

Help! COVID Ate My Program Savings!

*Faith DeBolt, Dan Bertini, Erin Wenger, SBW Consulting, Inc
Max Rennie, Puget Sound Energy*

ABSTRACT

A long-running Commercial Strategic Energy Management (C-SEM) program touching over 800 buildings encourages low-cost actions to reduce energy use, typically yielding energy savings of 3-5% of annual consumption. The program estimates savings with IPMVP Option C models built on meter, weather, and occupancy data (EVO 2016). However, in 2020 and 2021, Option C models alone could not decipher whether changes in energy use were due to the program or the COVID pandemic. The program sought a way to efficiently and reliably adjust savings for COVID impacts that could be readily applied to its C-SEM buildings without time-consuming interviews of each of the building energy managers.

The authors developed an Excel-based tool which renders a time-series of data in the form of discrete low and high steps, identifies which of those steps may represent a potential non-routine event (NRE), and estimates the value and nominal significance of the corresponding non-routine adjustment (NRA). Applying methods outlined in the IPMVP Application Guide on Non-Routine Events and Adjustments, the tool implements “NRE Approach #6 (Analyze Residuals from the Model)” and “NRA Method #7 (Develop a Pre-Post NRE Model)” to identify potential NREs and estimate corresponding NRAs (EVO 2020). The paper will describe the tool and its use to estimate COVID impacts on the energy consumption of buildings participating the C-SEM program.

Tools such as these will build confidence in energy savings estimates as more performance-based programs come online seeking to support the transition to net zero energy, carbon-neutral buildings.

Introduction

In 2020, Puget Sound Energy’s (PSE) Commercial Strategic Energy Management (C-SEM) program had about 800 buildings among 40-50 participants and a program savings target of 11,500 GWh and 800,000 therms. The C-SEM program primarily comprises school districts and municipal governments and motivates its participants to reduce energy use in buildings through operational and behavioral changes, in part, with performance-based financial incentives. These incentives are based on energy savings observed at the utility meter. To develop the energy savings estimates, for most participating buildings, Energy Management Engineers (EME) develop linear regression models with energy consumption as the dependent variable and heating and cooling degree days (weather) and occupancy as the independent variables. The baseline model is based on the typical energy use in recent years prior to program participation, i.e., energy use relative to weather and occupancy in the baseline period. Then the weather and occupancy of the performance period are applied to the baseline model to project what energy use the building would have had absent program intervention. The difference between this projected energy use and the metered energy use in the performance period, adjusted for any energy-impacting activities not related to the program such as capital projects funded through other programs or other non-routine events, is the energy savings due to the

program. The types of behavioral and operational changes that participating Energy Managers implement typically lead to 3-5% reduction in annual energy use. The types of buildings participating in PSE's C-SEM program tend to have statistically "well-behaved" energy use, meaning there is low noise, or uncertainty, in the models relative to the savings being achieved. In cases where low-uncertainty models cannot be fit to the data, such as campuses with central plants, EMEs use raw, unmodeled data for savings estimation.

The program uses daily meter data and monthly billing data to develop whole building models for each participating building. Additionally, the program requests quarterly reports from participants, though there is a lot of flexibility with this and participants are also allowed to submit an annual report instead.

When the COVID-19 pandemic hit the Puget Sound region of Washington state in late winter of 2020, schools sent students home and many office-workers began working remotely to comply with Governor Inslee's Stay-Home order. The C-SEM program participants were particularly impacted by this order, shutting down or otherwise drastically altering the operations of their buildings. All current participants have baseline periods prior to the start of the COVID-19 Stay-Home order. The cycle of performance periods varies for participants, with K-12 schools usually having school-year-based cycles with summer break at the beginning or end and other participant types typically having calendar year performance periods.

The COVID Stay-Home order dramatically impacted operations of C-SEM participant buildings, often reducing energy use many times greater than C-SEM-motivated energy savings during the first months of the order. Program staff needed to adjust savings to account for how much energy use change was due to COVID-related impacts versus program intervention. Without the ability to do that, the program was zeroing all C-SEM savings that occurred during the initial COVID shut down. Program staff sought a streamlined way to efficiently and systematically account for the portion of reduction in energy use the program can attribute to how the participant Energy Managers adjusted building operations, while avoiding or minimizing the need to interview and collect data from them. They contracted with SBW Consulting to get help with this problem. This paper describes a tool developed by SBW engineers to statistically detect and adjust for non-routine events, specifically those associated with COVID. The paper also summarizes the results of SBW's application of the tool to a sample of buildings as well as four use cases provided by program staff, demonstrating application of the tool across a broad range of scenarios.

Methodology

Detecting the Shutdown and Return-to-Occupancy Periods – NRE Detection Model

The *IPMVP Application Guide on Non-Routine Events and Non-Routine Adjustments* ("NRE/A Guide") describes seven approaches for detecting NREs (EVO 2020). The team chose approaches #3 and #6 since they readily work with the regression modeling that is already being performed in PSE's C-SEM program, as elaborated on below.

