at most 68% of the savings calculated by eTools showed up in the evaluated savings for the selected sites. This preliminary analysis did not address NREs, though it is unlikely that they could explain this low of an RR. See section 7.6 for analysis and discussion of NRE's in Phase 2. Some additional reasons for potential differences in the billing analysis versus eTools estimates related to the way the analysis was constructed are listed below. These differences are also unlikely to fully explain the large deviations in savings estimates:

- Different pre-implementation periods being modelled
- Differences between variable and fixed degree-day base models
- The weather normals used in the evaluation model were not the exact same as the 1970-2000 weather normals used by eTools

- Overall and seasonal pre-project evaluated site-level consumption show high correlation with individual site-level eTools estimates despite a difference in trends.
- The difference in trends indicates that the evaluation approach allocates a greater proportion of consumption to seasonal or weather-correlated consumption.
- All RRs were estimated with roughly 90/10 precision, meaning DNV is 90% confident that the true answer falls within the range of +/-10%.
- Comparison of eTools and evaluated savings were conducted for various project characteristics (heating end use, eTools version, and facility type) but at the individual characteristic level no discernible correlations were identified.

A caveat for the billing analysis is that the results are a purely empirical estimate of change in consumption from the existing technology period to the post-program technology period, controlling for weather. The billing analysis savings estimates may include non-program-related events (NRE) that impact consumption, which may obscure the estimated savings of the relevant EEM. Example NREs are as follows:

- Implementation of a control strategy different from the expected ex ante strategy
- Changes to operating schedules (hours of occupancy) or control strategies
- Behaviour of occupants (e.g., adjusting HVAC settings, etc.)
- Building shell renovations and additions, or changes to space usage (changing laundry rooms to gyms, etc.)

NREs are likely a significant driver of the extensive variation in the results at the site level but are unlikely to be primary drivers of the relatively poor RR at the population level. Non-program-related changes can cause either increases or decreases in post-period consumption. While the mean effect of non-program-related changes may make the RR worse, they are unlikely to be the primary driver of the low RR.

In Phase 1, some eTools projects had “replacement” savings in which “standard” units, were used as the baseline. Standard unit efficiency is based on mandated minimum efficiency ratings for newly manufactured units which are often higher than efficiencies of existing units. This was a structural bias in Phase 1 of the evaluation that caused the RRs reported in this memo to be higher than they would have been if only the advancement savings from eTools were utilized. See section 7.3 for discussion of the impacts of advancement savings in the Phase 2 analysis.

Some potential sources of error in the eTools savings include:

- Engineering default assumptions that are inaccurate which could lead to overestimation of savings
- Engineering errors related to interactive effects and additive limitations which could lead to inaccurate savings
- Inability to model complex manual operation of the baseline system. Control strategies like boiler purging, flue gas venting, supply temperature setback, etc. can be implemented manually in the existing system but that information can be difficult to gather or too complex to model in eTools which could lead to overestimation of savings.

Phase 2 is intended, in part, to address the biases from Phase 1, the influence of NREs, and the top two potential sources of error in eTools.

3 PHASE 2

3.1 Phase 2 objectives and approach

The objective of Phase 2 of the project was to identify the reasons that eTools estimates were greater than evaluated savings through engineering review, multivariate analysis, previous CPSV verification findings, and further analysis of Phase 1's sample billing data. This data will enable discussions and decisions regarding the future use of eTools in verification. The approach used in Phase 2 is described below.

3.2 Review of CPSV evaluation year 2019 results

Results from the most recent CPSV evaluation (EY2019) of boilers were used in the following sections 3.6, and 3.7. Further details are provided in those sections.

3.3 eTools version updates

eTools projects utilizing older versions of the calculator were migrated into the newest calculator version (as of January 2022) e7-00. Re-running older projects in the newest calculator was necessary to ensure results reflect the performance of the current eTools calculator and eliminate the potential variability in savings due to a mix of prior versions.

A newer version of eTools (e8-00) was released by EGI in March 2022, during Phase 2 of the study. A non-random sample of projects was updated to e8-00 to determine if there were significant differences in savings between e7-00 and e8-00. A significant difference in savings would warrant updating all projects to e8-00. The sample of projects updated to e8-00 resulted in negligible differences (<1%) in savings between their e7-00 and e8-00 counterparts. Therefore, e7-00 was utilized for the remainder of the Phase 2 study.

3.4 Extraction of eTools advancement savings

A secondary goal of updating savings for eTools projects utilizing the latest version was to extract advancement savings for all projects. Advancement savings are based upon the comparison of the consumption of the proposed boiler systems to the consumption of the existing boiler systems; these savings are more accurate for comparison to billing analysis results because of the common baseline between the two methods. The dataset utilized in Phase 1 contained only reported savings which were a mix of advancement and non-advancement savings. Many of the earliest projects included in the sample for this study utilized versions of eTools that did not always calculate advancement savings that could be extracted. Therefore, updating these projects to e7-00 enabled advancement savings to be extracted for all projects.

3.5 Adjusting existing boiler default efficiency

eTools utilizes a default thermal efficiency of 73% for existing boiler systems for which nameplate thermal efficiencies are unknown. This is significantly lower than the industry standard seen in most Technical Reference Manuals (TRMs) which often utilize 80% thermal efficiency as their baseline efficiencies for all replacement scenarios. To investigate the accuracy of this assumption, the thermal efficiencies of all existing boiler systems that did not utilize the default efficiency were reviewed. The efficiencies were then weighted by total system input capacities to determine the weighted average efficiencies for Space Heating (SH) and Domestic Hot-Water (DHW) systems. Results are displayed in Table 3-1.

Table 3-1. Existing non-default boiler thermal efficiencies

System Type	Total Project Count	Non-Default Project Counts	Min Thermal Efficiency (%)	Max Thermal Efficiency (%)	Weighted Average Efficiency (%)
Space Heating (SH)	369	92	58.0	97.0	80.1
Domestic Hot-Water (DHW)	188	85	70.1	97.0	81.8

The resulting efficiencies were more than seven percentage points greater than eTools' default efficiency. The weighted average efficiencies were utilized as default efficiencies to update advancement savings in projects that used default efficiency for existing boilers.

3.6 Adjusting proposed boiler settings

A review of the results from CPSV EY2019 revealed that the most common verification adjustments made to eTools boiler projects (based on customer reported information and data gathered from site visits) were as follows:

- Changes to boiler loop temperatures
- Changes to pumping, purge, and flue controls

In most cases, the changes were reversions of proposed setpoints and controls to those of the existing system. To investigate the potential overestimation of savings caused by overly ideal assumptions used for system commissioning and site operations, the values for the aforementioned parameters in the proposed systems were set equal to their existing system counterparts.

