IPMVP APPLICATION GUIDE ON NON-ROUTINE EVENTS & ADJUSTMENTS

INTERNATIONAL PERFORMANCE MEASUREMENT AND VERIFICATION PROTOCOL®

October 2020

EVO 10400 – 1:2020

IPMVP APPLICATION GUIDE ON NON-ROUTINE EVENTS & ADJUSTMENTS

INTERNATIONAL PERFORMANCE MEASUREMENT AND
VERIFICATION PROTOCOL®

October 2020

EVO 10400 – 1:2020

AUTHORS & ACKNOWLEDGEMENTS

Prepared by

Lia Webster, Facility Energy Solutions

Contributors

Acknowledgments

TABLE OF CONTENTS

List of Figures

List of Tables

List of Equations

List of Examples

INTRODUCTION

This document is an Application Guide that supports the *International Performance Measurement and Verification Protocol* (IPMVP)[1]. While the IPMVP Core Concepts provides an overview of non-routine adjustments (NRAs) relative to measurement and verification (M&V) projects, this Application Guide is intended to serve as an expansion on the topic.

In the context of M&V of energy, demand, or water savings, NRAs are used to compensate for unrelated facility-changes that impact savings and are not accounted for in the calculations. These non-routine events (NREs) are especially impactful in meter-based M&V methods, which capture all changes in energy consumption at the site level.

NREs represent a key risk element for projects using meter-based M&V method since NREs that go unaccounted for can introduce unacceptable levels of error and skew reported savings making them less meaningful. Similarly, NRAs applied improperly may have equally detrimental impacts on reported savings. The increased adoption of advanced meter-based M&V methods[2] mandates serious attention to properly managing NREs and NRAs and is the focus of this guide.

> *Meter-based M&V methods* are M&V approaches using energy data from utility meters or sub-meters and independent variables to create mathematical models[3] of energy use. They include IPMVP's Option C - Whole Facility and Option B - Retrofit Isolation All Parameter Measurement approaches.
>
> *Advanced meter-based M&V methods* imply the use of short-interval energy data and advanced statistical analysis software. AM&V is still a developing practice area spurred by the recent widespread adoption of AMI utility meters for electricity consumption[4].

The risks presented by ignoring non-routine events during the reporting period depend upon the party's perspective in the M&V effort (owner/utility sponsor, project developer/energy service provider), the magnitude of the impacts from the NREs, and whether the NREs *increased* or *decreased* energy use.

---

[1] See *IPMVP Core Concepts 2016*, Efficiency Valuation Organization (EVO).

[2] See L. Webster et al., *IPMVP's Snapshot on Advanced M&V*, EVO 2020.

[3] These approaches are inclusive of machine learning methods, although regression-based statistical models are typical and are the focus of this guide.

[4] Advanced M&V, sometimes called AM&V or M&V 2.0, uses statistical methods to calculate energy savings using data from advanced energy meters, such as those used in advanced metering infrastructure (AMI). Software that provide AM&V may be part of a packaged Energy Management Information System (EMIS) or created within commercially available or public domain analysis environments using languages such as SAS, R, or Python. In addition to calculating energy savings, these tools may also automate data collection, provide data quality control, evaluate multiple model forms to provide near real-time results and lowered M&V costs.

» Decreases in site-level energy use will inflate reported savings. This may result in overpayment of utility incentives and disbursements to project developers. This represents the most significant risk for utilities and owners.

» Increases in site-level energy use will reduce reported savings and result in underpayment of incentives, and can create pro forma cash flow issues. This represents the largest risk for project developers/energy service providers.

> *As noted in a related article Stopping M&V Adjustment Abuse[5]:*
>
> *"Non-routine adjustments place strong dependence on the engineering prowess of the measurement and verification (M&V) agent to estimate the impacts of the adjustments. **In many cases, the M&V agent is also the project implementer** (who may have a vested interest in the M&V outcome), **which creates an obvious potential for a conflict of interests**."*

This application guide presents detailed risk mitigation methods that can be used by stakeholders to manage non-routine events and adjustments. Moderating these risks is paramount when M&V is the basis for monetary transactions, including energy service company (ESCO) projects and 'pay for performance' utility projects and programs.

Fundamental risk mitigation strategies include:

» Ensure the regression-based baseline energy model is robust and includes all relevant variables and operating conditions.

» Identify and document all site-specific factors that could affect the energy use within the defined measurement boundary and track details of changes through the reporting period.

» Screen for *potential NREs* throughout the life of the project and make NRAs, as necessary.

The two general methods for identifying NREs are field observations (manual) and data-driven (analysis). The NRA approaches included focus on using project-specific energy and site data from the NRE period.

As reported in the Efficiency Valuation Organization's (EVO) white paper *IPMVP's Snapshot on Advanced M&V*, there is a need for guidance to help M&V practitioners identify and evaluate NREs and to apply NRAs. There is also a lack of examples of common NREs and NRAs.

This document fills an industry gap related to applying NRAs. It provides specific guidance for M&V practitioners and other stakeholders to:

» Plan for NREs and NRAs,

» Avoid NRAs by fully defining regression-based energy models,

» Identify and evaluate *potential NREs* that could require an *NRA,*

---

[5] T. Phillips *Stopping M&V Adjustment Abuse*, EVO 2018, available here.

» Make appropriate *NRAs* as needed, or change the M&V approach, if necessary, and

» Assess savings uncertainty introduced by making *NRAs*.

Most of this guide is focused on projects using advanced meter-based M&V strategies employing regression-based energy models. This is an increasingly utilized approach, which is especially useful for determining time-of-use electricity savings. Short interval consumption data from water, natural gas, or other fuels are less common. Impacts to these non-electric commodities are typically determined using monthly data and less complex model forms and are not directly addressed in this guide.

Although otherwise very robust, advanced meter-based M&V methods are especially susceptible to the potential need for NRAs. Since calculated energy savings include all energy use changes at the site, regardless of the cause, the reported savings are directly affected by NREs. The impacts of these non-measure-related site-level changes are offset by making NRAs. Accuracy of savings can, therefore, depend on the accuracy of these adjustments.

This guide also provides information on making NRAs when using M&V strategies that do not utilize regression-based energy models, including retrofit isolation and calibrated simulation approaches. Retrofit isolation M&V methods using IPMVP Options A & B, however, are focused on equipment- or systems-level performance and use a smaller measurement boundary with inherently fewer *key static factors* that may affect savings than those using whole facility energy data. Retrofit isolation methods must consider the factors that influence the energy demand and hours of use of the equipment within the measurement boundary, and NREs are limited to changes in these factors. Note that static factors that may affect savings may be outside of the energy measurement boundary (e.g., overall building schedule impacts savings from lighting retrofit).

Static factors are defined in IPMVP Core Concepts 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 in the energy model. If they change, Non-Routine Adjustments need to be calculated to account for these changes. Note: Those characteristics may include fixed, environmental, operational, and maintenance characteristics.

*Where **Non-Routine Adjustments** are individually engineered calculations to account for the energy effects within the measurement boundary due to changes in the static factors.*

Background

Routine adjustments and *non-routine adjustments* (NRAs) are fundamental to IPMVP's methods for calculating energy, demand, and water savings. These adjustments allow a fair comparison of energy used during two different time periods. They are part of the IPMVP savings equations detailed in IPMVP Core Concepts and included in Appendix 2.