Preferred Approach

The tool prefers to follow "NRE Approach #6 (Analyze Residuals from the Model)". This approach identifies potential NREs from the changes in energy consumption as they are reflected in the residuals of the data model, where the residual for each data point is the

difference between the actual energy usage value and the modeled value (a negative residual indicates that the actual usage is lower than the modeled usage). The tool creates a pre-post model with continuous variables in degree days and building occupancy, and indicator variables to represent the baseline (pre) and the performance periods (post). Using the mean and the standard deviation of the residuals, it generates a data stream of the standardized residuals and their probabilities in the form of discrete low and high steps, where step changes occur when the rolling average of the standardized residual crosses zero, i.e., switches from positive to negative, or vice versa. Each step in this data stream can then be interpreted as a potential NRE. The tool automatically identifies a potential COVID “Shutdown NRE” starting in March 2020 when the standardized residuals take the first negative step into an area where the probability falls below a nominal minimum threshold. Figure 1 shows the key data streams calculated from that model. Here the Shutdown NRE appears to have started on March 14 and extended through the end of the reporting year.

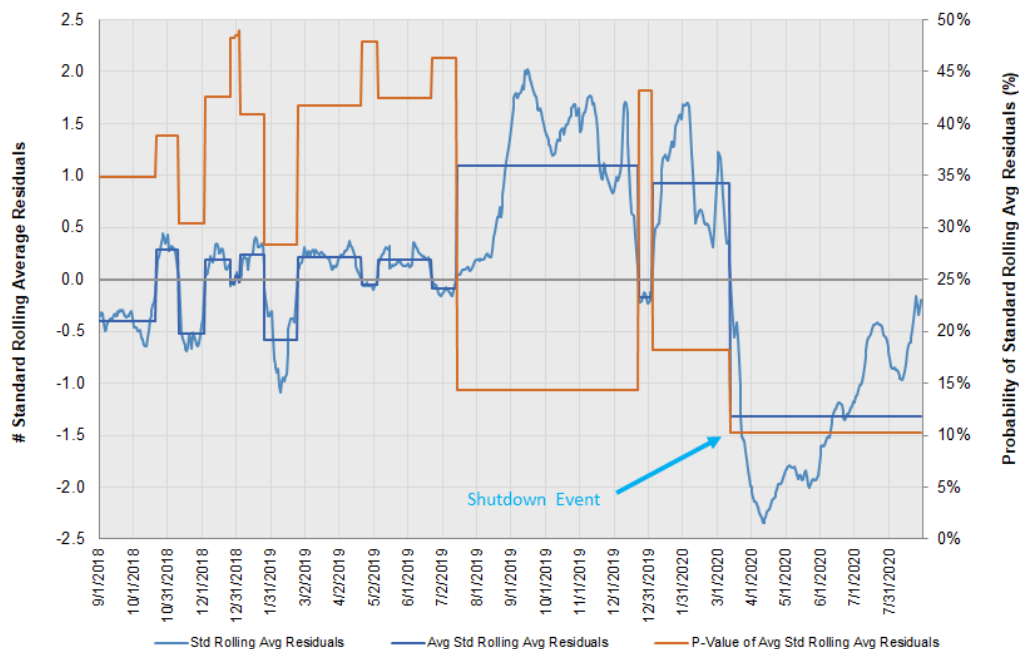


Figure 1. Discretized standardized residual model with probabilities, showing a potential NRE beginning on March 14th and continuing through the end of the performance year.

Optional Approaches

The tool also offers the option of applying “NRE Approach #3 (Evaluate Energy Data for Changes in Use Patterns)”. This approach detects the Shutdown NRE directly from changes in energy consumption and therefore does not require generating a data model. Unlike Approach #6, this approach is more likely to falsely detect an NRE where changes in energy consumption are the result of routine changes in the variables that normally drive the energy consumption, such as weather or occupancy. For example, this approach is more likely to detect an NRE where gas consumption routinely plummets in the summer. Figure 2 shows the results using this approach. Here the Shutdown NRE appears to have started on March 22 and extended through the end of the performance year.

