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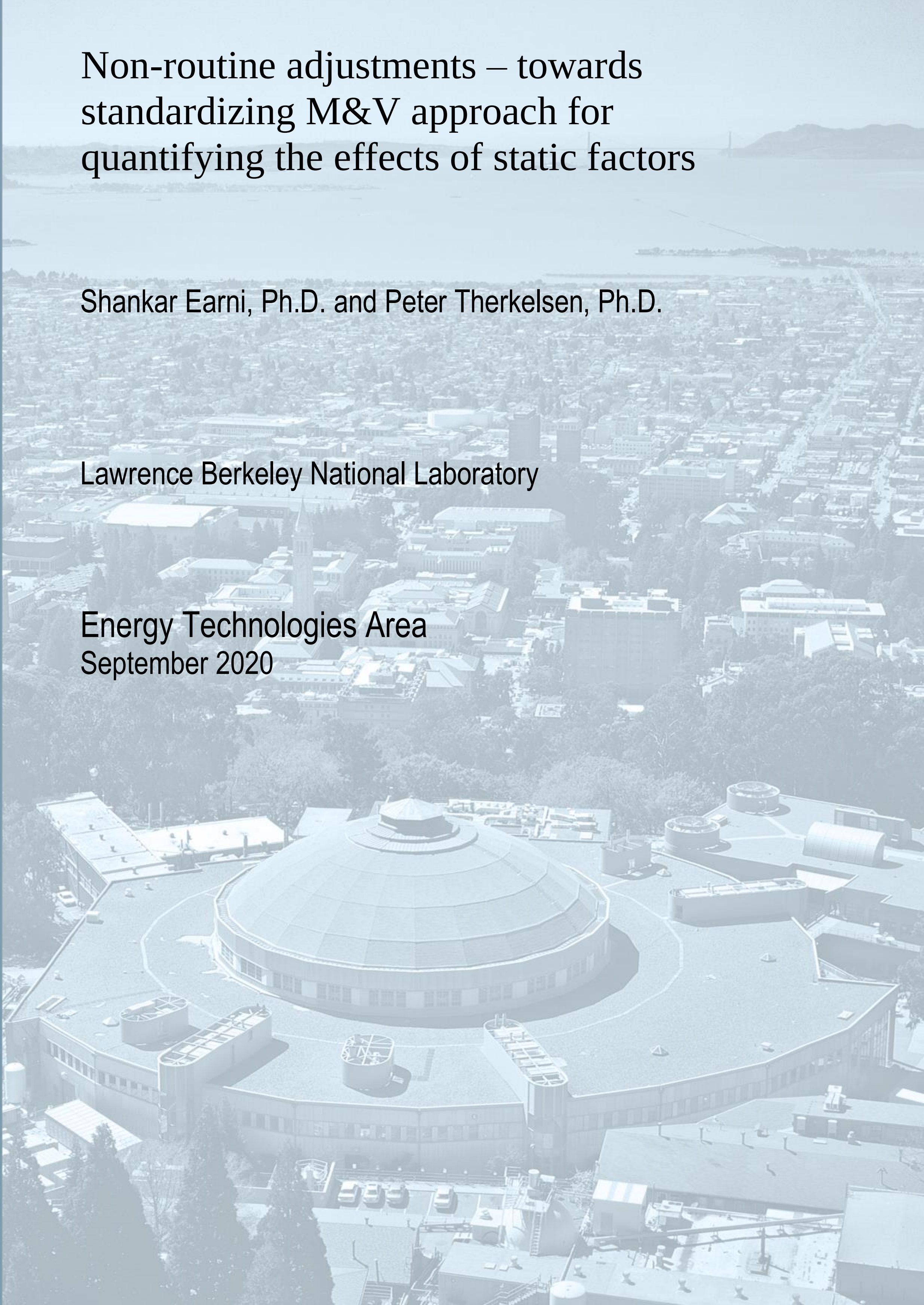

Non-routine adjustments – towards standardizing M&V approach for quantifying the effects of static factors

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Non-routine adjustments – towards standardizing M&V approach for quantifying the effects of static factors

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Abstract

The success of an energy management program relies on ensuring that the energy savings can be verified with an adequate level of certainty. Energy savings cannot be directly measured and hence have to be deduced by comparing the pre-retrofit energy consumption with post-retrofit energy consumption data adjusted to account for differences in conditions. These adjustments are needed, since conditions that influence energy consumption may not stay the same between pre- and post-installation phase of the project. These adjustments can often be routine when accounting for factors like production volume and weather that are expected to change and are included in the energy consumption adjustment model. Existing measurement and verification (M&V) resources and guidance mostly concentrate on developing models for routine adjustment of one or more factors that normally change. On the other hand, there are factors (static) like product mix, operating hours, gross square area, etc. that are assumed to stay constant during normal conditions. However, in order to adapt to dynamic market conditions, the industries are forced to react thereby leading to changes to these static factors. Identifying these static factors that warrant adjustment, called non-routine event, along with quantifying their effect on energy consumption can be complex and lack of proper guidance can exacerbate this issue. This paper reviews some of the current work in terms of how non-routine events are defined, characterized, detected and quantified based on a review of existing M&V guidelines, protocols and other relevant literature. This work also reviewed some of the existing non-routine events and adjustment practices to understand how these different aspects are addressed along with a discussion on some of the key challenges and gaps in the current guidance.