Routine adjustments are used to account for expected variations in independent variables (such as outdoor temperatures, occupancy levels, day-types, production metrics, etc.). In meter-based M&V applications, a mathematical model, most often a regression-based model, is developed that correlates the energy consumption to the appropriate independent variables. Routine adjustments are made by applying the independent variables (e.g., outdoor air temperatures, production rates) from the selected comparison period to the model(s).

Non-routine adjustments may be required when significant unexpected changes in energy use occur that are not due to variations in the modeled independent variables or the performance of the targeted project. NRAs are individually engineered calculations used to compensate for these changes to ensure that a fair comparison of energy use is made between periods.

The set of conditions used in the comparison is called the *basis of savings*. It is designated in projects as either baseline conditions, reporting period conditions, or some average or standard set of conditions. Depending on the basis of savings used, the difference in the energy consumption between the periods is called either *avoided energy consumption* or *normalized energy savings*.

» *Avoided energy consumption* typically uses the measured independent variables from the reporting period in the baseline model to determine the *adjusted baseline energy*, which is compared to the measured reporting period energy, as shown in **EQUATION** 14.

» *Normalized energy savings* are determined using a "normal" set of conditions (such as typical meteorological year (TMY) weather data) and require a separate model of the reporting period energy use. In this case, the *adjusted baseline energy* is compared to the *adjusted reporting period energy,* as shown in Equation 18.

Roadmap to Guide

This guide provides comprehensive coverage on NREs and NRAs. It is organized into nine sections that are intended to be used as building blocks through the life of a project.

» Section 1 describes how to potentially avoid making NRAs in meter-based projects and summarizes other recommended actions to manage NREs and NRAs.

» Section 2 provides a framework to characterize NREs and NRAs, outlines related M&V plan and reporting details, how to determine if making an NRA is warranted, and examples of potential NREs and NRAs.

» Section 3 details seven approaches to identify potential NREs.

» Section 4 provides specific considerations and guidance when making NRAs.

» Section 5 provides procedures for ten specific methods to make NRAs and when each is appropriate.

» Section 6 presents alternate methods to consider if making an NRA will not work.

» Section 7 details how to assess the uncertainty in savings introduced by making NRAs.

» Section 8 covers NREs and NRAs for IPMVP Options that do not use meter-based M&V methods.

» Appendices include additional details on static factors as well as the related IPMVP savings equations.

1 AVOIDING NON-ROUTINE ADJUSTMENTS

Accurate saving reporting mandates non-routine events (NREs) are identified and managed throughout a project's life, especially when using meter-based M&V methods. However, the likelihood of needing non-routine adjustments (NRAs) can be significantly reduced in many cases by improving baseline energy models. Avoiding NRAs with improved baseline models reduces project risk, improves the accuracy of reported saving, and potentially lowers M&V costs.

A robust regression-based model of the baseline energy consumption includes:

» Key independent variables (such as weather factors) and all significant secondary variables (such as occupancy levels) that influence energy use; and

» Documented details of the conditions during the baseline period, which include meaningful data on significant static factors (such as non-measure related process loads).

Including secondary variables in the baseline model can effectively avoid the need for NRAs in some cases. NRAs are not needed when the routine adjustments to the model using updated independent variables can account for all significant variations in energy.

> *This strategy can be summarized as:*
>
> ***Make the non-routine routine.***

If the secondary variables identified do not prove significant in the baseline model, tracking their details may allow them to be included in the model in the future should the need arise (see Section 5.3). Maintaining the specifics of these static factors over time is a key risk mitigation strategy (detailed in Section 2). It can be especially critical when savings are monitored for longer periods of time.

Unfortunately, avoiding the need for non-routine adjustments is not always possible.

1.1 Anticipating NREs

For any given facility, reviewing historic NREs and future plans at a site may provide the strongest indicator of future NREs, but unexpected changes may still occur. It is consistent with IPMVP guidance that sufficient resources are available to identify NREs and make needed NRAs while maintaining a cost-effective M&V effort.

Generally, the frequency of potential NREs occurring at commercial facilities tends to be less than at industrial sites where continual changes in products, equipment, the product mix, and the amounts of products are typical. Metrics for some of these production-related factors are often included as independent variables in the baseline energy model to reduce the need for NRAs. As discussed above, commercial sites may use the same strategy to reduce NRAs.

The rate of observed NREs varies and depends on the length of time monitored, the threshold set for a change in energy to be considered an NRE, the capacity to detect NRE changes in the electric load, as well as the successful validation of their causes.

1.2   Managing NREs and NRAs

Managing NREs and NRAs requires attention beginning in project development and baseline determination through the implementation[6] and reporting periods. Some of the key risk-mitigation actions applicable to various phases of an M&V effort are highlighted in Table 1 below and detailed elsewhere in this Guide.

TABLE 1: SUMMARY OF ACTIONS TO MANAGE NREs & NRAs THROUGH THE LIFE OF A PROJECT

Project Period	Action	Detail
All Project Periods	Screen for potential non-routine events	Implement multiple methods to detect potential non-routine events (NREs).
	Approximate impact of NRE on savings or energy use[7]	Evaluate the magnitude of the change in energy savings resulting from any potential NRE to gauge if making an adjustment is warranted.
	Determine root-cause of NRE and relationship to ECMs	Evaluate the site changes made and determine the relationship to the installed ECMs and modeled variables. NRE impacts must be evaluated in relation to the ECMs being measured and the M&V approach being used to determine if an NRA is warranted.
	Determine whether making an NRA is appropriate	Determine the next steps based on the estimated impacts and root cause of the potential NRE, which may include taking no action, making an NRA, or addressing the performance of the ECMs.
	If appropriate, make NRA	Using key characteristics of the NRE, select and apply an NRA method, evaluate the impact on savings uncertainty, and report savings and details of any NRAs.

---

[6] The implementation period is the time between the end of the baseline period and the beginning of the reporting period during which the planned energy project is installed.

[7] The impacts from an NRE on savings and on energy use will be the same when determining avoided energy consumption using meter-based methods.

Project Period	Action	Detail
Baseline Period	Review historical energy use data for anomalies	Identify and evaluate potential NREs in the baseline period. Review historical energy use data for potential NREs such as unusual usage patterns and discuss them with the site representatives. Identify any commonalities to be accounted for in the model as independent variables (e.g., % of facility leased), or verify a non-routine event occurred.
	Document key static factors and establish a plan to track them	Identify and document *key static factors* at the site that could impact energy use, and that may change during the duration of the project periods. Establish a method to track changes to key static factors through the reporting period.
	Define baseline period energy model	Select the baseline period (free of NREs), identify all potential independent variables, and create an initial baseline energy regression model.
	Include NRE and NRA methods in the M&V plan	Define project-specific *NRA threshold criteria* regarding what level of change(s) will warrant action, including making an NRA. Specify how NREs will be identified and verified and how energy impacts will be quantified and valued.
	Designate a back-up M&V method	Consider designating a back-up M&V method in the M&V Plan in case NRAs are not sufficient. Document sufficient details of the baseline conditions to support the selected method.
	Ensure adequate budgets allocated to identify NREs and make NRAs	Meter-based methods need to ensure adequate budget and resources are allocated to document and track static factors, identify NREs using data analysis, and make NRAs.
Implementation Period	Record installation dates for each ECM	Record implementation dates and expected savings profile(s) from the ECMs.
	Document details of installed ECMs	Document details of the installed ECMs to support an alternate M&V approach.
	Evaluate the implementation period for NREs.	Identify and evaluate potential NREs that occurred in the implementation period that may persist into the reporting period. Review site conditions (static factors) for changes, especially if the project implementation period extends for longer than a few months.
Reporting Period	Evaluate reporting period data for NREs	Identify and evaluate potential NREs from energy use data and reporting period energy model.
	Track changes to key static factors	Track and report changes to the project's key static factors.
	Report details of any non-routine adjustments	Include details of NREs encountered, and NRAs made in savings reports.