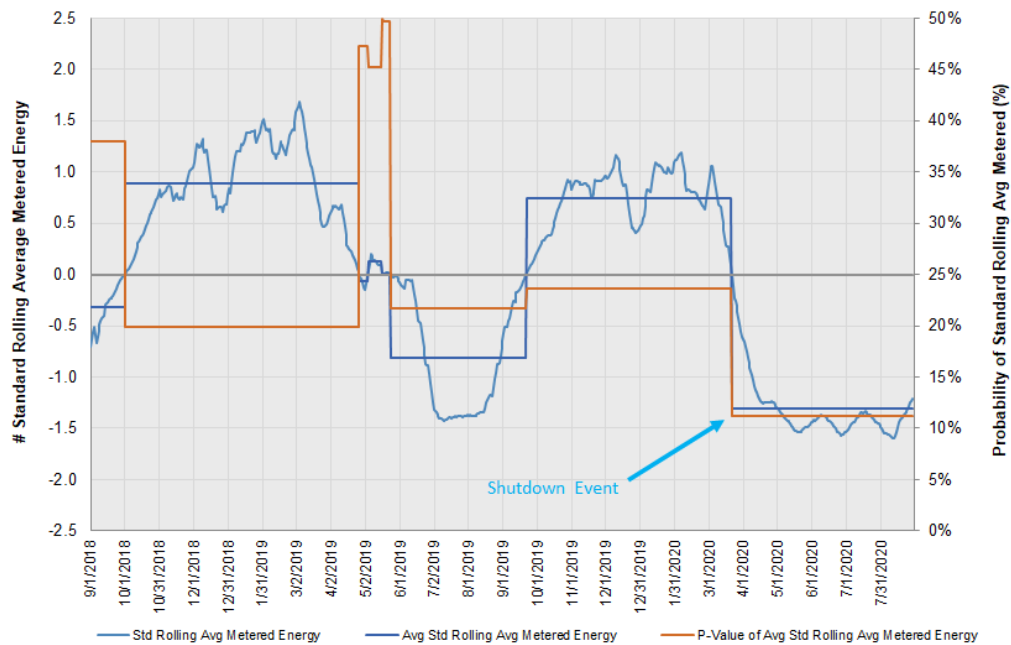


Figure 2. Discretized standardized metered data model with probabilities, showing a potential NRE beginning on March 22nd and continuing through the end of the performance year.

Assessing the Non-Routine Adjustments for Shutdown and Return-to-Occupancy – NRA Assessment Model

The tool automatically calculates the non-routine adjustment associated with the Shutdown NRE as it is identified using both approaches described above. In addition, it automatically calculates the NRA for the arbitrary case where the Shutdown NRE spans from March 1, 2020 through to the end of the performance year. As a fourth option, it can also calculate the NRA for a user-defined Shutdown NRE.

The IPMVP NRE/A Guide describes thirteen methods for estimating Non-Routine Adjustments (EVO 2020). The team considered each method and decided to apply “Method #7 (Develop a Pre-Post NRE Model)”. The tool generates a pre-post model in the same manner as it did to identify the Shutdown NRE but applies one additional indicator variable to represent the Shutdown NRE and another additional indicator variable to represent the “Return-to-Occupancy NRE”, which is nominally defined as the period of time from the end of the Shutdown period to the end of the performance year. If the Shutdown period extends to the end of the performance year, then this second additional indicator variable is not necessary.

The tool calculates the NRA for the Shutdown period as the product of the regression coefficient for the Shutdown NRE indicator variable and the number of days in the Shutdown period. If there is a Return-to-Occupancy (RTO) period, it also calculates the NRA for that period as the product of the regression coefficient for the RTO indicator variable and the number of days in the RTO period. Equation 1 below describes a regression model for daily energy consumption in terms of the independent variables and their respective regression coefficients. The tool supports up to three independent variables and nominally labels them as HDD, CDD and Occupancy. The actual independent variables are chosen at the implementer’s discretion.

$$1. E = C_0 + C_1x_1 + C_2x_2 + C_3x_3 + C_4x_4 + C_5x_5 + C_6x_6$$

where

E is the daily energy usage

C_0 is the base load

C_1x_1 is the HDD term

C_2x_2 is the CDD term

C_3x_3 is the Occupancy term

C_4x_4 is the Reference Year term

C_5x_5 is the Shutdown term

C_6x_6 is the RTO term

Here C_5 and C_6 are the regression coefficients for the Shutdown (x_5) and RTO (x_6) indicator variables, respectively.

The Shutdown and RTO NRAs are calculated as follows in Equations 2 and 3:

$$2. NRA_S = C_5 * n_s$$

where

NRA_S is the non-routine adjustment for the shutdown period

n_s is the number of days in the shutdown period

$$3. NRA_{PS} = C_6 * n_{PS}$$

where

NRA_{PS} is the non-routine adjustment for the RTO period

n_{PS} is the number of days in the RTO period

Judging the Significance of the NRAs

The significance of the NRA depends largely on the user-entered values for the unadjusted savings and the uncertainty in the unadjusted savings. The unadjusted savings entered by the user is the difference between the baseline model adjusted to current reporting period conditions and the metered data over the current reporting period, as shown below in the first two blocks of Figure 3. It does not include the adjustments for capital measures or adjustments for savings from previous performance years.