Introduction

Measurement and verification (M&V) can play a key role to not only evaluate the performance of a measure, project, or facility, but also helps to instill the necessary confidence in the energy management program. Choosing an M&V strategy is a balancing act between savings uncertainty and M&V costs. M&V strategy depends on the industrial site's risk tolerance, maturity of the technology, scope of the project, data availability and program requirements. Efficiency Valuation Organization's (EVO) International Performance Measurement and Verification Protocol (IPMVP) groups M&V approaches into four types: Options A, B, C, and D into two broad general groups: retrofit isolation and whole facility. Retrofit isolation methods look only at the affected equipment or system independent of the rest of the facility; whole-facility methods consider the total energy use and de-emphasize specific equipment performance. With the abundance of available energy and other relevant data at a higher granularity has invoked higher interest among practitioners to develop cheaper, better and faster M&V strategies to evaluate the performance of the systems, facilities, measures and projects. Unfortunately, energy savings cannot be directly measured and hence have to be deduced by comparing facility's energy consumption across different phases to estimate the associated energy savings. In order to ensure that the energy comparisons are meaningful and accurate, adjustments are needed, to account for changes in the operation conditions during the comparison periods. Some of these adjustments can be "routine" when adjusting for factors that are expected to change, like the weather, production in the case of industrial plants and are not that difficult to account for, given various available modelling approaches that can correlate energy consumption to these variables. On the other hand, factors like occupancy, operating hours, gross square area, that do not typically change between the baseline and achievement periods, often referred to as static factors, are harder to detect their change and adjust for their impact. These "non-routine" adjustments can be difficult partly due to lack of underlying data for these static factors that corresponds to the energy data to build a reasonable model that can be used to estimate their effect. But these changes have to be factored in and appropriate adjustments need to be made in order to assess the true impact of the energy conservation measure, project or a program. This process of defining these events that are a result of changes to these static factors, identifying this non-routine event, determining the need for an adjustment and quantifying the magnitude of these adjustments is somewhat fragmented and opaque, and can be somewhat contentious between the parties without proper guidance. This work focusses reviewing various available M&V guidelines and resources to develop an understanding of how these non-routine adjustments are being defined along with possible ways these changes to static factors are being identified along with techniques that are being adopted to quantify the effect of these changes. This work will review and characterize some of the current practices at one of the United States Department of Energy (DOE) programs in order to provide an understanding of some of the gaps and research needs in this area.

Background

Non routine event (NRE) is used to refer to changes in energy use that are not attributable to installed efficiency measures and not accounted for in the baseline model's independent variables (Touzani et al 2019). The changes are typically related to facility equipment or operations, including but not limited to renovations, facility expansion, equipment addition or removal, etc. For example, consider a scenario where a manufacturing plant that has installed multiple measures that are part of an energy management program to improve the energy efficiency of their operations. The implementation of these measures started on February 1st 2016 and ended on June 15th 2016. In order to evaluate the performance of these measures, the facility has chosen Option C whole facility level analysis as part of their M&V strategy. This involved developing a baseline model using 2015 energy data for both gas and electricity and the corresponding independent variables – outside air temperature and production volume. As part of the M&V strategy, this baseline model was used to predict the baseline energy consumption of the facility in the absence of these energy measures. This predicted baseline energy consumption is compared with the actual energy consumption during the post retrofit period which is determined to be 2017 to calculate energy savings. However, in 2017 the company added a new facility for machining new product line along with the addition of a new office building and cafeteria which increased energy consumption which is considered an NRE. Since this new facility and additions were not part of the energy consumption during the baseline period (2016), comparisons of model predicted baseline energy consumption and actual energy consumption in 2017 is less meaningful as it would skew the savings indicating a false impression that the installed measures might not be performing. In order to account for the true performance of these measures, some additional non routine adjustments have to be made so that the energy effects of the new added facilities can be properly taken into account while evaluating the performance of these measures.

Problem Statement

Non-routine event (NRE) detection and adjustments can get complicated especially with lack of proper guidance. This involves understanding as to what constitutes a change, mechanism to monitor and look for that change, gathering sufficient information and data surrounding the change in factors, along with ways to account for this change to make the necessary adaptations. Some of the related issues to the NRE detection and adjustments are:

- Defining what is a change in energy consumption that warrants adjustment
- Detecting that there is a change in energy consumption that needs an adjustment
- Identifying what static factor or factors caused the change in energy consumption
- Gathering preliminary data needed to understand that change in energy consumption is worth quantifying given the project's scope
- Gathering detailed data related to the static factor or factors in question during both the pre and post retrofit conditions
- Evaluate options to quantify the effect of the static factors depending on available resources and proficiency.

To understand the problem, related issues and its implications, the following formulation is developed. Assume an energy consumption profile for a given facility with a certain set of statistical characteristics mean (μ_1) and variance (σ_2) for the distribution. At time step, τ, an event or a set of events (NRE) occurred that changed the distribution that altered the mean (μ_2) and variance (σ_2).

$$X_i{\sim}N(\mu_{1,}\sigma_1^2)\ for\ i = 1, 2\ ....\tau \tag{1}$$

$$X_i{\sim}N(\mu_{2,}\sigma_2^2)\ for\ i = \tau + 1, \tau + 2 \ldots k \ldots n. \tag{2}$$

Where n is the length of the series, τ is the point where the change occurred, *k* is the point until which the change lasted. As part of the change point detection process is to identify if a detectable change happened that changed the distribution either in terms of the mean and or variance; and the next step is to identify when that change happened (τ).