3.7 Non-routine events investigation

Data collected from CPSV EY2019 evaluation revealed only 2 of 18 boiler projects reported potential NREs. One site reported pipe insulation on their SH and DHW systems after the boiler projects, which should increase billing analysis savings compared to eTools. The second site reported no NREs at the time of the evaluation but mentioned that there could be future increases in gas load, due to a potential new building, which should decrease billing analysis savings compared to eTools savings. As evidenced by the customer-provided information noted above, NREs can have effects on system consumption in either direction. The aforementioned sites were not included in the study's sample; therefore, it was not possible to determine the manifestation nor impacts of the expected NREs.

Additionally, analysis of consumption load shapes for sites with negative modelled savings and sites with high magnitudes of difference in fraction saved between eTools results and our evaluated savings was performed. Figure 3-1 shows the load shapes of the sites with the five highest and lowest differences in fraction saved between the savings produced by billing analysis and those reported by eTools. These 10 sites represent the largest outliers in the findings, but a visual inspection shows that there are no noticeable anomalies present.

Some sites do contain some bill periods where average daily consumption rises or falls significantly, but the patterns observed are repeated in both the pre and post periods. Sites, such as site 11, see a shift from zero usage in the summer to high usage in the heating season, but this trend is present in both pre and post periods.

Figure 3-1. Load shapes of top and bottom five sites with greatest magnitude of difference in fraction saved

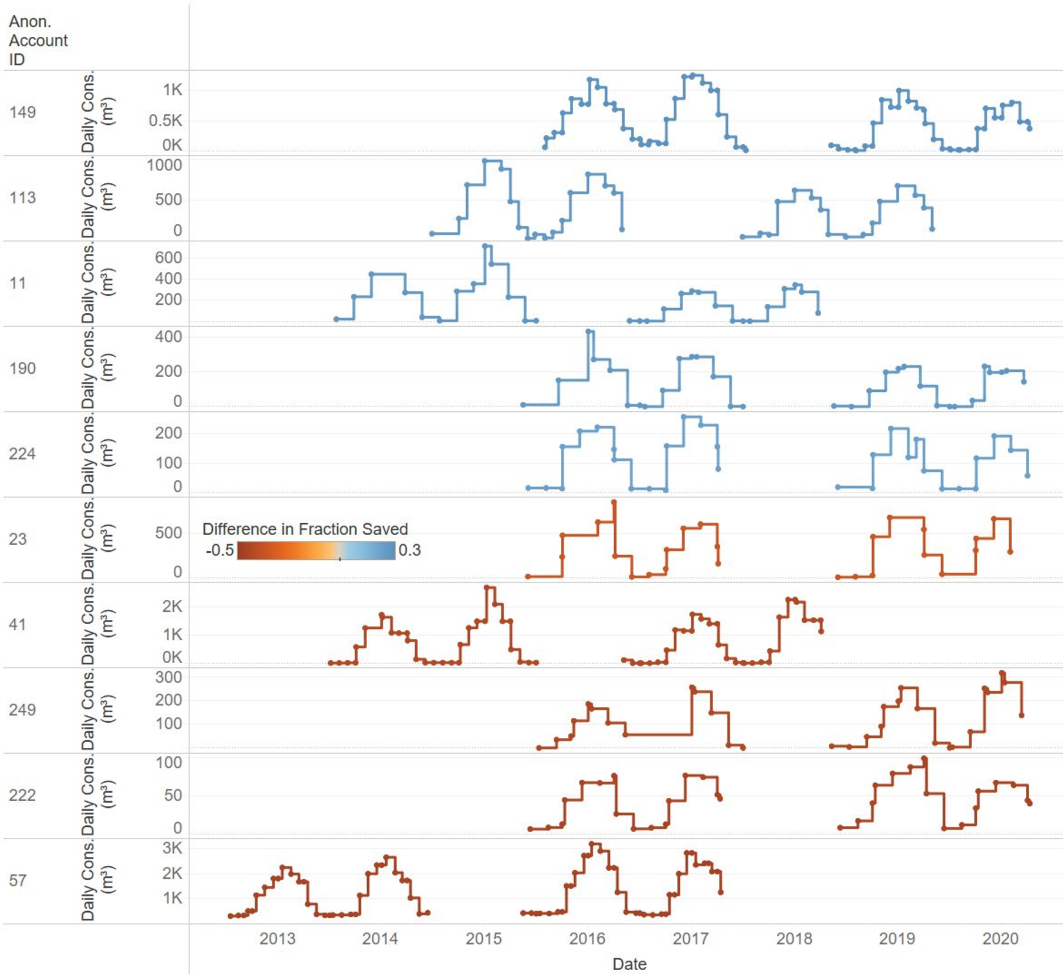
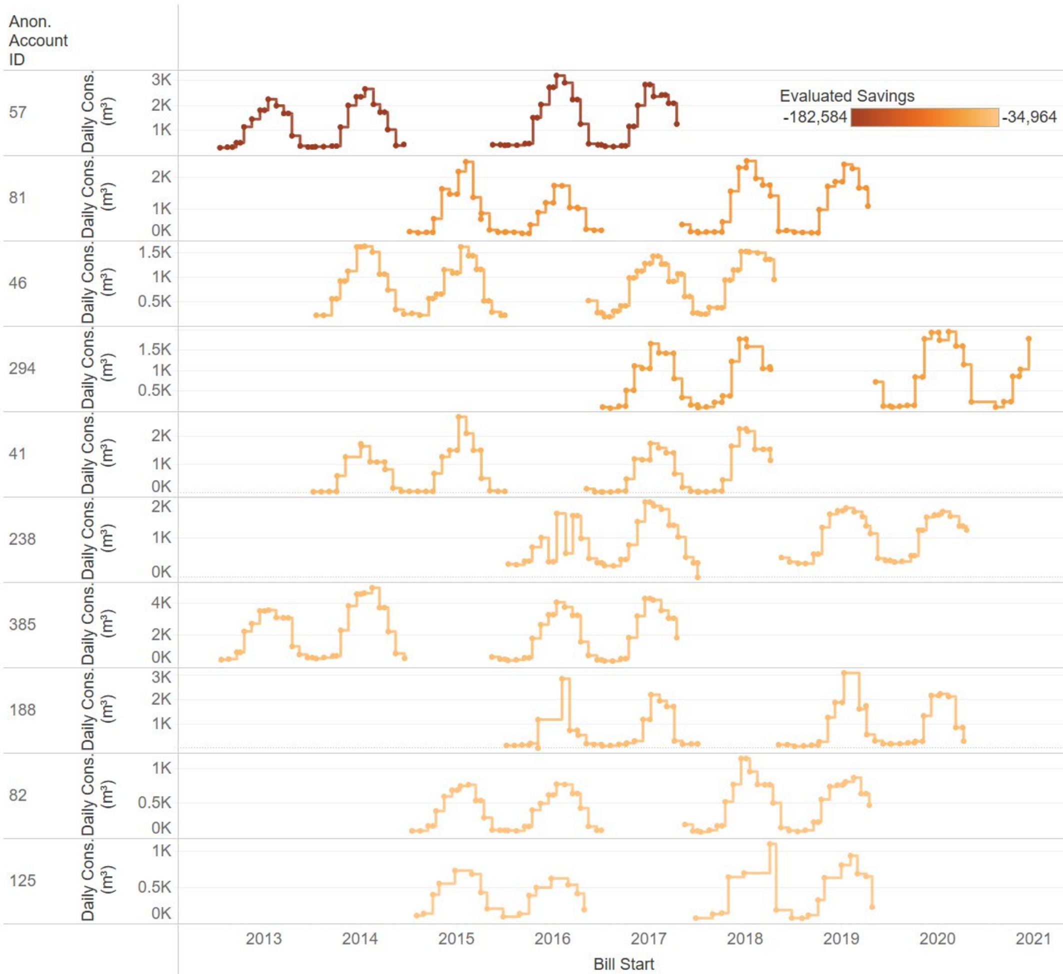