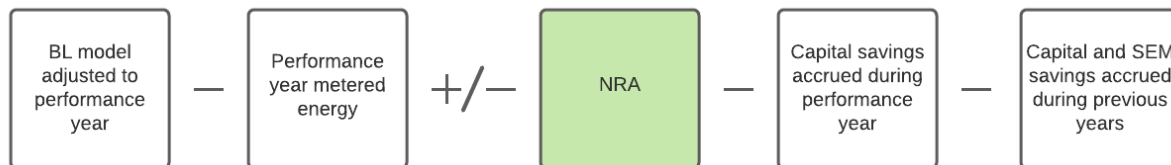


Figure 3. NRA application diagram indicating when the non-routine adjustment should be applied to the model.

The tool will advise against applying the NRA if it is less than its respective uncertainty. Additionally, the tool will advise that savings be zeroed if the adjusted savings is less than the uncertainty in the adjusted savings.

The tool calculates the uncertainty of the Shutdown NRA as the product of the critical t-statistic of the model, the standard error of the regression coefficient for the Shutdown indicator variable, and the number of days in the Shutdown period. Likewise, it calculates the NRA for

the RTO period as the product of the critical t-statistic of the model, the standard error of the regression coefficient for the RTO indicator variable, and the number of days in the RTO period. Since the two NRAs are not independent of one another, the tool assesses the total uncertainty of the two NRAs by summing the two uncertainties.

Since the unadjusted savings (entered by the user) and the NRAs (calculated by the tool) are independent of one another, the tool calculates the overall absolute uncertainty of the adjusted savings as the square root of the sum of the squares of the absolute uncertainty of the unadjusted savings (entered by user in terms of % fractional savings uncertainty and converted to absolute terms by the tool) and the total absolute uncertainty of the NRAs.

Results

The team tested the tool on 32 sites consisting of 24 schools, four community centers, two fire stations, and two government administration buildings providing a total of 32 electric samples and 28 gas samples. Using the three built-in approaches: Metered Energy Model, Residual Model, and Fixed Start Model (3/1/2020 to End of Performance Year), the team recorded Model Performance statistics including Coefficient of Determination (R^2), Coefficient of Variation - Root Mean Square Error (CV-RMSE), and Fractional Savings Uncertainty (FSU) for each model and compared them to determine which approach provided the best, most consistent result across the sample and for each site and fuel. Models with high R^2 , low CV-RMSE, and low uncertainty are preferred. The results presented here were all generated automatically from the tool with no manual changes.

Table 1 summarizes the number of times specific model types had the best performance of a given statistic. Residual models consistently outperformed metered energy models and fixed start date models across all statistics and fuel types except for gas CV-RMSE where the residual models had the lowest CV-RMSE the same number of times as the fixed start models across the sample. Based on the superior performance of the residual model, the team recommends that tool users select residual models as the primary approach for NRE detection.

Table 1. Count of best model performance statistics

		Lowest CV-RMSE	Highest R^2	Lowest shutdown NRA uncertainty	Lowest combined NRA uncertainty
All Sites	3/1/20 – End PY Model	15 (25%)	1 (3%)	0 (0%)	2 (6%)
	Residual Model	31 (52%)	26 (68%)	22 (61%)	21 (62%)
	Metered Energy Model	14 (23%)	11 (29%)	14 (39%)	11 (32%)
Electric Sites	3/1/20 – End PY Model	4 (13%)	1 (4%)	0 (0%)	2 (9%)
	Residual Model	20 (63%)	17 (71%)	14 (61%)	13 (57%)
	Metered Energy Model	8 (25%)	6 (25%)	9 (39%)	8 (35%)
Gas Sites	3/1/20 – End PY Model	11 (39%)	0 (0%)	0 (0%)	0 (0%)
	Residual Model	11 (39%)	9 (64%)	8 (62%)	8 (73%)
	Metered Energy Model	6 (21%)	5 (36%)	5 (38%)	3 (27%)

After applying the residual analysis method to all sites, the team found that the tool identified different shutdown periods between electric and gas at some of the sites. The tool tagged a Shutdown NRE period at 84% of electric sites and 57% of gas sites. The team believes the tool detected fewer significant gas NREs because of the timing of pandemic onset with normal seasonal reduction in gas use. In cases where the shutdown period for electric is substantially different from that of gas, the team recommends the user examine the charts in the tool to see if there are “near” NREs – those that barely missed the threshold for being tagged as an NRE – that would bring the shutdown periods into closer alignment between electric and gas. If so, the user should override the tool-generated shutdown period dates with manually entered dates.

While using the residual approach, the tool identifies the Shutdown NRE from the changes in energy consumption that are reflected in the time-series changes in model residuals. *It is important to recognize that the tool cannot know the cause of this potential NRE, so the user should confirm its source with the site SEM.* It may be a true COVID-driven NRE, some other random NRE independent of COVID, implementation of an energy efficiency measure or SEM action, or any combination of these different influences.