As part of the process, one might encounter three possible scenarios:

- Shift in the mean, with no change in the variance
  $\mu_1 \neq \mu_2$ and $\sigma_1 = \sigma_2$
- Shift in the variation, with no change in the mean
  $\mu_1 = \mu_2$ and $\sigma_1 \neq \sigma_2$
- Shift in the both mean and variation
  $\mu_1 \neq \mu_2$ and $\sigma_1 \neq \sigma_2$

In terms of what's known and unknown, here are the possible scenarios:

1. μ_1, μ_2, σ_1, σ_2 known, but not τ
2. μ_1, σ_1 known, but not τ, μ_2, σ_2
3. μ_1, $\sigma_1 = \sigma_2$, known, but not τ, μ_2

It is also important to define what constitutes a change in the load, $|\mu_2 - \mu_1|$ has to exceed a certain threshold (λ) in order to be considered a special cause, change to a static factor, that might be attributable to an NRE that warrants adjustment. Another important aspect is the establishing similar threshold for the time of duration for the event (k-τ). This will help to identify events that are longer than this threshold (T), in order to reduce the instances of false positives that may or may be related to the NRE.

Literature Review

According to IPMVP (EVO 2016), adjusted baseline energy is defined as *the baseline period energy consumption modified as part of routine and non-routine adjustments to account for changes in the reporting period.*

$$\text{Savings} \\ = (\text{Baseline Period Energy} - \text{Reporting Period Energy}) \\ \pm \text{Routine Adjustments} \pm \text{Non-Routine Adjustments} \quad (3)$$

Routine adjustments are defined as individually engineered calculations to account for the expected change in energy consumption or demand due to changes in the independent variables within the measurement boundary. Non-routine adjustment is defined as individually engineered calculations to account for the energy effects due to changes in the static factors within the measurement boundary, while a static factor is defined as those characteristics of a facility which affect energy consumption and demand, within the defined measurement boundary, that are not expected to change, and were therefore not included as independent variables. On the other hand, if these static factors change, non-routine adjustments need to be calculated to account for these changes. IPMVP (EVO 2016) specifies that for these static factors can be related to environmental, operational or maintenance. Some common examples of static factors needing non-routine adjustments are changes in the facility size, number of weekly production shifts, number of occupants, amount of space being heated or air conditioned, type and volume of products being produced, building envelope characteristics (new insulation, windows, doors, airtightness), amount, type or use of the facility's and the user's equipment, indoor environmental standard (e.g. light levels, temperature, ventilation rate). ASHRAE Guideline 14 (ASHRAE 2014) characterizes nonroutine adjustments are made to account for changes to static factors that affect relevant energy consumption, such as changes to facility's use or operations, including but not limited to renovations, facility expansion, changes in usage, addition or removal of equipment. This guideline equates non-routine adjustments to baseline adjustments. SEP M&V Protocol (US DOE 2018) sets forth the verifiable methodology for determining and demonstrating achievement of the energy performance improvement level claimed by an organization for a defined facility.

This protocol which is geared towards industrial sector equates routine adjustments with normalization which is used to account for regular changes in relevant variables. According to ISO 17743 (ISO 2016), non-routine adjustments are made where there are effects that significantly influence energy consumption, but which occur relatively infrequently and are not as a result of any intentional EPIAs or policy-induced measures.

DEFINING NRE

BPA's MT&R guidelines (BPA 2018) provides the following scenarios for NREs that would trigger a reassessment of the baseline model include:

- Process Change: These changes can be considered substantial if energy consumption characteristics of the facility change as a result of a process change. In general, the baseline model is only valid for the range of the independent variables observed for the baseline period that was used to build the model. The SEP Protocol (US DOE 2018) provides a general guideline that the data for the independent variable during the reporting period be within three standard deviations (±3σ) from the mean of the baseline data set. ASHRAE Guideline 14 (ASHRAE 2014), advises: "apply the algorithm for savings determination for all periods where independent variables are no more than 110 % of the maximum and no less than 90 % of the minimum values of the independent variables used in deriving the baseline model." Some of the examples of a major process change can relate to a shift in plant operations from batch-type to continuous or due to an uncontrollable and unforeseen change in raw material types, grades, or properties that changes the energy intensity.
- Static Change: These are changes to load within a well-defined boundary and with minimal interactive effects, that are not expected to change based on the initial assessment of the facility. Examples of a static change are an addition of a new exhaust fan for safety/environmental purposes or added section of the facility in which the energy flows can be easily isolated.
- Changes to exogenous factors: Buildings (SCE 2018) and facilities in general may exhibit gradual changes in energy use due to external effects, such as up or downturns in the local economy, or other causes that increase or decrease building activity and energy use. Over time, such effects may become significant, and bias the savings estimate.

BPA (BPA 2017) additionally proposes the following categorization scheme to characterize non-routine events phase: Baseline, implementation, reporting; duration of the change – short term – one that that occurs for a limited number of days – usually one or two days); temporary – one which spans several weeks to several months; permanent change – one that lasts forever; energy impact correlation – constant; varying with time; varying with weather; varying with both time and weather; varying with a different independent variable (production). Table 1 summarizes aspects that need to be taken into account while characterizing an NRE in addition to some of the ones described above from various guidelines.