2 NON-ROUTINE EVENTS

This section covers planning for, identifying, and evaluating non-routine events for projects using meter-based M&V methods, although the considerations presented are generally inclusive of other M&V methods.

Non-routine events (NREs) are unexpected changes in energy use within the *measurement boundary*[8] resulting from changes in *static factors,* which are not accounted for in the energy savings calculations and not related to the targeted energy project.

NREs can include a broad array of temporary or permanent site changes. Variations in occupancy densities, facility run times, system operating parameters (e.g., set points, lighting levels, production rates, equipment staging), and equipment installed may be NREs. Additional examples of common NREs are provided in Table 2.

As noted in IPMVP, performance deficiencies or equipment problems that are present in the baseline but are resolved by the installed measures or project (e.g., inoperable lighting fixtures replaced) may similarly require non-routine adjustments to report savings accurately.

Appendix 1 includes an extensive list of possible static factors. Unexpected changes in energy use from variations in static factors are the most significant complication faced by Option C approaches and can be problematic for other M&V Options as well.

2.1 Overview of Non-Routine Events

Changes at a site that affect energy use are common and often unavoidable and must be accounted for when energy savings are determined from metered energy data. Some facilities are more dynamic and prone to changes that are *potential NREs*, and their occurrence becomes more likely with longer reporting periods.

When an energy consumption change is unrelated to the energy project and is due to changes in static factors, then it would be considered an NRE. If the impact from the NRE on the savings is significant enough, then a non-routine adjustment (NRA) is required.

» *Potential Non-Routine Event* – Evidence indicates unexpected changes in energy use within the measurement boundary, which may be attributable to changes in static factors (i.e., variables not included in the energy model).

» *Non-Routine Event – S*pecific changes in site characteristics or static factors were verified. Does not necessarily require action.

---

[8] Measurement boundary and other concepts are detailed in EVO's *IPMVP Core Concepts, 2016*.

» *Significant Non-Routine Event* – Verified NRE that triggers the need to make a non-routine adjustment, based on project-specific criteria.

The progression in terms reflects the typical assessment process of observing a change that has occurred, assessing the root cause, and taking corrective action if required.

2.1.1   Key Characteristics of Non-Routine Events

Once the occurrence of a potential NRE has been confirmed, the key attributes of the event need to be established.

Since NREs may vary from very simple changes (e.g., removed end-use equipment with a constant load) to extremely complex modifications (e.g., added a new industrial process affected by weather and production levels), a framework for characterizing these events is provided in Table 3.

The categories and descriptions included are succinct and can provide consistency in describing NREs.

The complexity of the NRE is captured by the physical t*ype of change* made, the *load impacts,* and the *type of load impacts* that resulted. These and other details on the NRE are needed, including how the NRE is affected by schedules, operating conditions, and other independent variables.

EXAMPLE 1: EXAMPLE DESCRIPTION OF TYPE OF CHANGE FROM NON-ROUTINE EVENT

> A detailed description of the physical type of change and the type of load for a simple NRE might be new equipment with a constant load variable schedule based on outside air temperature, with increased electrical demand and consumption. Permanent installation of ten (10) new identical constant volume exhaust fans with 5-hp nameplate were added to the west sunroom and are enabled to run when outdoor air temperatures are over 80°F/27°C.

This information can be used to gauge whether an NRA is warranted by:

» Establishing whether the potential NRE is due to the performance of the ECMs,

» Confirming impacts on the accuracy of energy savings calculations,

» Defining changes in load due to the potential NRE, and

» Identifying likely independent variables related to the NRE's variation in energy use, such as outdoor air temperature.

The *timing and duration* of a non-routine event will impact the approach in making an NRA. NRA methods vary based on when the NREs occur (baseline, implementation, or reporting period), and if the event is temporary or permanent.

However, if the *frequency of the NRE* is periodic, its designation as an NRE should be reevaluated. Infrequent but normal events such as annual maintenance are typically not considered NREs. If an event

occurs from time to time at the site, such as "Holiday", it is not really an NRE but a part of normal operations[9].

Some recurring events may be incorporated into the baseline or reporting period energy model(s) as a unique day type, depending on the frequency, duration, and impact of the periodic event. In some cases, however, the reporting period may include conditions that were not present in the baseline period (e.g., short-term maintenance) but are considered normal and do not usually warrant an NRA.

TABLE 2: EXAMPLE SITE CHANGES THAT MAY CONSTITUTE A NON-ROUTINE EVENT

Type of Change	Type of Site-level Change	Example
Structural	Change in total heated and cooled building area	Addition of new classroom wing
	Envelope modifications (windows, doors, insulation, leak sealing)	Weatherization project completed
Operational	Changes in equipment operating hours unrelated to energy measures	The new tenant has a longer occupancy schedule in a section of the facility extending operating hours of related HVAC equipment
	Change in temperature setpoints	New tenant changes occupied cooling setpoints from 76°F/24°C to 72°F/22°C during occupied hours
	Changes in equipment staging and setpoints	Change in ventilation rates and air-side temperature setpoints in the main air-handling unit
End-Use Loads / Equipment	Change in use type	Section of facility occupancy changed from office space to light manufacturing
	Addition of end-use equipment	Additional IT equipment added to an office space
	Removal of end-use equipment	Removal of lighted displays for advertising throughout
	Change in occupancy density	100 additional employees added to existing call-center
Process Related	Change in production volume	A third production shift added to the manufacturing facility
	Variation in raw materials	Smaller diameter of logs processed at the sawmill
	Change to finished product	Add a new grade of product
	New environmental regulation	Change in wastewater effluent nitrification limits or laboratory exhaust fan minimum speeds
New Energy-Related Project	Renewable energy or energy storage project	Installation of solar photovoltaic (PV) system
	Energy conservation measures (ECMs)	Retrofit performed on overhead interior lighting fixtures

[9] As discussed in IPMVP, normal operations at a facility include all expected modes for equipment and systems that occur under a full range of conditions (e.g., across various seasons or production rates).