It is also important to recognize that *what the tool identifies as the Shutdown period may not reflect the most deviant change in energy consumption over the modeled timeframe.* For cases such as this, the tool allows the user to enter their own dates for the Shutdown period.

Use Cases

Program EMEs are using the non-routine event/non-routine adjustment (NRE/NRA) tool to estimate the impact that a non-routine event has on facility energy profiles. The user inputs daily consumption and up to three different independent variables. Once data has been input, the tool will automatically update and determine which independent variables have a statistically significant impact on energy consumption, those that are not statistically significant can be toggled off and removed from the regression model.

The tool has been applied to a wide range of facilities including large commercial customers, school districts, government organizations and higher education. It is important to communicate with building operators to determine whether the building was shut down and validate when the shutdown period began/ended.

This section depicts four different applications of the tool and how the EME came to a decision as to which adjustment to apply to the facility’s energy model. The four examples included depict a shutdown period identified with the residuals approach, a facility that had multiple shutdown periods, a shutdown but no RTO period based on metered energy, and a facility that had energy savings measures implemented during the shutdown period.

The first example was at a government organization that saw shutdowns at their facilities in mid-March 2020. The performance period for this analysis ran from 1/1/2020-12/31/2020. The original weather-adjusted model showed 2,274 kWh in savings, which correlates to a 400% increase in savings year over year. Figure 4 below shows the clear decrease in consumption from year to year.

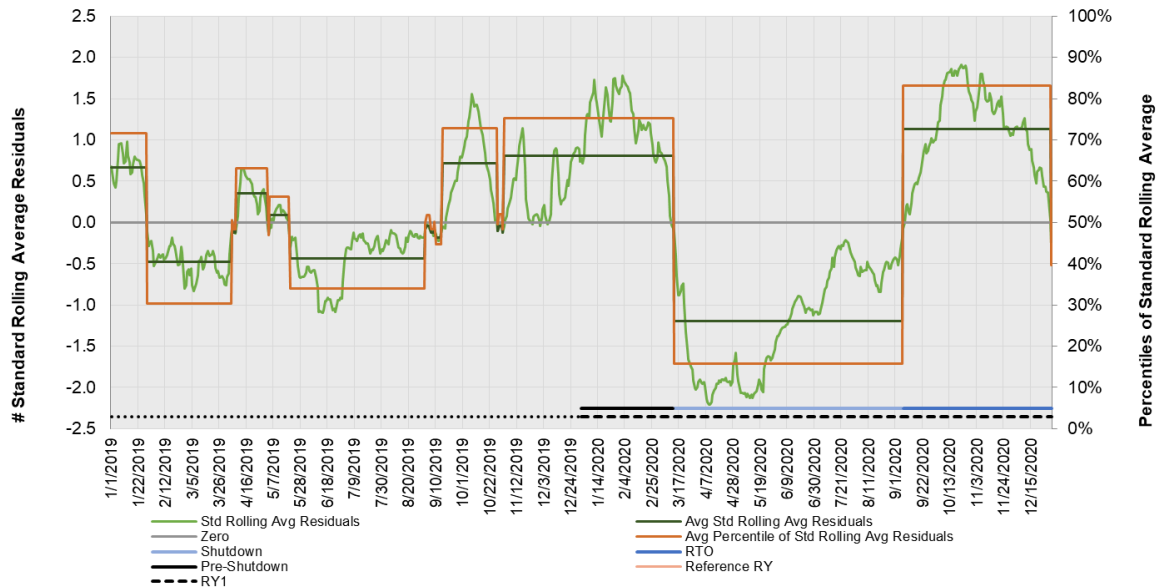


Figure 4. Standard rolling average and percentiles of residuals for a government building showing a possible shutdown extending from March 13th, 2020, through September 6th, 2020.

After inputting daily facility data into the NRE/NRA tool, the tool flagged an NRE and calculated the impact of the NRE. The recommended method for this tool is the adjustment based on residuals. The tool's built-in features include determining the statistical significance of each independent variable. In this case the reference year was not statistically significant, and this variable was removed from the NRA model. This tool recommended both a shutdown NRA and an RTO NRA. The tool has built in features that help you to determine the NRA model's validity and whether to accept the adjustment that the tool is recommending. Figure 5 is the output that the tool creates once data has been input. The bottom row is a validation check that flags a cell if the uncertainty in the NRA or the uncertainty in the PSE unadjusted savings is greater than the NRA.