Figure 3-2 likewise shows the five sites with the greatest magnitude of negative savings from DNV's evaluation. Again, these sites show no significant discrepancies between pre period data and post period data that would suggest the presence of NREs. While some of these sites' billing data contained payment periods with long durations (such as site 188 and site 125), no statistically significant relationship can be established between the length of bill periods and the evaluated savings or the difference in fraction saved.

Figure 3-2. Load shapes of 10 sites with the least evaluated savings



3.8 Comparison of consumption normalization methodologies

An investigation into the differences between the consumption normalization method implemented in eTools and the method utilized in billing analysis was conducted. The following are findings about the eTools methodology:

- eTools suggests a baseload (non-seasonal use) value, from the billed consumption data. This is selected as the lowest consumption value, but it is up to the user to utilize the suggested value or select a different period.
  - Because some facilities (schools, etc.) can have zero summer consumption, manual baseload values can be entered.
  - Baseload can be selected by eTools from a different billing year than the data selected for the seasonal baseload.
  - Baseload does not currently account for the potential seasonal change in DHW usage.
  - Other potential baseloads (besides DHW) are estimated via engineering assumptions and subtracted from the eTools suggested baseload.
- There were often temporal differences between the billing period, meter read date, and actual HDD weather data used.

- For example, a meter read date in February could represent consumption in December and January but would use HDD from February.
- This issue is present in versions of eTools up to e7-00 but was corrected in e8-00. Our investigation showed no quantifiable impact of this correction on normalized consumption values which are equal for the sample of projects updated to e8-00.

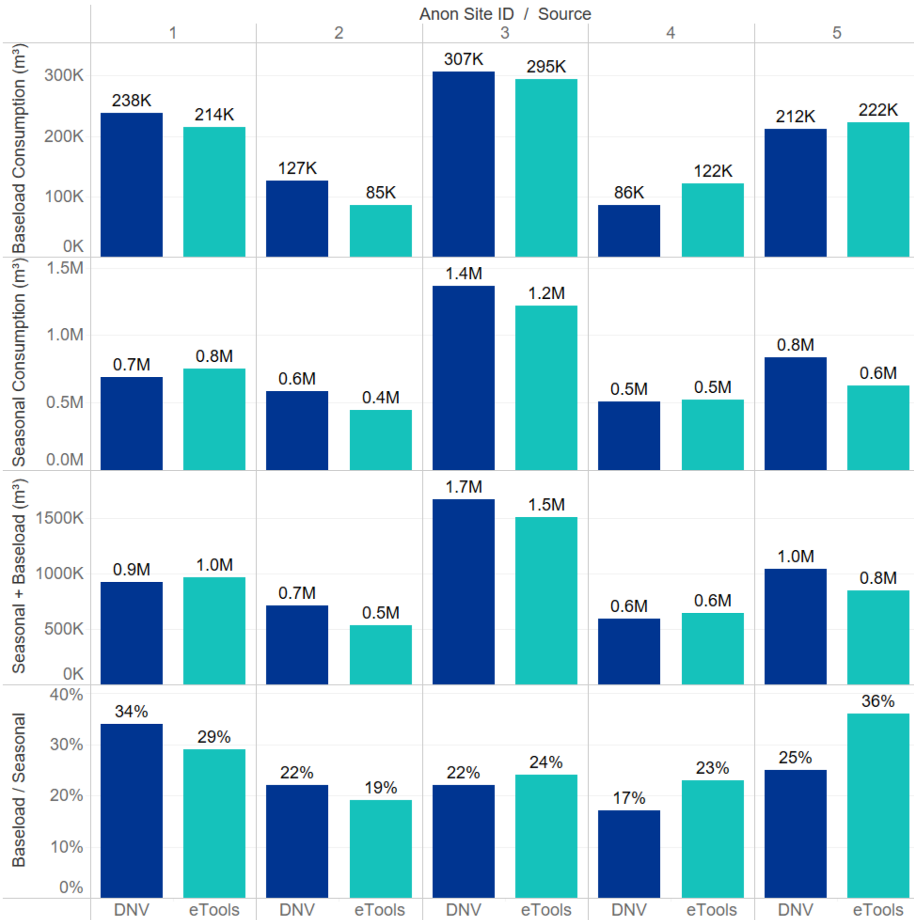
- Because the baseload is removed manually, the seasonal consumption regression equations are constrained to a zero-intercept due to the baseload being removed in prior steps.
- Annual actual weather seasonal consumption is calculated using the regression. That number is weather normalized by the application of a linear scalar of the ratio of normal to actual HDD. This is an unfamiliar but satisfactory approach made possible by the manual separation of the baseload.
- eTools maintains monthly values, adjusting them with pre-set monthly profiles meant to attempt to account for non-heating months with nominal HDDs and to account for building HVAC schedules.
  - It is unclear how the monthly values feed into the wider calculation of savings. Basic weather normalization occurs at the annual level.
  - No sources or documentation were provided for the values of the monthly pre-set profiles, nor the logic behind their application
- When there is insufficient billing data the estimated average daily consumption utilized in the regression gets the same weight same as all the other data points. The industry standard practice is weighting by the number of days in a billing period.

In summary, eTools utilizes a methodology with some departures from industry standard practice. EGI was unable to provide documentation explaining the reasons behind their departures from standard practice, so in many cases we could not confirm the rationale. These departures from standard normalization methodology raised doubts about the accuracy of the baseload and seasonal values resulting from it. Specifically, they created concern that the baseload savings were being underestimated, while the seasonal load was being overestimated. In fact, comparison of evaluated versus eTools seasonal load belies this concern. Furthermore, the overall small difference between evaluation and eTools pre-period consumption indicates that methodological differences did not lead to substantially different estimates of consumption.