The key aspect being the magnitude of the load that's impacted as a result of the NRE. This magnitude can be assessed by setting a threshold in relation to the baseline or post retrofit load. This will help to focus on a select few NREs rather than vast many that can potentially impact energy consumption significantly (reducing the number of false positives). In addition to the magnitude, another key aspect is duration of the NRE, whether this event lasts for a few days or for a longer time or is it permanent. Having parameters to define and characterize the duration in relation with some thresholds would be useful in focusing on events that are meaningful. This would also depend on the frequency of the data that's available for analysis- for example if the available data is monthly, some of the shorter duration events will be harder to detect through a quantitative based approach. On the other hand, having data that's too granular might be noisy and could potentially generate false positives when detecting NREs. Another important aspect to consider is to identify if there is any pattern to the changes to energy consumption pertaining to the NREs. For example, NREs that are heating related will only occur during the winter season. Addition of weekend shift will only affect energy consumption during that period. All these different aspects of the NREs discussed above directly translate into energy consumption, and hence should be the final indicator to decide if a given NRE warrants adjustments. It's important to note for each of the different aspects that are discussed, even though pass their threshold tests, their energy consumption as a result of the NRE may not be large enough to warrant adjustments. Hence, this associated energy consumption is the final barometer to indicate if an adjustment is warranted, this can be done by comparing this energy consumption to the baseline or post retrofit energy consumption or the proposed savings along with model uncertainty.

DETECTING NRES

Once the NREs are defined, the next step is to identify these NREs if and when they occur. This can be done either through feedback from facility personnel that are involved with day to day operations or through quantitative data-based approaches or some combination.

Human feedback – direct knowledge of the building or from the customer

Most of the current NREs are identified and documented by facility personnel about any changes to the facility's characteristics, performance or operation. These changes can be documented to specify the type of static factor (e.g., gross square footage), duration of the change (e.g., occurred for 2 months during the verification period starting in September). This manual process can be cumbersome especially if the personnel are not familiar with the facility and or operation or if the facility is considerably large for keeping track of all these changes. It is important to have an organizational structure, process and system in place to identify NREs and the associated static factors that need to be reported that affect energy consumption significantly.

Statistical based approaches

Detecting NREs based on purely the knowledge of the facility personnel can be very difficult and some level of quantitative analysis is needed to either supplement or corroborate the information from the facility personnel. Some of the statistical process control techniques (Taylor 2000) (Koutras et al. 2007), may be used for this quantitative analysis, to detect and diagnose NRE cases. The Shewhart X-bar with an R- or S- chart is an excellent tool for detecting special causes that lead to large changes whether sustained or isolated abnormal cases that appears to come from some distribution other than the in-control distribution. In contrast, this type of control chart may instantly detect a large shift in the process level. Several rules were outline (Kiemele et al. 1999) to indicate an out-of-control signal. As discussed above, Shewhart charts are more suitable to detect sudden shifts or changes to the distribution and not good to detect

Table 1. Characterization Matrix for NRE.

Characteristic	Options	Details
Magnitude	Low High	Can be defined by specifying a threshold in relation to the magnitude of the baseline energy consumption, proposed savings and model uncertainty
Duration	Temporary Permanent	To be defined and its relation in relation with a threshold and frequency of the data that's available for analysis
Frequency	Often	Important aspect to identify how often does this change happen and with identifying any cyclicality (e.g., every summer, September, 3rd week, Sunday)
Phase	Baseline Interim Post retrofit	Defining when this change occurred – baseline, interim post retrofit, middle of the baseline
Type	Structural, Operation (Load, Schedule) End Use	Specify if the NRE is related to the load or schedule change or both. Also, in terms of CL or VL or loads; TS and VS for schedules
Impact Correlations	Time Variant Weather Variant Other Independent variable dependent (Production) Combination	Specify if the event has any characteristics that can be correlated with any of the independent or other variables

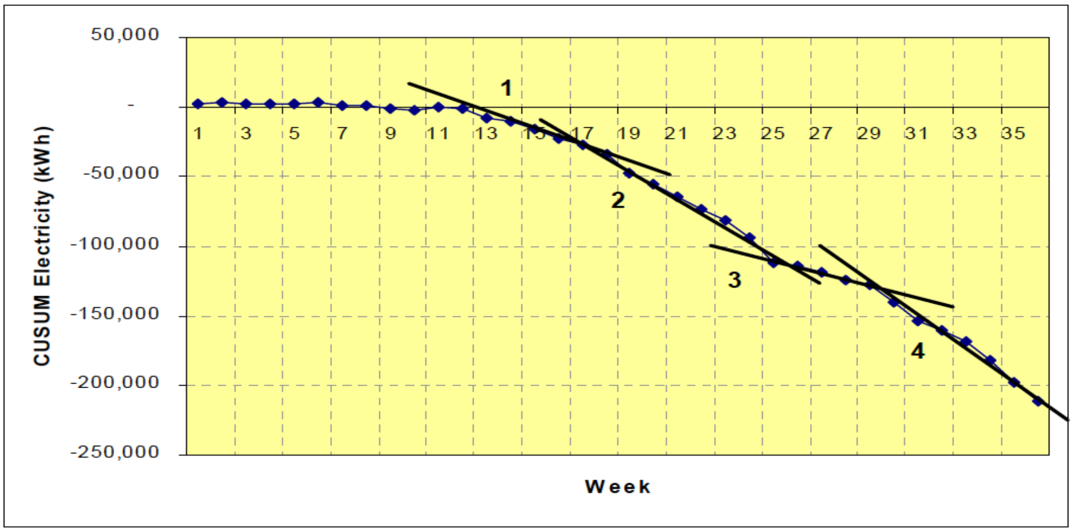

Figure 1. CUSUM chart showing sections corresponding to changes to energy consumption (Wallace & Greenwald 2007).