TABLE 3: KEY CHARACTERISTICS OF AN NRE PROVIDES THE FRAMEWORK FOR MAKING AN NRA

Characteristics of NRE	Options	Details
Type of Change	Structural	Specify how the NRE is related to schedules, operations, end-use loads, process changes, or energy-related projects.
	Operational	
	End-Use Loads / Equipment	
	Process-related	
	New Energy-Related Project	
Energy Impact	Increase	Identify if change increased or decreased energy use and specify energy source impacted.
	Decrease	
Type of Energy Impact	Constant load	Specify the type of load and scheduling characteristics of the NRE that can be correlated with any independent variable or combination of variables, such as outdoor air temperature, production-based metrics, or other variables.
	Constant load - Fixed Schedule	
	Constant load - Variable Schedule	
	Variable load - Fixed Schedule	
	Variable load - Variable Schedule	
Duration	Temporary	Determine the exact dates and times of the start and finish, where applicable, of the NRE. Time increments need to match the frequency of the data that is used for analysis.
	Permanent	
Frequency	One-time	Identify how often this change happens and evaluate if it is a reoccurring event. If the NRE is found to be periodic, it should be considered in the model where possible.
	Periodic	
Project Period	Baseline Period	Identify the project period in which the NRE occurred.
	Implementation Period	
	Reporting Period	

2.1.2 Planning for Non-Routine Events and Non-Routine Adjustments

Although non-routine events are, by definition, *unpredictable,* they should be planned for, especially when using meter-based M&V methods.

The keys to managing NREs include planning for potential NREs and periodically evaluating results for potential NREs. These activities and considerations begin during project development and continue through the reporting period. (Summarized above in Table 1: Summary of Actions to Manage NREs & NRAs Through the Life of a Project.)

2.1.3 Example Non-Routine Events and Possible Non-Routine Adjustments

Making an NRA to revise the savings calculations is a possible outcome from some potential NREs and is covered in Sections 4 and 5. Awareness of the types of changes that may arise and examples of the potential follow-on actions can help set expectations.

Examples of potential NREs and possible actions, including making NRAs, are outlined for each project period (i.e., baseline, implementation, reporting) and duration (i.e., temporary or permanent) of the event are presented below in Table 5: Example Non-Routine Adjustments Considering Project Period and Duration of Potential NREs.

2.1.4 Include Key Details in the M&V Plan

The level of detail included in the M&V plan on NREs will vary, but key elements are needed to effectively manage the evaluation of potential NREs and the implementation of NRAs.

The key elements to specify in the M&V plan when using meter-based M&V methods include:

1. Procedures for ongoing tracking of static factors and reporting changes (see Section 2.1.5 - Document and Track Changes to Static Factors).

2. Data required from the installation period (e.g., Installation start dates and completion dates for ECMs; an annual profile of expected savings from installed ECMs).

3. Methods to check data for NREs and to validate site-reported NREs.

4. Values of key static factors documented during the baseline period and how changes will be tracked during the project.

5. Project-specific threshold criteria for investigating NREs (see Section 2.1.6 - Set Threshold Criteria for Acting on Non-Routine Events)*.*

6. Procedures for handling missing data, including estimating independent variables and energy use data.

7. Details on how NRAs will be made, including criteria for omitting data, and how impacts on savings will be valued. (Since detailing all possible scenarios and adjustment approaches may be impractical, the M&V plan may instead choose to reference specific portions of this guide or other sources.)

8. A designated back-up M&V approach for the project or individual ECMs. Collect and document related data*.*

9. Reporting requirements for Non-Routine Adjustments (see Section 2.1.7 – Define Reporting Requirements for NRAs).

Details on each of these topics should be determined and included in a project's M&V plan.

2.1.5   Document and Track Changes to Static Factors

Static factors are those characteristics of the facility, installed equipment, and operational parameters that are not accounted for by independent variables in the regression-based energy models.

> As noted in IPMVP Core Concepts:
>
> Identifying facility changes that will require non-routine adjustments is the significant primary challenge associated with Option C, particularly when savings are monitored for long periods.
>
> Therefore, periodic inspections should be performed of all equipment and operations in the facility during the reporting period. These inspections identify changes in the static factors from baseline period conditions. Such inspections may be part of regular monitoring to ensure that the intended operating methods are still being followed. **A lower cost alternative, most applicable to smaller projects or facilities, can be to track energy performance over time, normalized for operating conditions, and inspect the facility for changes when adjusted performance shows a persistent change.**

In general, projects using meter-based M&V methods need to identify and document the sites' static factors that could significantly affect energy use and have the potential to change over the project's duration. If static factors are not documented along with the details of the ECMs, it may be impossible to assess potential NREs. Assessing potential NREs is required before making an NRA to ensure reported energy savings are the result of the targeted measures.

Technically, the list of static factors includes all equipment that uses the targeted energy source — from large central plants or process-based equipment to laptop computers and other plug loads. However, in many cases it may be more practical to identify and document the *key static factors* for the specific project

The *key static factors* should be identified based on:

» The measurement boundary of the ECMs,

» The saved energy source (e.g., electricity, natural gas, fuel oil, etc.),

» Primary loads using the energy source (for meter-based methods), and

» Independent variables used in the analyses.

For example, an M&V effort to quantify electric savings would not need to track the operating parameters of the facility's gas-fired boilers. Similarly, at a site where electric loads from an on-site kitchen are relatively inconsequential, tracking changes in kitchen operations is likely not warranted.

Key static factors in meter-based approaches often include:

» Overall facility parameters and envelope conditions,

> » Large energy-using equipment and system specifications and their operating parameters (e.g., equipment size, staging, and setpoints), the loads (e.g., tons of cooling, number of people, ventilation rates), and related operating schedules,

> » Operational items identified by the site staff, insights gained through discussions with the facility owner or through inspections that can change during the installation and reporting periods. (Explanations for any past energy anomalies found may indicate future changes and can help identify items that may represent significant independent variables).

Example metrics that can be considered for tracking changes in static factors are included in Appendix 1. This is an extensive list of parameters and includes major facility items like conditioned floor area and various system-level details such as chiller part-load efficiency curves for process chillers. Depending on the project, some items typically listed as *static factors* may be used as independent variables in the models or could be characteristics affected by the ECMs.

The level of effort that can be required to document and track the numerous static factors is a key challenge in implementing meter-based M&V approaches and is why stable facility operations is a recommended pre-requisite for using these M&V methods. The cost of tracking changes in static factors depends on the facility's size, the likelihood of static-factor changes, the difficulty of detecting changes, and the surveillance and reporting procedures already in place.

Since potentially expensive, creative solutions may be needed to establish a cost-effective documentation and tracking strategy. Ideally, the static factors will be documented as part of an energy study[10], and their initial values can easily be included in the M&V plan. Tracking subsequent changes to key items can be challenging, depending on circumstances. Site staff is often the most qualified and best suited to track key static factors for changes. Regular reports from site staff, scheduled interviews, or other resources such as periodic reports from energy management systems or maintenance management systems can be effective. If possible, define specific formats to track key static factors and report substantial changes.

The budget for making NRAs needs to be available and may include efforts to validate changes to static factors, data analyses, and transactional costs. The cost and level of effort required compared to the overall project value need to be considered for each project. If the value of the savings is low, it may be preferred to change M&V options and not use a meter-based M&V approach.