A further investigation looked at billed consumption data, actual weather data, and normal weather data manually extracted from eTools for a sample of sites. Because manual extraction was necessary, only a small sample of five could be assessed. DNV's normalization process was applied to the data from the sample sites and no conclusive directional bias was identified for the normalized season loads being generated by eTools. The seasonal loads generated from this analysis were both greater than and less than their eTools counterparts, see Figure 3-2.

Overall, while we have some concerns with the approach used in eTools for consumption data normalization, the small sample of sites we could look at in detail did not provide evidence that a clear bias was being introduced by the approach.

Figure 3-2. Differences in seasonal and baseload consumption calculated by eTools and DNV



3.9 Multivariate regression analysis

Phase one considered the divergence between the billing analysis and eTools individually across several characteristics without discovering any obvious individual drivers of the differences. It is possible that multiple variables could have a combined effect on the divergence of eTools estimates from billing analysis estimates. In this case, the joint effect of these variables could be difficult to see in those individual, bivariate comparison graphs. To explore this possibility of a joint effect across multiple characteristics, a multivariate linear regression was conducted to see if multiple variables affect the divergence in ways that were not obvious individually.

The multi-variate analysis resulted in the variables, shown in Table 3-2, being statistically correlated with eTools advancement savings greater than billing analysis savings. Further investigation was conducted to dig deeper and identify any sub-variables that may be statistically correlated with the overestimate of savings, but the model did not identify any.

Table 3-2. Variables correlated with eTools' overestimation of savings

Variables	DESCRIPTION	Percentage of Phase 2 sample	RR	Fractional Savings
AHU	Flag for presence of AHU in baseline or proposed	28.4%	67.6%	17.4%
SH_LL	Flag for proposed lead-lag control in space heating system	13.4%	59.5%	15.7%
Comb_New	Flag for proposed combined space heating and domestic hot water systems	17.8%	66.3%	18.6%

3.10 Interactivity with evaluation adjustments

In the Custom Program Savings Verification (CPSV) evaluations, 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.

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

The gross realization rate in CPSV has historically included adjustments for findings (related to characteristics and control settings of the existing or efficient boiler systems) that in theory would also affect the results of the billing analysis, which creates a risk of double counting of adjustments if a realization rate from this study were also applied. DNV investigated this potential double counting between billing analysis findings and previous adjustments from past evaluations. There were two potential pathways available.

- Plan A: focus on CPSV sites that overlapped with the eTools billing analysis sample
- Plan B: review all historic CPSV sites and separate out adjustments that would be captured by billing analysis

After investigation, Plan B was selected as the optimal path forward, because the estimated overlap of CPSV sites with eTools study sample was approximately 3%. The estimate was based on finding only 41 commercial boiler projects from the past three rounds of CPSV (2015-2018 program years), and that the eTools study used only 25% of the original population of sites.

For Plan B, each of the previously evaluated 41 eTools commercial boiler projects from 2015-2018 were reviewed and the CPSV adjustments were categorized into: those that billing analysis would capture, i.e., most adjustments to the characterization and control settings on the existing or efficient boilers and those that billing analysis would NOT capture, such as most adjustments solely to the “standard” boiler characteristics, changes to advancement period length, or measure life. After categorizing the adjustments, the CPSV realization rates for each project were updated to reflect only the adjustments that do not overlap with billing analysis. Sixteen projects required adjustments to CPSV RR, shown in Table 3-3. The other 25 projects had no adjustments (100% RR).

Table 3-3. CPSV RR adjustments

Year	Measure ID	Measure Description	Adjustment Category	CPSV RR	Without Double Counting RR
2016	RA.LC.MR.145.16	Boiler - Hydronic Condensing	Existing, Installed	89%	100%
2016	RA.LC.MR.215.16M	DHW boiler	Existing, Installed	142%	100%
2016	RA.LC.MR.191.16A	Space heat and DHW boiler	Interactivity	111%	100%
2016	RA.LC.COM.OTHER.003.16M	Space heating boiler	Existing	136%	100%
2017-2018	RA.CT.18.0335	SH Boiler replacement	Existing, Installed	131%	100%
2016	RA.LC.MR.202.16	Space heating boiler	Installed	100.20%	98.30%
2017-2018	RA.CT.18.0191	High-efficiency space heating boilers	Installed	97%	100%
2017-2018	RA.CT.18.0330	DHW boiler replacement	Installed	137%	100%
2017-2018	LW.CT.18.0008	DHW Boiler Replacement	Installed	90%	100%
2017-2018	RA.CT.18.0215	Conversion from separate to combined SH/DHW boiler	Installed	94%	100%
2017-2018	RA.CT.17.211	High-efficiency, space-heating boiler replacements	Installed	94%	100%
2016	RA.LC.MR.172.16M	Boiler - Hydronic High Efficiency	Installed	144%	123%
2016	RA.LC.MR.204.16	Space heating boiler	Installed	100.20%	101.2%
2017-2018	RA.CT.18.0303	Replaced separate SH and DHW boilers with boilers that serve both loads	Installed	98%	100%
2017-2018	RA.CT.18.0589	Replacement of 2 SH boilers	Installed	93%	100%
2017-2018	RA.CT.17.422	Upgrade to two condensing space-heating boilers	Installed	119%	100%

After separating the adjustments for the 41 sites DNV expanded the results to the population using ratio estimation, which is the standard approach used for sample expansion in CPSV. The ratios estimated are described in the formulas below.

Notation: The following terms are used in calculating the adjustment factors:

G_{Tj} = tracking estimate of gross savings for measure *j*

G_{T8j} = eTools version e8-00 tracking estimate of gross savings for measure *j*

G_{Fj} = full engineer verified estimate of gross savings looking at all adjustments for measure *j*,

G_{NBj} = engineer verified estimate of gross savings looking at only adjustments that do not overlap with billing analysis for measure *j*,

w_{Vj} = weighting factor for measure *j* used to expand the CPSV sample to the full population

V = number of measures in the CPSV sample

G_T = tracking estimate of gross savings for the population of boilers studied

G_V = verified estimate of gross savings for the population of boilers studied

R_E = billing analysis adjustment estimated in phase 2 of this study

The Full CPSV gross realization rate R_F is calculated directly:

$$R_F = \frac{\sum_{j=1}^{V} G_{Fj} w_j}{\sum_{j=1}^{V} G_{Tj} w_j}$$

The overlap factor R_O is calculated as a ratio of non billing analysis verified savings and full CPSV verified savings:

$$R_O = \frac{\sum_{j=1}^{V} G_{NBj} w_j}{\sum_{j=1}^{V} G_{Fj} w_j}$$

To calculate verified savings we can multiply the three realization rates R_E, R_F, and R_O with the gross tracking savings

$$G_V = G_T \times R_E \times R_F \times R_O$$

Alternatively, we can calculate the non-billing realization rate R_{NB} as a ratio of non billing analysis verified savings and tracking savings:

$$R_{NB} = \frac{\sum_{j=1}^{V} G_{NBj} w_j}{\sum_{j=1}^{V} G_{Tj} w_j}$$

And then to calculate verified savings we can multiply R_E and R_{NB} with the gross tracking savings

$$G_V = G_T \times R_E \times R_{NB}$$

The first formula is preferred if the evaluator and the EAC choose to use the overlap factor (R_O) from this study rather than calculate from the CPSV sample itself. For example, if future CPSV sample of commercial boilers is small then this formula may be preferable.