	Shutdown	RTO	RTO + Shutdown
Shutdown based on Residuals	177 days	115 days	293 days
Date Start	3/13/2020	9/7/2020	3/13/2020
Date End (inclusive)	9/6/2020	12/31/2020	12/31/2020
NRA	-1,611	-144	-1,755
Impact % of Current RY	-22.6%	-2.0%	-24.7%
Uncertainty in NRA	103	76	179
% Uncertainty in NRA	6.4%	52.7%	10.2%
Adjusted Savings	663	2,130	519
Uncertainty in Adjusted Savings	466	461	489
Adjusted FSU			12.1%
Actual Energy Use as % of Expected Energy Use Without COVID	58.4%	95.1%	74.6%
R ²			74.5%
CV(RMSE)			22.1%
t-Test against Reference RY	0.0%	92.0%	0.0%
t-Test against Pre-Shutdown	0.0%	0.0%	0.0%
t-Test against Shutdown		0.0%	
NRA > Uncertainty in NRA and/or Uncertainty in PSE Unadjusted Savings	TRUE	FALSE	TRUE

Figure 5. Tool output summary of results for the government building model presented in Figure 4 including RTO variable in the model.

In this instance, the RTO indicator variable was removed from the model as the uncertainty in adjusted savings was larger than the NRA. Figure 6 shows the model results after removing the RTO indicator variable from the model, the final adjustment was a 1,565 kWh reduction in savings, resulting in 683 kWh in savings being claimed at this site.

	Shutdown	RTO	RTO + Shutdown
Shutdown based on Residuals	177 days	115 days	293 days
Date Start	3/13/2020	9/7/2020	3/13/2020
Date End (inclusive)	9/6/2020	12/31/2020	12/31/2020
NRA	-1,565	0	-1,565
Impact % of Current RY	-22.0%	0.0%	-22.0%
Uncertainty in NRA	100	#DIV/0!	100
% Uncertainty in NRA	6.4%	#DIV/0!	6.4%
Adjusted Savings	709	2,274	709
Uncertainty in Adjusted Savings	466	#DIV/0!	466
Adjusted FSU			12.1%
Actual Energy Use as % of Expected Energy Use Without COVID	58.4%	95.1%	74.6%
R ²			74.3%
CV(RMSE)			22.2%
t-Test against Reference RY	0.0%	92.0%	0.0%
t-Test against Pre-Shutdown	0.0%	0.0%	0.0%
t-Test against Shutdown		0.0%	
NRA > Uncertainty in NRA and/or Uncertainty in PSE Unadjusted Savings	TRUE	#DIV/0!	TRUE

Figure 5. Tool output summary of results for the government building model presented in Figure 4 excluding RTO variable from the model.

The next example demonstrates how the tool can detect multiple NREs that occur within the same performance period. The chart in Figure 7 shows there are two distinct shutdown periods, the first occurring in March 2020 with a return to typical building operations in June. The second shutdown occurs in September and runs through the end of the performance period in December.

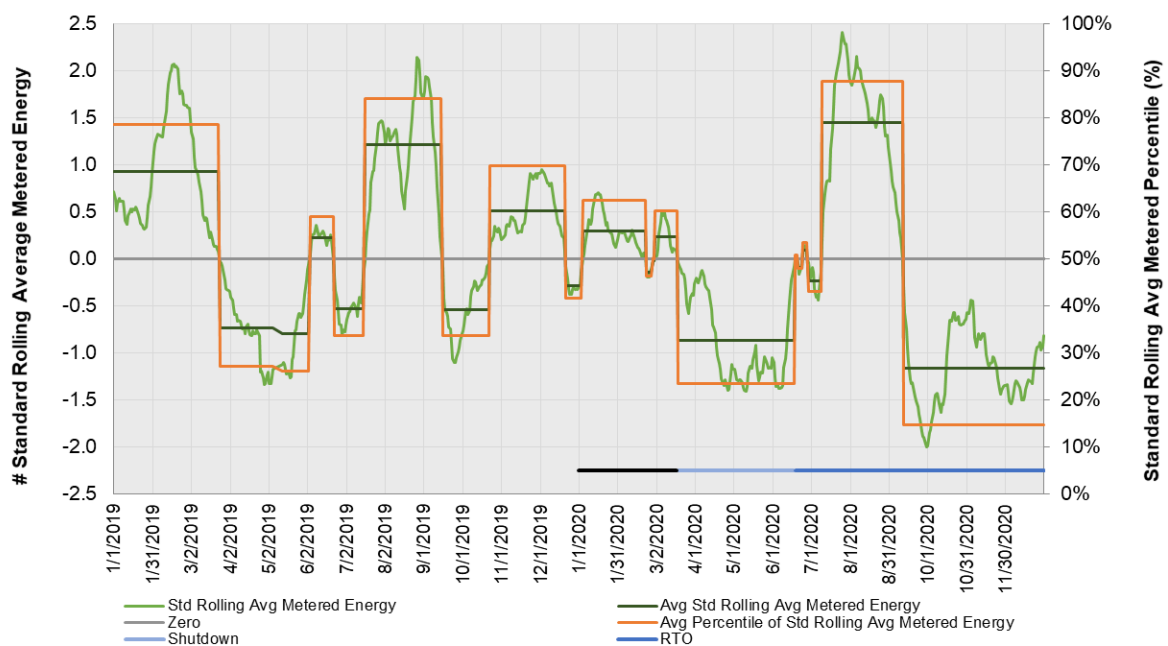


Figure 7. Standard rolling average and percentiles of residuals for a building with two distinct shutdown periods and a period of normal operation between them.