2.1.6   Set Threshold Criteria for Acting on Non-Routine Events

Criteria for when an NRE's impacts on savings are 'significant' enough to warrant making an NRA will vary from project to project. Project-specific *NRA threshold criteria* should be included in the M&V plan to define when a potential NRE is significant and additional action is required; including specific metrics for investigating potential NREs may be appropriate. Criteria for action should be equally warranted if NREs increase savings or decrease savings.

A difference in reporting period savings from expected savings can sometimes warrant additional review to provide assurance of project performance, but it does not necessarily indicate a potential NRE. It is important to note that expected savings estimates may not be accurate, especially those based on limited data such as

---

[10] Energy audits based on ASHRAE level 2 audits generally include this level of detail.

estimated savings values from a utility program or a generalized ECM calculator and some custom calculations. Generally, however, a sustained increase in energy use relative to the adjusted baseline may be a red flag since most M&V projects expect to see sustained decreases in energy consumption.

Determining the *NRA threshold criteria* for acting on potential NREs should be established in consideration of four key elements:

» **Savings' accuracy that is possible.** The accuracy of the energy models (e.g., standard error) for a specific project will limit the ability to identify and adjust for NREs using regression-based methods. The uncertainty in the values predicted by the energy model must be much lower than the impact of a potential NRE at any given time to be evident (see Section 7)[11].

» **Cost of analyses**. Substantial time can be spent identifying potential NREs and making a subsequent NRA. Transactional cost considerations may include the initial NRA as well as any required subsequent adjustments. To lower costs, longer projects may validate NREs immediately but only make periodic NRAs.

» **Value of savings.** The value of an NRE is typically based on the marginal utility costs (incremental cost of saved energy) and may include time-of-use rates. Still, other factors, such as maintenance costs, may be considered. The impact of an NRE is largely affected by the timing within the project. Permanent NREs occurring early in a project will have greater impacts on energy savings than similar NREs that arise late in the reporting period.

» **Savings' accuracy that is needed**. The accuracy of reported savings is improved by accounting for NREs throughout a project but is not always required. The context of the M&V assessment is important since making NRAs may be essential for project implementers under a pay-for-performance project structure. In contrast, only major NREs might be considered significant in a high-level evaluation study of multiple projects that do not include payments for reported savings.

Note that the costs of making an NRA and the value of an NRA may present a split incentive between parties, especially if an NRA will decrease reported savings. NREs which decrease loads result in NRAs that also decrease reported savings, which may negatively impact the project cost-effectiveness or return-on-investment.

Equal consideration must be given to potential NREs that decrease reported energy savings to those that increase reported energy savings. Precautions such as reporting NRE screening details or conducting third-party reviews should be taken to avoid the possibility of biased savings reporting.

The NRA threshold criteria specified in the M&V plan should be as specific as possible. When feasible, identify specific types of changes and related metrics, so the determination is unambiguous. Detecting changes in energy use patterns and key static factors is fundamental to identifying potential NREs.

---

[11] The rule of thumb included in the IPMVP is a minimum of 5% overall impact to baseline energy is typically required to determine savings using through AM&V also applies to identifying potential NREs.

Changes to specific static factors, e.g., weekly HVAC operating schedules change by more than 10 hours and fall outside the expected range of 65 to 75 hours/week, as determined by trend data from the control system.

Anomalies in energy use patterns, e.g., residual analyses indicate an unexplained change in energy use of more than +/- 10,000 kWh over any two-week period.

A percent change in overall energy use, e.g., monthly energy use in the reporting period, is more or less than 15% above adjusted baseline energy for any month (well outside the range of expected savings or normal variations in consumption).

Reported energy savings vary substantially from expected, e.g., normalized energy savings are 15% more than expected.

2.1.7   Define Reporting Requirements for Non-Routine Adjustments

Like all savings calculations, non-routine adjustments require reporting that is *transparent*.

Energy savings reports should highlight any NRAs made during the reporting period. Detailed descriptions of the non-routine event, analyses conducted, and how the NRA follows requirements in the M&V plan should be provided. Electronic data and calculations should be available.

Additionally, details from any NRAs made throughout the history of the project need to be tracked and included in M&V reports. Key details to track on NRAs implemented include:

1. NRE description (including details of the site changes made and their characteristics such as temporary/permanent, constant/varying load, load added/removed, etc. discussed in Section 2.1.1);

2. Dates of NREs;

3. How NRE was detected and validated;

4. Details of the site changes that occurred, description of energy impacts, and the relationship to the ECMs;

5. Overall energy impact to savings in energy units and value of NRA, as appropriate;

6. The relative (percent) increase or decrease to baseline or reporting period energy use;

7. Method and details of NRA made, including all related data, methods, sources, assumptions, and equations used;

8. Total savings, including NRA, and impacts on savings uncertainty.

2.2   Initial Data Needed To Evaluate Potential Non-Routine Events

Regardless of the approach used to identify *potential NRE*s, the key information to gather for the initial assessment is outlined in Table 4.

TABLE 4: INITIAL DATA NEEDED ON POTENTIAL NON-ROUTINE EVENTS

Data Needed	Details
Date(s) and times affected by NRE	Define the NRE period's start date and end date and times, where appropriate. Since metered data analyses require precise dates and times, the level of detail on the start and end times needs to align with the increment of data used in the analysis (e.g., hourly)
Cause of the NRE	Impacts to site characteristics (static factors) such as changes to monthly operating hours or the details of new equipment installed
Broad nature of change in energy use	The energy source(s) affected and the magnitude of the impact on energy use and energy savings.
	Increase or decrease in baseload, peak loads, or both
	Increase, decrease, or shift in operating hours and energy consumption
Scope of ECMs implementation	How the ECMs save energy, including systems and equipment impacted
Project-specific criteria for addressing NREs	Details from the M&V plan, if available

2.3   Is it an NRE? Does it warrant making an NRA?

For most projects, there may likely be many potential NREs that occur, but few, if any, will warrant making a non-routine adjustment to the energy savings. To make this determination, the steps are to:

» Confirm the root cause of the potential NRE, and its relationship to the ECM, and

» Make an initial rough estimate of the impacts on energy savings or the total energy use for meter-based methods.

Either of these determinations may be made first, depending on circumstances.

After the cause of a potential NRE is validated, a more rigorous assessment of impacts on the energy savings can be conducted when an NRA is applied.

2.3.1   Determine Root Cause of the Change

Although it is tempting to consider periods of inconsistent energy consumption as an NRE, IPMVP requires verifying the physical basis of a potential NRE[12]. Assessing NREs requires identifying the root cause of the energy change at the site so that any impacts on the performance of the energy conservation measures (ECMs) and their savings can be understood.

Details regarding the changes in static factors at the site (e.g., specific changes in building ventilation rates or increases in data center loads) are required to gauge how the changes in energy consumption relate to the ECMs and if the calculated savings are accurate. Confirmation that a potential NRE is *not* related to the ECMs

---

[12] Operational verification is a requirement in IPMVP.

being evaluated and is *not* part of normal operations is necessary. For example, an increase in energy use due to an override on variable speed drives installed as an ECM would NOT be a non-routine event — savings did not occur and correcting the ECM's performance would be warranted. Similarly, a normal seasonal increase in loads during the summer (e.g., agricultural warehouse affected by seasonal harvest) would not be an NRE.