The second formula is preferred if the evaluator and the EAC choose to rely solely on the CPSV sample and not use the overlap factor (R_O) from this study. Assuming the CPSV engineering data collection is conducted in a manner consistent with historical precedent, then the additional marginal cost for calculating the overlap factors during future CPSV are negligible in comparison. This formula is preferred if sample sizes are large enough that the evaluation team and EAC feel comfortable that the result will be reliable.

This study's results are applicable to eTools version e8-00. As the program moves into more modern versions of eTools beyond e8-00 it will be necessary to calibrate the new version(s) of the tool to e8-00 as well to ensure major calculation changes between versions do not result in double counting. This calibration factor is not included in the above formulas, but would also be a multiplier in calculating G_V , based on CPSV sample/backup sites and calculated as the ratio of e8-00 savings to the savings from the more modern tool. In this scenario both tracking and evaluation use the modern version of the tool throughout and a correction factor for updated eTools version is calculated:

$$R_{V8} = \frac{\sum_{j=1}^{V} G_{T8j} w_j}{\sum_{j=1}^{V} G_{Tj} w_j}$$

Table 3-4 shows the Full CPSV gross realization rate (R_F), overlap factor (R_O), and non-billing realization rate (R_{NB}) calculated using the 41 boilers that were in the previous 3 rounds of CPSV. The case weights from the original studies were used and are interpreted as the number of projects that a sampled site represents in the population studied. Precisions provided are not finite population corrected (FPC Off), which is appropriate for ratios that are intended to apply to a future population rather than the specific population studied.

Table 3-4. CPSV RR and CPSV RR adjustment factor

Ratio	n Measures	Ratio	+/- at 90% Confidence, FPC Off	Relative Precision at 90% Confidence, FPC Off
Full CPSV gross realization rate (R_F) (for reference)	41	102.16%	5.1%	5.0%
Overlap Factor (R_O)	41	97.39%	3.6%	3.7%
Non-billing realization rate (R_{NB}) (for reference)	41	99.50%	3.8%	3.9%

3.11 Phase 2 results

The impacts of the adjustments and investigations described in Phase 2 were as follows:

- Updating all sampled projects to version 7 resulted in an increased RR of 75%.
- Switching to comparing to only Advancement Savings resulted in a decreased RR of 55%.
- Re-setting the default existing boiler efficiency to values of 80.1% for SH and 81.8% for DHW resulted in an increased RR of 70%.
- Re-setting the proposed boiler controls to existing settings resulted in an increased RR of 79%.
- eTools departs from standard practices in several ways with respect to weather normalization, the exact impact of the weather normalization process on eTools results is difficult to quantify but appears to be limited.
- The multivariate regression analysis did not identify any further specific variables that explain the remaining difference between eTools estimates savings and evaluated savings.
- The analysis of NREs did not identify any systematic impact of NREs.

The remaining unexplained difference between eTools estimates and evaluated savings is an 11 percentage point difference between evaluated fraction saved and eTools v7 advancement fraction saved, Figure 3-4. That is, with the adjustments to eTools described above, and using the most up to date eTools version, eTools still overestimates savings relative to evaluated savings by 2.1 million cubic meters, or 27%, based on the most recently audited year, 2020.

The final sample for Phase 2 was 321 accounts, a sub-set of the Phase 1 accounts whose eTools projects were able to be successfully updated to the latest eTools version. Figure 3-3 displays the realization rates, reported savings, and advancement savings across the various eTools versions (and iterations) from this study. The "…All Savings" columns incorporate a mix of baselines, existing and standard. Columns labelled "…All Advancement" use only the existing baseline which is a more apt comparison for the billing analysis results which use the existing baseline. The columns containing "…+ Efficiency" incorporate the default efficiency changes explained in Section 3.5, and the column containing "…& Controls" also incorporates the system controls changes explained in Section 3.6. Retrospectively, without the recommended parameter updates, the RR is 55%. With the recommended parameter changes, a forward-looking RR of 79% is appropriate.