The tool automatically flags and selects which NRE to make an adjustment for, but it also has a manual override that allows you to pick which NRE to make an adjustment for.

	Pre-Shutdown	NRE1	NRE2
		15	21
Date Start	1/1/2020	3/19/2020	9/12/2020
Date End	3/18/2020	6/18/2020	12/31/2020
Previous RY	87.6%		
	0.26	0.23	0.15
	Select First NRE	Auto	
	Select Last NRE	Auto	

Figure 8. Image depicting automatic NRE detection from tool.

Figure 8 above shows the automated function that selects the NRE but by clicking on the cells containing “Auto”, the user can select the specific NRE to make the adjustment on. Figure 9 below demonstrates this.

	Pre-Shutdown	NRE1	NRE2
		15	21
Date Start	1/1/2020	3/19/2020	9/12/2020
Date End	3/18/2020	6/18/2020	12/31/2020
Previous RY	87.6%		
	0.26	0.23	0.15
	Select First NRE	Auto	
	Select Last NRE	Auto	

Figure 9. Image depicting option to manually select NRE timeframe in tool.

Being able to select which NRE to create an adjustment for allows for two NRAs to be applied to this site. The first shutdown adjustment ran from 3/19/20-6/18/20 and the tool recommended a decrease of 1,659 kWh in savings. The second shutdown adjustment ran from 9/12/20-12/31/20 and the tool recommended a decrease of 5,470 kWh in savings. There was no RTO adjustment made to the model between the two NREs because the site returned to typical operations during that time period. In total, the NRA for this site was a decrease of 7,129 kWh in savings.

Another example comes from a large commercial customer. This site has a performance period that spanned from 3/1/2020 - 2/28/2021 and the original model showed 3,743,049 kWh in energy savings during the performance period. Figure 10 shows the large decrease in consumption when facility shutdown occurred in 2020, with no clear return to occupancy following the facility shutdown.

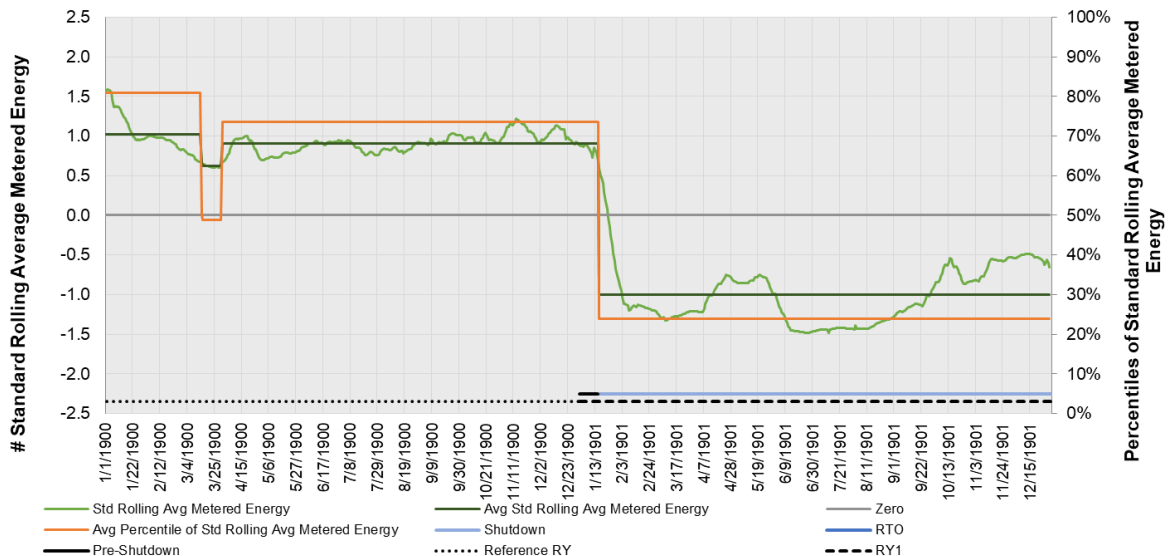


Figure 10. Standard rolling average and percentiles of metered energy for commercial site with no visible return to occupancy.