small and sustained changes. On the other hand, tools like cumulative sum (CUSUM) chart and the exponentially weighted moving average (EWMA) chart can be used to detect sustained changes where accumulated variation is used for detecting small shifts, with less sensitive to effects of autocorrelation. The power of CUSUM chart can be applied to detect anomalies in energy consumption (Wallace & Greenwald 2007) (Figure 1).

The CUSUM graph therefore consists of straight sections separated by kinks; each kink is associated with a change in pattern, each straight section is associated with a time when the pattern is stable. The critical points on the CUSUM graph are the changes in slope of the line. These can be easily seen, and more precisely located by laying straight lines over the more or less constant slope sections, as illustrated in Figure 1. The changes to slope occurred at weeks 12, 18, 25 and 30, which may and may not be expected. In the context of high frequency time series data analysis, two enhanced detection options were also explored- one that uses dissimilarity metric and another that uses PELT changepoint algorithm (Touzani et al. 2018). The dissimilarity metric (Touzani et al. 2018) measures the proximity between the actual post-retrofit energy consumption and the projected baseline (which is generated using a statistical baseline model, and used as the counterfactual in the savings estimate) to partially automate, and therefore streamline the process of detecting NREs in the post-retrofit period and making associated savings adjustments. A simple F-test was used (Goldberg et al. 2019) to identify major changes in consumption patterns at a site. The F-test is used to determine whether a degree-day regression should have a single set of coefficients across the entire time period, or two different sets of coefficients before and after some change point. This method looks only for "regime change," that is, a "permanent" change in the consumption pattern after some change point identified from the analysis. This test can be used with daily consumption data.

QUANTIFYING THE EFFECTS OF NRES

Once the NREs are identified, the next step in the process is to quantity the effect of this event in order to make the necessary adjustment to account for that change. The following section discusses some of these approaches to quantify the effect of an NRE:

1. Statistical based models:
   a. To account for the effects of the NRE, a new independent variable that reflects the change can be added, if that variable proves to be statistically significant, along with its coefficient to the baseline model (ASHRAE 2014, BPA 2018) can be added to the baseline model. For example, if cooling were added to a building in the post retrofit period, that was not part of the baseline energy consumption, then the newly added independent variable like cooling degree-days or outside air temperatures, can be used to account for the energy consumption related to cooling.
   b. BPA's MT&R guidelines (BPA 2018) outlines the utilization of an existing baseline model, with the addition of an "indicator variable" placed in the data set at the time of the change. The impact of the change is thereby quantified by solving for the indicator variable coefficient using regression, following a suitable data collection period.
   c. BPA's Potential Analytics for Non-Routine Adjustments outlines the following four statistical based approaches to quantifying the impact using a model (BPA 2018):
      i. Analysing the time series data of residuals for a model that includes the time period of change and estimate the magnitude of the change from the change in the residuals.
      ii. Use a pre-post model with a 'mini baseline' and 'mini post' period. The mini baseline is the shorter time period that exists within a baseline or reporting period and is prior to the NR change. The mini post is similar – for a NR change that is ongoing, it is the shorter time period within a baseline or post period that includes the NR change. The pre-post model uses an indicator variable for the mini post period, and the coefficient on the indicator variable is the NRE impact.

    iii. For a change of long duration, especially one that is ongoing through the time period, the time periods around the non-routine change will be treated as a mini baseline and a mini post period, and model the change by subtracting the mini post period energy use from an adjusted baseline developed from the mini baseline period. This can be done using either a forecast or backcast approach, depending upon which mini period has better coverage for the independent variables.

    iv. For a temporary NRE of relatively short duration, the entire period can be used to develop the model excluding the portion of the period that includes the non-routine change. This model can be used in conjunction with the independent variable(s) for the times that include the non-routine change to estimate energy use for the entire period as if the non-routine change had not occurred.

2. Sub-metering-based approaches: According to ASHRAE (ASHRAE 2014), the most straightforward and possibly easiest way to account for the changes due to an NRE, is to submeter the effect. If the change involves new equipment or facility space, isolation of the electrical load through a dedicated submeter and the ensuing savings are the result of subtracting sub metered energy use from the gross savings (BPA 2018).

3. Calculation based approaches: Industrial SEM Impact Evaluation Report (SEM 2017) recommends non-routine adjustments during the baseline or reporting period energy consumption be made by using an engineering estimate. These methods can be roughly classified into two categories – detailed comprehensive method and a simplified method – based on the effort it takes to develop these methods (Zhao et al. 2012). The comprehensive methods are very detailed and typically hourly models to calculate facility's energy consumption by factoring in external climate conditions, facility construction, operation, utility rate schedule and HVAC equipment, and other inputs. On the other hand, simplified methods are more localized approaches based on aggregate models where the energy consumption of a system or a subsystem is calculated based on engineering principles, with certain reasonable assumptions.