Figure 3-3. eTools version, advancement, and parameter update savings comparison

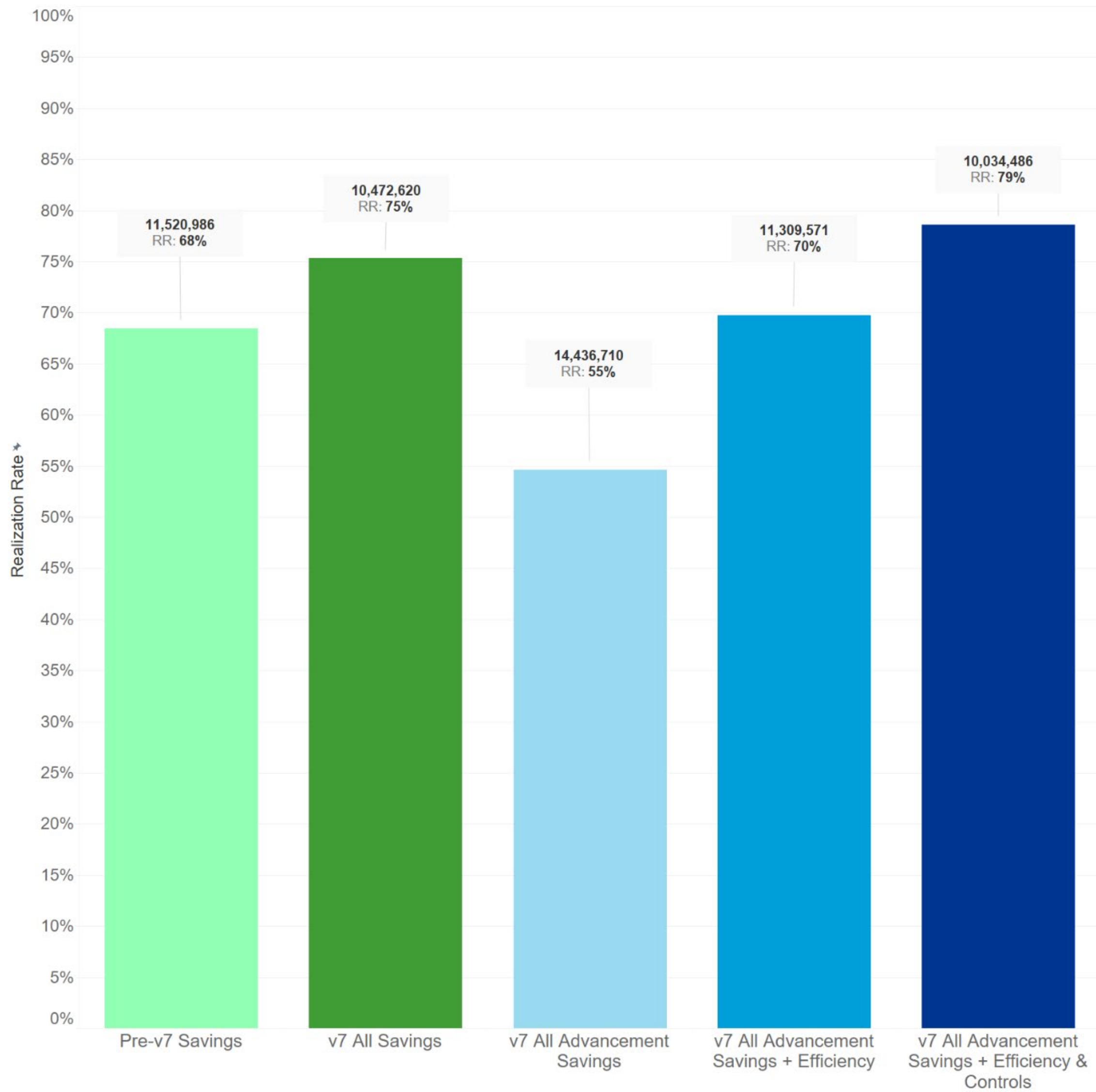
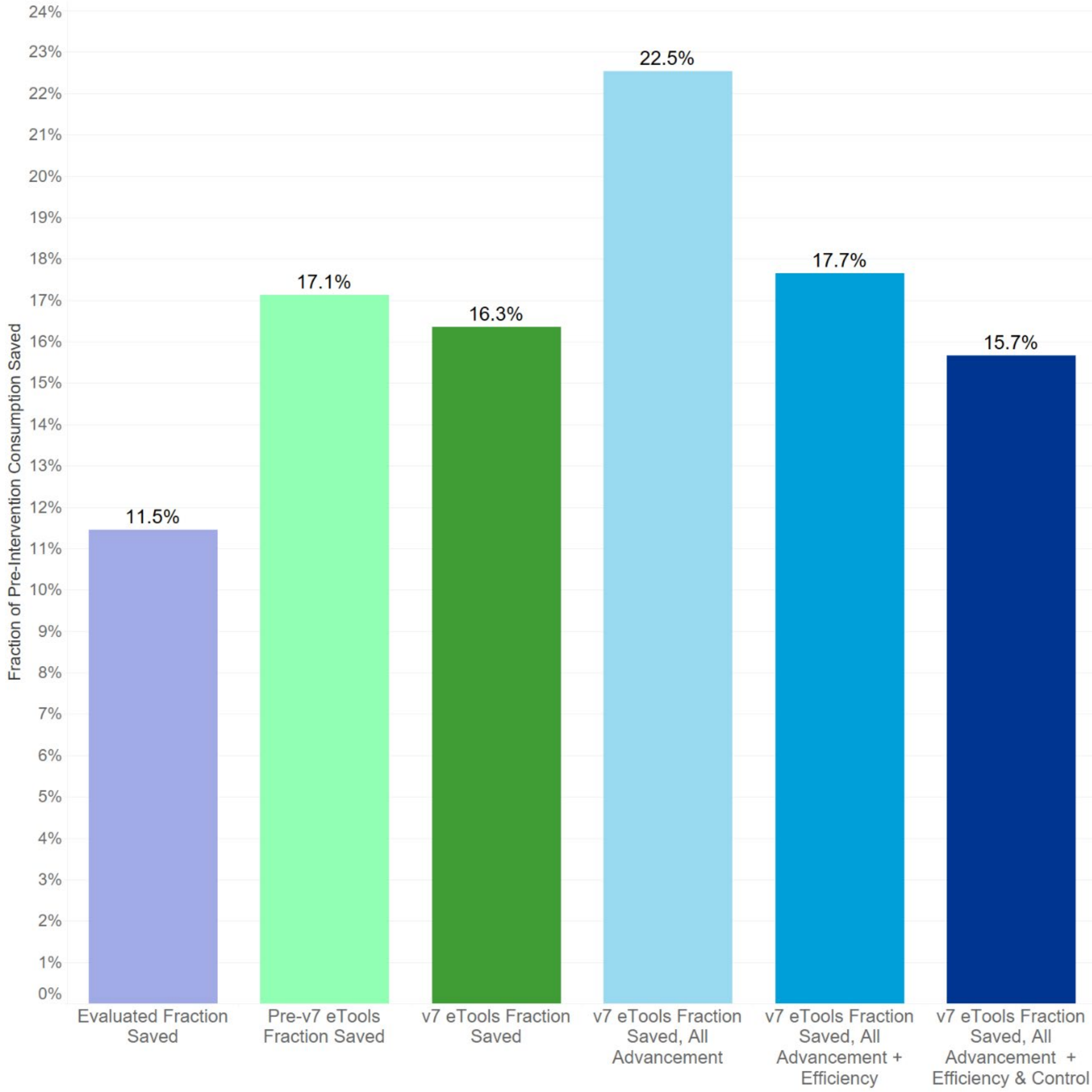


Figure 3-4 focuses on the fractional savings, i.e., savings as a percentage of pre-intervention consumption. The final difference between the fractions saved for evaluated (billing analysis), and eTools v7 advancement + efficiency & control changes is only 4.2% of consumption. If NREs are the cause of the difference between the two methods (evaluated and eTools) then they would have to account for an increase in consumption of 4.2% of pre-intervention consumption across all sites in the Phase 2 sample.

Figure 3-4. eTools version, advancement, and parameter update fractional savings comparison



EGI contracted with evaluation consultant Demand Side Analytics to perform a comparison group analysis to assess trends and NREs. Such a study intends to determine if there exists a general trend in consumption that would bias billing analysis results. Such a trend, as estimated from non-participant changes in consumption, would provide an estimate of the effect of general trends in usage as well as of all kinds of NREs except those participant NREs associated with program participation (but not tracked) which would remain unaddressed in this attempt to address potential NRE bias. The analysis involved identifying a group of similar non-participant sites, finding a match for each participant among those non-participants based on pre-period consumption and then looking at the change in non-participant consumption pre- to post- based on the participant installation date. DSA replicated the process on random subsets of the overall identified non-participant population to develop a distribution of possible consumption changes over time from different comparison group compositions. The results of this billing analysis of program non-participants (Appendix #) by EGI found consumption increases between 0.3-1.2% of weather normalized pre-period consumption with a mid-point of 0.8%. If the findings of the EGI study are assumed to hold true for the sample of accounts utilized in this study then the difference in fraction saved would decrease from 4.2% to 3.4%, a reduction of 19%. If the increase in post-period consumption from EGI's study is incorporated into this study's evaluation results the Phase 2 RR increases from 0.79 to 0.84. In summary, it is unlikely that any additional studies of consumption trends will find an increase in gas consumption large enough to conclude that NREs account for the remaining difference between billing analysis and eTools results.