In the easiest cases, an NRE is reported by site staff who will flag changes and provide details of potential NREs on energy projects (after being obligated and trained to do so). These details must be validated before an NRA is considered. When an NRE is reported, review the energy use data for evidence of the change in both timing and magnitude. If an analysis of energy data does not support the information reported, a site visit or other investigations should be conducted to gather data on the potential NRE, confirm changes in the site's static factors, and to verify the continued performance of the ECMs.

Alternatively, when a potential NRE is identified by the M&V analyst, follow up with site personnel is needed to assess the underlying cause of the change in energy use. It is helpful if the analyst is familiar with the project and has an existing rapport with the site staff. Regardless, interviews will need to include targeted questions about the nature of changes at the site, the effect on ECMs, and the status of key static factors. In some cases, a third-party site visit may be warranted to confirm details.

If the root cause of a potential NRE cannot be determined and validated, it is not appropriate to make a non-routine adjustment.

2.3.2   Make an Initial Estimate of Impacts to Energy Savings

Estimating the effect an event has on the energy savings is critical to determining if the impacts are significant enough to warrant spending the time and resources needed to pursue a non-routine adjustment. Initial estimates of impact to energy savings are critical to limit time spent analyzing potential NREs that may not be significant. Typically, an initial rough estimate to gauge impacts on savings can be made to help limit the analysis before confirming the details of a potential NRE. The project-specific *NRA threshold criteria* in the M&V plan (discussed in Section 2.1.6) should be consulted, if available, to determine if the impacts from the NRE are significant enough to justify action.

Low-budget strategies[13] to consider for an initial estimate include:

» Use engineering estimates[14] from details on the site changes.

If information on the site changes is known, an engineering estimate based on the details of the site changes can gauge the impacts on energy savings.

» Make a 'top-down' estimate from changes in energy-consumption data.

Changes in energy use data can be assessed and quantified from observed changes in whole-facility energy-use or load profiles.

» Analyze residuals from the energy model.

---

[13] Strategies to improve the initial estimated savings impacts and make a non-routine adjustment are included in Section 4.

[14] Engineering estimates based on physics or 'bottoms-up' analyses cover a range of accuracies and are detailed in BPA's *Engineering Calculations with Verification* and CACx's *Verification of Savings for Retro-Commissioning Projects*.

If a model for the period is available, the sum of residuals during the NRE period should be roughly equivalent to the energy impact of the NRE. The order of magnitude of the NRE may be underestimated since the NRE period is included in the model and is also affected by model accuracy, as detailed in the uncertainty discussion in Section 7.

» Use the difference between the reported energy savings and expected energy savings with caution.

Often, a potential NRE is flagged when reported savings are significantly more or less than expected. The difference in reported and expected energy savings may represent the changes due to an NRE, depending on when it occurred during the reporting period. The energy impacts from NREs accrue over time, so impacts from an NRE late in the reporting period may not be immediately discernible, making this method less reliable than others.

EXAMPLE 3: INITIAL ESTIMATE OF POTENTIAL NRE'S IMPACT USING ENERGY DATA

> Using hourly heat-maps of energy intensities or assessment of load curves, a change in the average after-hours energy use from 7 pm to 7 am was apparent. The near-constant baseload increased by an average of 25 kW for a ~month; the approximate increase in usage would be 30 days x 12 hours/day x 25 kW or +9,000 kWh for the period.

EXAMPLE 4: INITIAL ESTIMATE OF POTENTIAL NRE'S IMPACT USING ENGINEERING ESTIMATES

> The facility's scheduled operating hours decreased by 15 hours/week, which affected some ECMs, including the lighting efficiency retrofits and motor upgrades. Based on the reported schedule change, these ECMs would be affected by 15 x 52 = 780 hours per year. For a lighting retrofit that reduced average loads by 50 kW and an average motor load reduction of 10 kW, the approximate impact to the energy savings is a reduction of approximately 39,000 + 7,800 or 50,700 kWh/year.

2.3.3   Possible Outcomes

The logic chart shown in Figure 1 outlines the next steps after a potential NRE has been identified. Other actions required for the assessment of an NRE are to determine the root cause of the change and to make an initial estimate of the impacts to savings. Any action taken will depend on the answers to these questions:

» Is the potential NRE related to the performance of the energy project or ECMs?

» Is the potential NRE part of normal operations?

» Are the savings significantly affected?

The possible outcomes of this evaluation are:

» Fix performance of the energy project or ECMs,

» No action is warranted, or

» Make a non-routine adjustment.

In some cases, the M&V plan may specify using some other savings estimation method or action rather than making an NRA if limited by costs or feasibility (e.g., cannot validate details of a potential NRE due to limited documentation of baseline conditions).

**Potential non-routine event (NRE) identified.
Is a non-routine adjustment (NRA) warranted?**
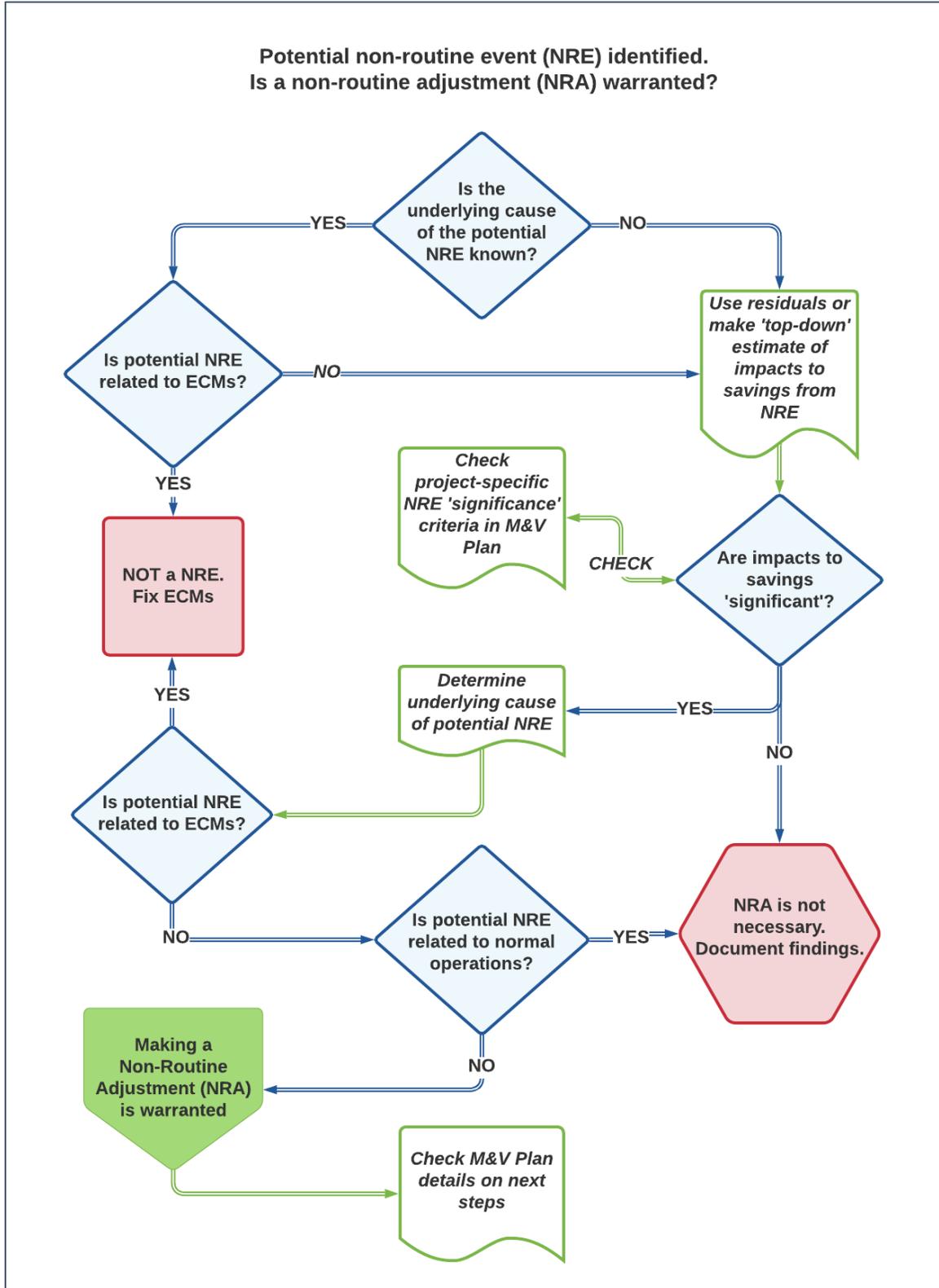
FIGURE 1: LOGICAL FLOW CHART FOR ASSESSING POTENTIAL NON-ROUTINE EVENTS FOR METER-BASED M&V