In this example the NRA method based on residuals recommended an adjustment of 2,033,607 kWh, which would mean the site would have 1,709,442 kWh in savings. In the year prior to this analysis the site saved 705,559 kWh, so it was determined that the NRA that utilized the residuals method underestimated the impact of the NRE. The adjustment based on metered energy usage recommended an adjustment of 3,004,420 kWh, which meant the site would've saved 738,629 kWh without the impact of COVID. As there were no energy saving measures implemented at this site during the performance period, the shutdown based on metered energy brought the savings estimate within an acceptable range to claim savings at this facility. It is important to note that there needs to be communication between the user of the NRE/NRA tool and facility operator to accurately understand what is going on at individual sites so that the correct NRA is applied.

In the final example, the facility was shut down due to COVID-19 and the building operator took the opportunity of having an unoccupied space to implement measures that saw a further decrease in consumption. The tool flagged a NRE and, using the NRA based on residuals method, recommended an adjustment of 258,743 kWh and a RTO adjustment of 441,414 kWh. The tool recommended a total decrease of 700,157 kWh in savings. The original model for this site had 957,885 kWh in savings and with the adjustment this brought the final savings being claimed to 257,728 kWh. In previous years this site had consistently had more than 400,000 kWh in savings annually, so this NRA represented a potential over adjustment to savings. Since there were energy savings from measures that were implemented during the shutdown period, the tool combined the shutdown and efficiency measures into one NRE and recommended a larger adjustment be made. If efficiency measures are implemented close to or within the time period of

an NRE, the tool alone is unable to decipher which savings are attributed to the NRE and which savings are attributed to energy efficiency implementation. To overcome this limitation, the program is waiting until the following performance year to identify and claim the savings from the efficiency measures.

Another beneficial feature of this tool is the user-defined shutdown method, which allows the dates that the facility was shut down and returned to occupancy to be entered manually. This allows users of the tool to communicate with building operators to specify exactly when a building shut down, giving a more accurate estimate for the adjustment being made to the model.

The tool produces the familiar goodness of fit model statistics, enabling the user to better understand the validity of the NRA and determine whether to accept the model or not. These include R^2 , CV-RSME, FSU and % uncertainty in NRA. It is up to individual EMEs and program managers to determine what threshold needs to be met to deem models as acceptable. ASHRAE Guideline 14-2014 Measurement of Energy, Demand and Water Savings recommends that the baseline model “shall have a maximum CV-RSME of 20% for energy use” and a criterion of 65% FSU at 80% confidence (ASHRAE 2014).

As of the submission of this paper, program EMEs have applied the tool on 32 participant sites so far since July 2021 to detect and adjust for non-routine events impacting meter-based savings estimation. The tool estimated over 9 million kWh and over 13,000 therms in non-routine adjustments, allowing the program to claim 3.6 million kWh and 7,300 therms rather than writing off all savings or egregiously overclaiming savings for these sites. These adjusted savings comprise 54% of C-SEM electric savings and about 2% of C-SEM gas savings for program year 2021. The program is applying other methods for adjusting savings at other sites for less complicated situations, such as those with shorter shutdown periods that can be omitted from the model, or when the model goodness of fit criteria cannot be met which is a frequent occurrence for gas models. Additionally, poor quality interval meter data requires extra effort to clean and prepare the data for use in the NRE tool.

Conclusions

The NRE tool is one of many technological innovations that emerged out of the challenges of the COVID pandemic. It demonstrates the resourcefulness of engineers and analysts applying advanced M&V methods to create tools that allow programs like Strategic Energy Management to remain focused on implementing behavior change in facility operators, rather than training them to be statisticians. The NRE tool helps level the playing field both at the individual practitioner level and at the program level, reducing resources required to reliably estimate savings attributable to program interventions. Not only do such tools allow facility operators of more diverse backgrounds to successfully participate in the program, but they also make programs more cost-effective. In this case, the program has been able to recover and claim savings it would have otherwise lost due to cost-prohibitive efforts of gathering the detailed data required to develop bottom-up savings estimates for each site based on each energy efficiency action taken. Further efforts are needed to improve access to and quality of the energy data as well as the independent variable data to better fine-tune the models. It is the authors' hope that these efforts will continue along with implementation of the other analytical methods and approaches described in the IPMVP NRE/A Application Guideline. These types of analytical tools are becoming increasingly crucial as behavior- and performance-based energy efficiency programs are scaled to help decarbonize all buildings, regardless of where they are located or who operates and occupies them.

References

EVO 2016. *International Performance Measurement and Verification Protocol (IPMVP), Core Concepts*. Washington, DC: Efficiency Valuation Organization (EVO). <https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp>

EVO 2020. *IPMVP Application Guide on Non-Routine Events & Adjustments*. Washington, DC: EVO. https://evo-world.org/images/denisdocuments/NRE_TOC.pdf

ASHRAE. 2014. *ASHRAE Guide 14-2014: Measurement of Energy, Demand, and Water Savings*. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). https://ansi.cachefly.net/preview-pages/ASHRAE/preview_ASHRAE+Guideline+14-2014.pdf