4. Simulation based approaches: These approaches are also based on engineering principles. They are built on elaborate physical functions or thermal dynamics to precisely calculate the energy consumption for the whole building level or for sub-level components. Since these are very intricate and detailed models, they employ commercially available software. Building these models and running the analysis involve specialized skills and can be resource intensive.

Current practices

Superior Energy Performance is a certification program that recognizes excellence in energy management. Certification to the SEP program requires certification to ISO 50001 Energy management system – Requirements with guidance for use and third-party verification of energy performance improvement. Specific requirements for SEP certification are defined in the ANSI/MSE 50021 Superior Energy Performance – Additional Requirements for Energy Management Systems standard and its normative references. SEP M&V Protocol (US DOE 2018), a normative reference for ANSI/MSE 50021, sets forth the verifiable methodology for determining and demonstrating achievement of the energy performance improvement level claimed by an organization for a defined facility.

Additionally, this protocol outlines some of the processes and procedures and requirements for non-routine adjustments including documenting the rationale for an adjustment, general reasonableness of the methodology and calculations, the adequacy of the metering and monitoring methodologies, and conformance of the calculations applied. Non-routine adjustments shall be identified in an application to the SEP administrator and as part of the verification of energy performance improvement. In order to understand the state of non-routine events adjustments in SEP program, several of these completed applications were reviewed to document and catalogue the various approaches that are used to document, identify and quantify the effects of NREs. As part of this process, sixteen applications were reviewed and results are summarized in the Appendix Table A.1. Based on the analysis, here is the summary of that analysis using the characterization framework established in previous sections:

1. Rationale for adjustment: Most of the NREs in the applications are due to addition of a new process equipment to increase the operational efficiency and or to increase the production. While some of these changes are related to outsourcing operations to outside contractors or to other facilities at a different location within the organization.

2. Phase: Almost all of these NREs occurred during the achievement period, which is defined as the period immediately following the conclusion of the baseline period.

3. Duration: All the NREs reviewed can be categorized as permanent where the change persisted for the entire achievement period.

4. Identification: The reviewed applications indicated that all of these NREs were identified by the applicants and their personnel based on the information from the field.

5. Magnitude of the impact: Most of the adjustments were related to electricity, although there were a few that were related to natural gas consumption. These adjustments ranged from 1–20 % of the baseline energy consumption.

6. Quantification method: Most of the adjustments were based on the sub-metering the affected portion of the facility to adjust the energy consumption appropriately. Although there were a couple related to adjusting through a regression-based approach.

7. Quantification approach:

    a. Statistical modelling: In one of those cases where an NRA was conducted to adjust for a new product line, a new regression model was developed using the volume from the new production lines for the reporting period

(Case 1 in Table A.1 in Appendix). The coefficient for that new production variable from the new model was used to calculate the needed adjustment to adjust the energy consumption. In another case, where a new added facility, a monthly ratio was calculated by comparing consumption for the 12 months before the expansion to the 12 months after completion. These monthly ratios were used to adjust the baseline appropriately to account for energy this additional space. In another case (Case 16 in Table A.1), where a laboratory was moved to an off-site location during the reporting period which significantly reduced the electricity consumption. The adjustment included a model that was built with pre NRE data and its prediction was compared with the post NRE consumption to calculate the net affect due to the lab's energy consumption.

b. Submetering based approaches: Most of the surveyed approaches were sub-metering based where the affected system or equipment is isolated and the energy consumption data is collected and analysed to calculate the necessary adjustments. In one of those cases, a new equipment that uses natural gas, was added that was not part of the baseline. This natural gas consumption was determined through submetering, and this data is used to calculate the ratio of the steam consumed by the new equipment to the steam consumed by the entire steam system. The ratio/adjustment was applied during the reporting period to calculate the natural gas consumption by the new equipment and adjust the baseline appropriately. For instance, take the case of a manufacturer (Case 7 in Table A.1), where a sub-metering was used to adjust the product to account for removal of two sets of welding machines in two distinct phases – one set during the baseline period (2013) while the other set during the verification period (2016). As a result, this facility's electrical consumption was adjusted to account for these changes during both the baseline and reporting period. The electrical consumption for the first set of welders was estimated by subtracting the electrical consumption recorded by the electrical meter for each of the first six months in 2015 from their consumption for the corresponding months in 2013. The difference for each month was subtracted from the corresponding month during the first 6 months of 2013 as part of the adjustment. The electrical consumption for the second set of welders was estimated by subtracting the electrical consumption recorded by the electrical meter for each of the last four months in 2016 from the consumption for the corresponding month in 2015. The difference for each month was added to the corresponding month during the last 4 months of 2016 as adjustments.

c. Calculation based approaches: There were some adjustment approaches that relied on engineering calculations to supplement and or augment some of the sub-metering data. Consider cases (Case 6 and 8 in Table A.1), where additional facilities were added, where an adjustment is needed to account for this additional energy consumption. As part of the adjustment, the electricity and natural gas were sub metered for this additional area. Further adjustments were made to account for additional cooling load provided by chilled water from centralized chillers using engineering estimates and calculations. Similar engineering-based estimates and calculations were made to account for the heating load satisfied by central plant boilers. In another case (Case 7 in Table A.1), where some of the data gathered from loggers, was supplemented with information gathered from interviews of supervisors and operators regarding the operation, the power rating, and loading of the equipment to calculate the overall adjustment that's needed for an NRE.