TABLE 5: EXAMPLE NON-ROUTINE ADJUSTMENTS CONSIDERING PROJECT PERIOD AND DURATION OF POTENTIAL NREs

Project Period	Duration	Example	Characteristics of Potential NRE	Possible Action
Baseline Period	Temporary	▪ Any	▪ Any	Exclude NRE period data and document as an NRA (NRA Method #1)
		▪ Any	▪ Any	Pick a new baseline period after the NRE has ended
		▪ One week of 24-hour operations for on-site emergency	▪ Operational changes ▪ Increase in energy consumption and demand ▪ Complex weather dependent load	Omit data (NRA Method #1) or modify the baseline energy model to include as a day-type (NRA Method #3)
		▪ Large HVAC packaged unit off-line for service during two-weeks	▪ Change in end-use equipment ▪ Decrease in electrical and natural gas consumption ▪ Variable time-dependent load	Keep in the baseline period and document in the M&V plan as a standard operating procedure. Define as a unique day-type in a model if needed (NRA Method #3).
	Permanent	▪ Change in scheduled operating hours from 12 hours/day to 10 hours/day	▪ Operational changes ▪ Decrease in electrical and natural gas consumption ▪ Variable weather dependent load	Choose a new baseline period that begins after changes (NRE) are complete, and operations are steady-state. Otherwise, create a new predictive regression model for the baseline period and determine the impact of the NRE using a 'pre-post NRE' approach, and incorporate it into the baseline energy model (NRA Method #7)
		▪ New dedicated outdoor air system installed to increase in ventilation rates for improved indoor air quality	▪ Change in end-use equipment ▪ Increase in electrical consumption and demand, and increased natural gas consumption ▪ Variable weather dependent load	
		▪ Add production of new product line	▪ Industrial process change ▪ Increase in electrical demand and consumption ▪ Variable load dependent on production and weather	Use backcasting (Alternate Method #1) to calculate avoided energy consumption rather than wait for a full period under new operating conditions
		▪ Installed solar PV system	▪ New energy project ▪ Reduction in electric demand and consumption ▪ Variable load based on irradiance levels	Sub-meter kWh from solar PV system used by facility in 15-minute increments and add metered energy use to the adjusted baseline energy (NRA Method #2)
		▪ Upgraded security lighting	▪ Change in end-use equipment ▪ Constant scheduled load ▪ Decrease in electric consumption	Use sub-metered energy (NRA Method #2)

Project Period	Duration	Example	Characteristics of Potential NRE	Possible Action
Implementation Period	Temporary	▪ Any	▪ Any	Ignore NRE. Screen site for permanent changes not associated with ECMs
	Permanent	▪ Convert offices to small data center	▪ Any	Determine ECM and NRE dates and equipment details and install sub-metering if possible (NRA Method #2). Consider redefining the baseline model to include ITE loads (NRA Method #3). Otherwise, model NRE using a 'pre-post NRE' model to determine impacts, which include both ITE and weather-related HVAC loads (NRA Method #7)

Project Period	Duration	Example	Characteristics of Potential NRE	Possible Action
Reporting Period	Temporary	▪ 24-hr shifts during some projects	▪ Periodic event ▪ Increase in electric and natural gas consumption ▪ Variable load based on weather and number of people	Exclude NRE period data and document as an NRA (NRA Method #1) or reconstruct baseline model to include 24-hour shift-days as a unique day-type or add the number of people as an independent variable (NRA Method #3)
		▪ Electric heating inadvertently enabled to operate	▪ One-time event ▪ Increase in electricity consumption ▪ Constant weather dependent load	Quantify impact by creating an 'NRE adjustment model' using data during the NRE period and apply as an NRA to adjusted baseline energy use in avoided energy consumption calculation (NRA Method #5)
	Permanent	▪ New condensing boilers installed	▪ New energy-related project ▪ Decrease in natural gas consumption ▪ Variable load driven by weather	Ignore impacts from ECM since there are limited interactive effects with electric loads being monitored for savings
		▪ Add new space to the facility	▪ Structural changes ▪ Increase in electrical demand and consumption ▪ Variable load based on weather and monthly schedules	Sub-meter energy use from electrical panels serving new space for the duration of the project (NRA Method #1)
		▪ Changes to operating hours and chiller plant staging	▪ Operational changes ▪ Decrease in electrical demand and consumption ▪ Variable load based on outdoor air temperature (i.e., cooling load)	Create a model for the project period that includes an indicator variable for the NRE to determine impacts since large weather-based variable loads can invalidate existing models due to changes in the underlying relationships between temperature and energy use (NRA Method #7)
		▪ Replaced inefficient motors in boiler plant	▪ Change in end-use loads ▪ Reduction in electrical demand and consumption ▪ Variable load based on weather (i.e., heating load) and occupancy schedule	Use residuals from the reporting period model to quantify impacts to affected hours and apply as an ongoing NRA baseline energy use (NRA Method #4)

3 DETECTING NON-ROUTINE EVENTS

It is important to note that energy use is not entirely predictable, and periods with anomalous energy use will occur. Not all *potential NREs* can be explained or traced to corresponding site changes and addressed with NRAs. Some unaccounted variations should be expected. Similarly, potential NREs that are short in duration with limited impacts may often be ignored, whereas larger, sustained changes usually warrant investigation.