Table 3-5 displays the pre-intervention consumption values used in the preceding figure. The eTools consumption values decreased from pre-v7 to v7 because the weather normals were updated to utilize more recent data.

Table 3-5. Pre-intervention consumption for fractional savings

Source	Pre-Intervention Consumption (m3)	Notes
Evaluated (Billing Analysis)	68.84MM	-
eTools pre-v7 (Original Reported Savings)	67.29MM	Weather normals from 1971-2000
eTools v7	63.53MM	Weather normals from 1981-2010

3.12 Phase 2 conclusions

The results of this study show that, after key engineering assumptions are refined, eTools can provide a reasonably accurate estimate of aggregate advancement savings. The study did not address factors external to the eTools calculator that could cause deviations from savings estimates and whose impacts could be studied, such as:

- Contractor equipment installation processes
- Boiler system commissioning processes
- End user operation and maintenance of boiler systems

eTools is a sophisticated engineering-based estimation calculator that exceeds industry standard practice and generates local knowledge of implementation practices. There are no other boiler savings estimation models that are known to be more accurate, nor any known to be in development. Changing tools for evaluation will introduce additional uncertainty as to the causes of differences in verified vs. claimed savings.

Performance gaps in energy efficiency performance simulation software persist across all kinds in jurisdictions around the world. Despite significant performance gaps found in building energy conservation measures, for both new and retrofit buildings, no jurisdiction has discarded their performance simulation software. EnergyPlus, 3E Plus, Integrated Engineering Software, etc. are all used to provide forecasted savings in buildings even those these are seldom fully realized.

3.12.1 eTools and implementation recommendations

1. eTools advancement projects should not utilize the current 73% thermal efficiency default value, it should utilize site specific values, supported by documentation. If no defensible site-specific values are available the efficiency values identified in this study, 80.1% for space heating and 81.8% for domestic hot-water heating, should be utilized.
2. Site specific documentation verifying any anticipated controls or setpoint changes should be gathered by Enbridge after boiler system commissioning. If documentation verifying control changes are unavailable, then the installed systems should be assumed to utilize the same controls and setpoints as the existing systems.

3. Improve upon the weather normalization method for consumption data through adopting industry standard practices (ASHRAE, IPMVP, etc.) and thoroughly documenting the rationale for any deviations from those standards. Given the upward trend in temperatures, eTools should utilize weather normal values based on the 10 most recent years of data.
4. Investigate potential sources of bias in savings estimates associated with Air Handlers, Lead-lag installations, and combined systems. While the evaluation was not able to test changes to these settings in eTools, the multivariate analysis found that these characteristics were associated with errors in estimated savings.
5. More rigorous data collection for existing and new boiler systems to capture empirical information to refine values for the various eTools' parameters that impact boiler performance, such as:

    a. Impacts of insulation on boiler shell heat losses
    b. Boiler purge frequency and associated heat losses
    c. Hot water load of combined systems
    d. Percentage of load served by lead boilers in lead lag systems

3.12.2 Evaluation recommendations

The recommendation for OEB and EAC's consideration for future eTool commercial boiler evaluations are:

1. Continue using eTools for implementation and evaluation. eTools is a sophisticated engineering-based estimation calculator that exceeds industry standard practice and generates local knowledge of implementation practices. There are no other boiler savings estimation models that are known to be more accurate, nor any known to be in development. Changing tools for evaluation will introduce additional uncertainty as to the causes of differences in verified vs. claimed savings. The use of this modelling software is akin to other building simulation software which contains known performance gaps in energy efficiency measures that persist across all kinds of jurisdictions around the world. Despite these performance gaps, no jurisdiction has discarded their performance simulation software. EnergyPlus, 3E Plus, Integrated Engineering Software, etc. are all used to provide forecasted savings in buildings despite rarely being accurate for an individual building.

    a. eTools advancement projects should not utilize the current 73% thermal efficiency default value, site specific values (supported by documentation) should be utilized. If documented site-specific values are not available the efficiency values identified in this study, 80.1% for space heating and 81.8% for domestic hot-water heating, should be utilized by implementers and evaluators.
    b. Site specific documentation verifying any anticipated controls or setpoint changes should be gathered by Enbridge after boiler system commissioning. If documentation verifying controls changes are unavailable, then the installed systems should be assumed to utilize the same controls and setpoints as the existing systems.
    c. Version e8-00 of eTools was the latest version reviewed during this study and should be utilized by the evaluation team to assess any projects using eTools e8-00 or earlier.
    d. Projects using a version of eTools more modern than e8-00 should use the modern version of eTools in evaluation. A "between version" calibration factor that takes the savings from version e8-00 relative to the new version should be employed to ensure that the changes from one version to another are accounted for without restricting the evaluation to using only version e8-00 prior to re-calibrating the billing analysis (see below in point 5). This calibration can be calculated using the sample plus the backup sample of projects in the evaluation (those that the evaluation requests files for as part of the typical evaluation process).

2. Future evaluations of eTools commercial boiler projects should continue in a manner consistent with Custom Project Savings Verification (CPSV) evaluations from 2015-2018 while updating the model to eTools version e8-00 or more modern. This means updating inputs to eTools based on site-specific data collected through evaluation activities.

3. After implementation of list items 1.a. and 1.b., the recommended realization rate from this study (84%), can be applied to evaluate aggregate eTools boiler gross savings. This recommended realization rate uses that described in 1a) above as well as incorporates the findings from EGI's study of non-participant natural gas consumption trends (APPENDIX A), explained in Section 3.11.
4. A correction factor for the double counting between evaluated gross savings and billing analysis should be utilized. As part of this study, it was found that based on past projects, the adjustment factor was 0.97. An alternative to using this factor is to re-estimate the correction factor based on the sample of projects evaluated in CPSV to apply to that year's CPSV results. The determination of which to use will be made by the evaluation team with input from the EAC and OEB. The primary factor in the decision will be the sample size of boilers evaluated.
5. eTools should be periodically calibrated via billing analysis to improve the accuracy of aggregate savings estimates. The precise cadence/timing of the calibration cannot be defined at this time in part because evaluation budget consideration necessarily have a role in determining the timing. Re-calibrating the billing analysis will be more about changes in use of eTools (defaults, assumptions and data entry choices) and less about the changes in the underlying calculations, which will be captured in the suggested "between version" calibration factor in 1d.
   The OEB and EAC should consider the following key factors when determining whether a billing analysis calibration should be conducted:
    a. Whether EGI's internal user guidelines for eTools have changed in a manner that materially impacts savings estimates produced. As informed by Enbridge's analysis of the impact of its user guideline changes to eTools. Materially in this case would be a change that is expected to change boiler savings by more than 5% in aggregate for boilers in the program. Note that 5% is a starting point to inform the EAC when it is time to start planning the next study.
    b. If newer eTools versions are found to produce savings materially different from the versions evaluated in this study As informed by Enbridge's analysis of the impact of its updates to eTools and/or the calibration factors estimated in 1d above. If calibration factors in 1d exceed 10% it is of higher priority to conduct another calibration. 10% is a starting point, given that 1d is likely based on a relatively small sample, it is prudent to use a higher threshold than 5a. If there is sufficient post-case heating data (minimum of two heating seasons) for the population of sites to be included in the billing analysis
    c. If there is sufficient post-case heating data (minimum of two heating seasons) for the population of sites to be included in the billing analysis

3.13 Additional thoughts

This section covers alternative pathways forward, or potential areas of further inquiry, that are not recommended but were considered as options.