Discussion and Conclusions

One of the challenges to evaluating the performance is the ability to adjust pre and post intervention energy comparisons to normalise their operations. These adjustments are considered routine when the factors that are affecting the energy consumption can be explained through a model that normalizes energy for changes to these factors. On the other hand, non-routine adjustments are made to account for changes to static factors that are not normally expected to change. These changes to these factors are becoming more and more common. To account for these changes and their adjustment procedures, more guidance is needed so that a more transparent and standard process that increases the confidence in energy projects and programs can be adopted. The following section summarizes some of the key challenges and gaps in the current guidance as it pertains to non-routine events and adjustments:

1. One of the key fundamental issue is the lack of standardized definition and framework to characterize static factors. This needs to consider the list of possible static factors for a given facility, along with their normal expected range and a clear definition of what constitutes an NRE in a transparent and standardized manner. Some of the existing literature classify these into temporary or permanent, although it is not clear as to what is considered to be a temporary event. Additional guidance around defining these temporary events while taking into consideration the frequency of the data that's available for analysis is needed. Another possible way is to define these NREs using the characterization methodology, based on ASHRAE guideline 14, that's used to determine the M&V strategy given the project or measure details, that is based on whether the change effects the load or schedule or both. Having a clear definition as to what constitutes an NRE will be a good start to making this adjustment process transparent. Also, developing a standardized language and verbiage to document these events in the M&V plan would also help to clearly state upfront as to what constitutes an NRE. For example, occupancy or occupancy density is expected vary from x to y. If these factors exceed y or go below x by k%, for certain period of time t, either during the baseline or intervention period or that constitutes an NRE.

2. Most of the current NREs are detected by field personnel through a mostly manual process with some supporting data as an aid. However, in order to make this a transparent

and less labour intensive, quantitative approaches based on the change point detection algorithms are emerging. However, it is not clear as to what methods work better given a type of NRE or a circumstance or data availability. A more thorough investigation of various quantitative based approaches and their applicability would be helpful in providing a more specific guidance for practitioners given their use case.

3. Another major issue with quantitative based NRE detection approaches is the lack of understanding if discrepancy in energy consumption can be assigned to a specific cause and in turn to a change in a specific static factor. By not knowing exactly the specific cause of the anomalous energy consumption, proper root causes like inefficiencies or deficiencies in performance might be overlooked. Research is needed to ascertain that the anomalous energy consumption is caused by changes to one or more static factors to ensure that issues related to performance are not missed.
4. Several approaches that align with different M&V options for measuring and quantifying the impact of the event are reviewed including the calculation and submetering based approaches that are the most common, along with some of the statistical model-based approaches. More research is needed to understand what approaches to use given the specific case of NRE and when it occurred.
5. A key step in this adjustment process is to determine whether the impact of the event is material that merits quantification and adjustment. This involves establishing some kind of threshold for what is considered 'material', so only the "correct" NREs are addressed. Research is needed to establish a process to calculate these thresholds to identify if the adjustment is warranted by taking into account the baseline energy consumption, savings and model uncertainty.
6. Irrespective of what approach is used to detect and quantify these adjustments, there is inherent uncertainty that need to be assessed. None of the literature that was reviewed discussed this aspect specifically, although some of the uncertainty approaches developed by IPMVP and other protocols for various M&V options can be adapted for determining this uncertainty. More research needs to be done on how these existing approaches for determining the uncertainties can be used towards developing a more specific guidance for the M&V practitioners.

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Appendix

Table A.1. SEP NRA Cases.

Case	Rationale for adjustment	Phase	Impact correlation	Identification	Magnitude	Quantification method	Quantification Approach
1	A new product line is added that uses more energy.	AP	Production	Human feedback	6.3 % for electricity; 19 % for NG	Regression	A new regression model was developed using the volume of the new production line for the reporting period, the coefficient for that production from the new model was used to calculate the needed adjustment from the baseline model.
2	A new piece of equipment was added that uses a significant amount of natural gas.	AP	Minor process change	Human feedback	1.60 %	Sub-metering	NG used by the new equipment is determined by submetering; the ratio of the steam consumed by the new equipment to the steam consumed by the entire steam system is determined. The adjustment is applied during the reporting period by subtracting the natural gas consumed by the new equipment from the natural gas consumed by the entire steam system.
3	A heat transfer fluid chiller was put into service to increase production. The chiller continued to operate but due to other operational problems production increases had not been realized.	AP	Minor process change	Human feedback	5.00 %	Sub-metering	A separate meter was installed to meter the electricity consumption from HTF chiller.
4	An inhouse nitrogen generation process was installed to replace daily nitrogen deliveries.	AP	Minor process change	Human feedback	7.00 %	Sub-metering	The electricity used by the process is metered. The monthly metered amount was subtracted from the monthly site electricity amount.
5	A new production line was installed which increased electricity consumption and pounds of production.	AP	Production	Human feedback		Sub-metering	The electrical energy used by the new line is metered separately. This data is subtracted on a monthly basis from the total facility electrical consumption.
6	A new support building was added, no change in production numbers.	AP	New building	Human feedback	7.70 %	Sub-metering	All actual energy consumption for the new building were metered and subtracted from the overall total energy consumption of the campus.