3.13.1 Alternatives to using eTools

The only reasonable alternative to using eTools for ex ante estimates and correcting the models with ex post information, from CPSV evaluation or regularly conducted billing analysis, is to change the program structure to a pay-for-performance program. DNV has yet to come across a modelling software that attempts to model savings from boiler ECMs as granularly as eTools. Most other efficiency programs utilize rudimentary prescriptive algorithms to determine boilers savings that would likely have worse RRs than eTools if they were checked against billing analysis results. Additionally, performance gaps in energy efficiency measures persist across all kinds in jurisdictions around the world. Despite significant performance gaps found in building energy conservation measures, for both new and retrofit buildings, no jurisdiction has discarded their performance simulation software (EnergyPlus, 3E Plus, Integrated Engineering Software, etc.) are all used to provide forecasted savings in buildings even those that are seldom fully realized. If eTools is discarded then the program structure will likely need to be changed to a pay-for-performance program, there will be new risks because:

- Only billing analysis (which has its complexities and risks) could be utilized for the evaluation of such a program.
- Quality and consistency of pre- and post- project documentation could diminish, leading to a lack of transparency into the ECMs that were implemented, and increasing the difficulty of interpreting and contextualizing the billing analysis results.
- Identification of potential NREs would become more important, and the methods to identify them (described in Section 3.13) introduce their own complexities and risk.
- Program participation could suffer due to reduced or eliminated upfront incentives.
- Differences in contractor equipment installation processes
- Differences in boiler system commissioning processes
- Differences in end user operation and maintenance of boiler systems

3.13.2 Control group study

A control group study was initially proposed to attempt to quantify possible population wide consumption trends or NREs (discussed in earlier parts of this report) that may be conflated with and included in the billing analysis estimates. EGI contracted with another evaluator, Demand Side Analytics, to perform a control group study similar to the study we would provide. The results from that analysis were consistent with the methodology DNV would employ and provided evidence of a trend of minor increases in consumption that would lead to a slight downward bias on billing analysis savings estimates. Having reviewed the DSA study carefully, DNV does not believe further control group study is justified and, we have incorporated those estimates into our discussion to demonstrate that they have limited effect on the overall findings of the analysis.

3.13.3 Customer NRE surveys

Investigation of NREs based on customer reported information to be utilized in adjusting eTools project savings is typically reserved for CPSV evaluations. However, there is potential value to the qualitative information that could be gained in a focused survey of the sites sampled for Phase1 and Phase 2 of this study. There are a few areas of concern to consider prior to pursuing a customer survey to learn about potential NREs:

1. Many of the projects were completed over 5 years ago, before 2017. Getting accurate information about events that far back will require a carefully crafted survey instrument with stakeholder input.
2. The desired use case for qualitative information acquired about customers' NREs is unclear and will have to be discussed amongst stakeholders to inform the design of a robust survey instrument.
3. Even if all the points above are addressed and agreed upon by stakeholders, the surveys could still result in low response rates or insufficient information. As a point of comparison, the discovery of potential NREs in the population of sites that implemented boiler projects in CPSV EY2019 was ≤11%.
4. As there continues to be pressure from all levels of government and the public for customers to reduce their fossil fuel use, data on NREs from past years may become increasingly out of date and misleading.

These risks should be carefully considered and properly mitigated in the scoping of customer surveys targeted at identifying NREs.

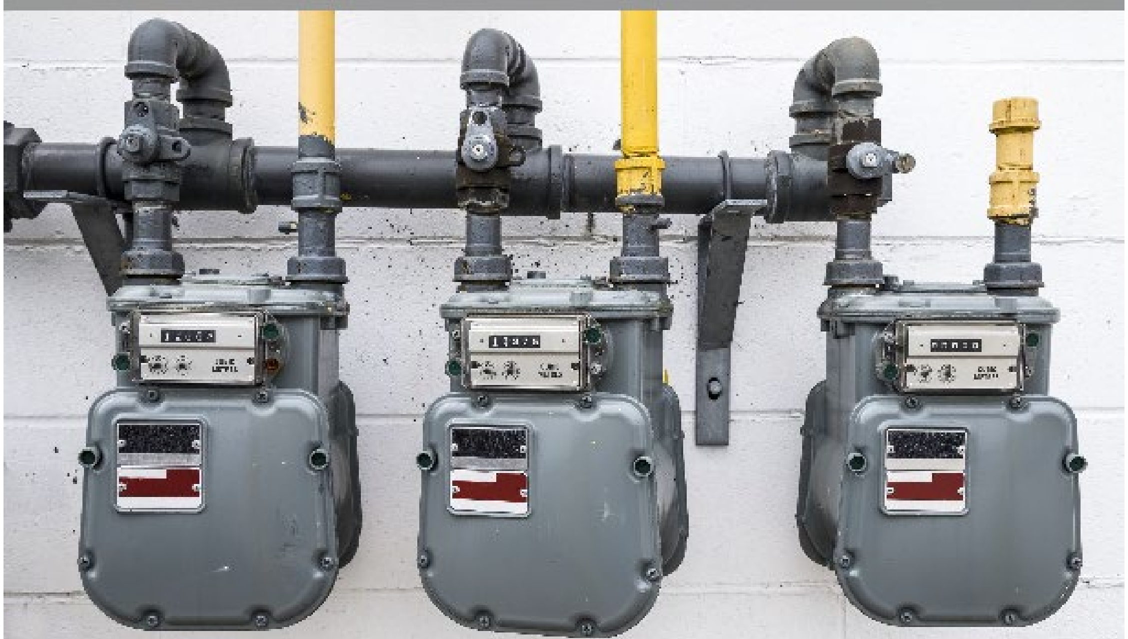
DNV

APPENDIX A. ENBRIDGE NON-PARTICIPANT BILLING ANALYSIS

Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

Preliminary Report

Non-Participant Billing Analysis



Prepared for: Enbridge Gas Inc.
By: Demand Side Analytics
February 2022

About DNV

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