The table continues on the next page . . . →

Table A.1. SEP NRA Cases (continuation).

Case	Rationale for adjustment	Phase	Impact correlation	Identification	Magnitude	Quantification method	Quantification Approach
7	Moved two sets of welding equipment to an outside plant in two phases – the first occurred during the BP (2013), while the second set was removed in AP (2016). This reduced the electrical consumption of the facility by the amount associated with the first set of welders in the first 6 months of 2013 and by the amount associated with the second set of welders the last 4 months of 2016.	BL and AP	Minor process change	Human feedback	~Deducted 215,865 kWh from BP ~27,162 kWh added to the RP (2016)	Sub-metering	The electrical consumption for the first set of welders was estimated by subtracting the electrical consumption recorded by the electrical meter for each of the first 6 months in 2015 from the consumption for the corresponding month in baseline period (2013). The difference for each month was subtracted from the corresponding month during the first 6 months of baseline period (2013) for use in the SEnPI calculation. The electrical consumption for the second set of welders was estimated by subtracting the electrical consumption recorded by the electrical meter for each of the last 4 months in 2016 from the consumption for the corresponding month in 2015. The difference for each month was added to the corresponding month during the last 4 months of AP (2016) for use in the SEnPI calculation.
8	Addition of a new facility for machining new product line along with the addition of a new office building and cafeteria.	AP	Facility addition	Human feedback	SMC: 3 % of the site's total energy consumption. STC Office Building accounts for roughly 1–2 %.	Sub-metering along with engineering calculations	Both electricity and natural gas usage are on separate utility meters for the new facility· The majority of the office's electrical consumption is sub metered. The cooling is done through central plant chillers; therefore, the cooling load of the building was calculated using an engineering estimate. The direct natural gas usage for the cafeteria of the facility is sub metered. The heating of the Office Building is done using central plant boilers; therefore, the heating load of the facility was calculated using engineering estimates.
9	A new building was added that increased the building footprint by 50 %.	AP	Facility addition	Human feedback	20 %	Sub-metering	Electricity consumption is metered separately for the new facility; while NG consumption is adjusted based on the difference between the consumption before and after the change. The production volumes are also adjusted by comparing the numbers before and after the change went into effect.
10	The change May–October 2014, resulting in 20 % increase in the total finished facility square footage.	AP	Facility addition	Human feedback	6–8 %	Sub-metering	A ratio was calculated by comparing consumption for the 12 months before the expansion to the 12 months after completion. A ratio was calculated for electric, natural gas and water. This ratio indicates the increases that can be attributed to this additional finished space. The ratio was applied to the baseline year data for electric, natural gas, and water.
11	The change involved replacing an old of body paint line with a new energy efficient one in January 2013.	AP	Process change	Human feedback	10 %	Sub-metering	The energy consumption from the new paint line was metered separately. The metered energy consumption of the new paint line was subtracted from the reporting period before calculating the energy performance improvement.

Table A.1. SEP NRA Cases (continuation).

Case	Rationale for adjustment	Phase	Impact correlation	Identification	Magnitude	Quantification method	Quantification Approach
12	Approximately 20 small presses and 2 lasers were removed due to outsourcing, thereby reduced the electrical consumption and decreasing the internal heat gain and an increase in the amount of heating required for the facility in winter.	AP	Process change	Human feedback	153,143 kWh was added and 261 MMBtu natural gas consumption was subtracted.	data loggers and calculations	Data loggers were installed to monitor the energy consumption of typical equipment. Energy impact for rest of the equipment was calculated based on interviews of supervisors and operators regarding the operation, the power rating, and loading of the equipment.
13	Assembly line was removed from one plant to another that resulted in decreased electrical consumption associated with pneumatic system and tools.	AP	Process change	Human feedback	3.50 %	data loggers and calculations	Data loggers were installed to monitor the energy consumption of typical equipment. The adjustment is based on the data logger data and engineering calculations used to approximate the change in energy consumption for the non-routine adjustment.
14	The energy consumption at the plant was significantly affected as a result of removal of welders from plant operations.	AP	Process change	Human feedback	3 % 33,000 kWh	Sub-metering	Analyzed submeter data in 2011, 2012, and 2013; compared the average consumption for June–December in 2011, 2012, and 2013. They also compared the average consumption for January–May for 2011, 2012, and 2013 in order to see the expected variability.
15	The change involved an addition of welding equipment accounting for approximately a 16 % increase in the total electricity consumption of the facility.	AP	Process change	Human feedback	16 %	Sub-metering	After installation of the new equipment the total facility electrical consumption was adjusted every month by subtracting the monthly meter reading for the new equipment from the monthly utility meter reading to obtain net facility electricity consumption. This net facility consumption is the total facility consumption that would have occurred without installation of the new equipment.
16	The change involved moving a laboratory to an off-site location during the reporting period which significantly reduced the electricity consumption for the facility.	AP	Process change	Human feedback	3.25 %	Sub-metering	This model was built considering only the 2013 electric consumption. The 2013 electric model was used to forecast 2014 consumption based on actual CDD & HDD for 2014. The difference between model forecasted data for 2014 and the actual consumption data for the months May ‘14 through Dec ‘14 was considered to be the lab consumption.