When evaluating for potential NREs, there are two critical considerations:

» **Beware of 'false positives'**. NRE detection methods based on data analyses and change detection approaches are prone to indicate a possible NRE when none have occurred[15]. This is generally heightened with short-duration data and using longer increments (e.g., daily instead of hourly). More than one NRE detection method may be advisable, and suspect data should be validated before conducting further analysis (e.g., the sum of interval energy data matches utility billing data).

» **Screening for NREs may identify modeling issues**. Many potential NREs reflect the omission of significant independent variables or periodic operational modes from the regression energy model. Often significant independent variables can be unknowingly ignored or inappropriately identified as 'static factors'. Many NRAs can be avoided by including these items as independent variables in the energy model.

In general, including and tracking an additional independent variable is preferred over making periodic NRAs or ignoring the impact from NREs on savings. For example, if the percentage of leased space changes multiple times over a baseline or reporting period, it might be better treated as an independent variable than evaluating multiple events and making subsequent adjustments.

STRATEGIES TO IDENTIFY NRES WITHOUT A REGRESSION-BASED ENERGY MODEL

The approaches to identify NREs are significantly reduced when energy data for the period is limited, and an energy model has not been developed, such as during the beginning of the reporting period. Approaches to consider in these circumstances are NRE Approaches #1 - 5, which help identify NREs when a reporting period model is not available.

Since these approaches (#1 – 5) do not require a regression energy model, they can be applied periodically to find potential NREs. Detecting NREs early in the reporting period offers a considerable advantage for identifying anomalies early rather than waiting up to a year after the fact when the project is being assessed for savings. These approaches include:

» NRE Approach #1: Identify Changes in Static Factors,

---

[15] Berkeley Lab's NRE detection algorithm included in the RM&V2.0 software tool is not recommended for wide-spread deployment due to the frequency of false positives (Touzani, S. et al., Statistical change detection of building energy consumption: Applications to savings estimation. Energy and Buildings, 2019).False positives can be a significant issue in other NRE detection strategies as well(Goldberg, M. and Mahone, T., *Can the Non-Routine become Routine? Dealing with Non-Routine Events in Normalized Metered Energy Consumption,* IEPEC 2019).

» NRE Approach #2: Use Monitored Site Data,

» NRE Approach #3: Evaluate Energy Data for Changes in Use Patterns,

» NRE Approach #4: Analyze Data for Outliers, and

» NRE Approach #5: Track Energy Savings using a 'CUSUM' Chart.

STRATEGIES TO IDENTIFY NREs USING A REGRESSION-BASED ENERGY MODEL

The other strategies covered, NRE Approaches #6 – 7, require analysis of energy model outputs for the period being evaluated for NREs. This significantly expands detection capabilities, but timely application during the reporting period may be limited. A reporting period model can be developed using less than 12 months of data and improved over time as more data become available, especially when using hourly (or even daily) data.

Once you have a valid reporting period or baseline-period energy model, there are several additional approaches that can be used to identify NREs.

These NRE Approaches are most effective when using an accurate energy model and include:

» NRE Approach #6: Analyze Residuals from the Model, and

» NRE Approach #7: Reporting Period Energy Savings Are Higher or Lower Than Expected.

The details of these seven NRE detection approaches follow.

These or other techniques should be used to validate baseline and reporting-period conditions and ensure the reported savings are unaffected by significant NREs. Projects calculating avoided energy consumption may choose to develop a reporting period model for NRE detection purposes.

3.1   NRE Approach #1 — Identify Changes in Static Factors

Requirements:	▪ Baseline period static factor metrics, and ▪ Site contact(s)
Identifies:	▪ Most significant changes at a site

The easiest and most utilized method to identify NREs is through reporting from the site[16]. Ideally, the M&V Plan specifies regular reporting from the site on key static factors and includes criteria to warrant additional notifications.

---

[16] In a review of projects requiring non-routine adjustments in DOE's SEP Program the need for NRA were all reported by the site.

Setting expectations with the site staff to provide regular reporting on changes during the project helps facilitate ongoing follow-through. The involvement of the site staff can provide timely reporting on NREs, offsetting the need for NRE detection analytics and site-visits, lowering overall M&V costs.

Relying solely on site-level reporting, however, can sometimes lead to inaccuracies. Site reported changes should be verified using energy data analysis, if possible, to validate impacts are as expected in both timing and magnitude. Often, when an NRE is reported, other site changes will inadvertently go unmentioned, especially at larger facilities. When projects are reported, it is common that some details or smaller changes may be overlooked. Confirming the unaffected static factors is recommended so that any unmentioned changes are not included in the assessment of the NRE.

If needed, third-party site-inspections or surveys can be used to identify or confirm changes in a project's key static factors.

3.2 NRE Approach #2 — Use Monitored Site Data

Requirements:	▪ Advanced reporting from on-site monitoring systems (e.g., energy sub-metering or control systems)
Identifies:	▪ Unexpected operating conditions

Data gathered by on-site monitoring systems can be used to identify changes in sub-metered energy use or operating conditions to flag potential NREs. Trend data from building control and monitoring systems have become a viable tool thanks to improvements in data management, storage, and remote access through the adoption of web-based systems[17]. These platforms may include remote data collection and analysis capabilities and may allow sub-metered energy data and system-level data from the sites that can be used to flag changes in site operations.

The ease and level of automation in using this approach will vary by the degree of site instrumentation and engineering support. This approach is especially useful for energy projects that require ongoing tracking of specific operating conditions such as space temperatures and operating hours.

This approach might work well for sites conducting continuous commissioning improvements or do not have a regression-based energy model. In practice, it is typical to use system-level data to investigate the cause of potential NREs after one is flagged at the whole-facility level to minimize the number of false-positives[18].

Sites that utilize energy sub-meters have a substantial advantage in identifying and managing NREs. Sub-metered energy data from key energy-using systems allow unexpected changes in whole-facility energy use

---

[17] Both building automation systems (BAS) and energy management and information systems (EMIS) capabilities may include fault-detection and diagnostics (FDD) and advanced energy modeling. Some platforms allow for custom anomaly algorithms and reports. In some cases, reports from computerized maintenance management systems (CMMS) may also be useful.

[18] Huang H., et al., From Local Optima to Overall Optimum: A Field Study of Model-Based Anomaly Detection in Commercial Buildings, ACEEE Summer Study, 2020.

to be pinpointed and quantified. With sufficient sub-meters, it may be possible to automate the identification and analyses of some types of potential NREs.

> A project site located in Denver, CO, uses fault-detection algorithms in their HVAC control system to monitor the performance of key systems and report significant deviations from expected operations. Quarterly reports from the system are provided to identify faults that could be non-routine events in the M&V effort underway focused on upgrades to the central chilled water plant. The automated report from February showed that the air-side economizer on one of the five large air-handlers had failed closed in late December and was inoperable until mid-January; the ~100-ton economizer unit failed to operate for 152 hours during the quarter. Subsequent analysis of the energy use data confirmed a matching increase in whole-facility energy use.

3.3   NRE Approach #3 — Evaluate Energy Data for Changes in Use Patterns

Requirements:	▪ 15-minute or hourly energy data, ▪ Data visualization tools (e.g., Excel)
Identifies:	▪ Changes in facility operating hours and/or loads

Energy use data can be evaluated to identify changes in energy use patterns using simple data visualization tools such as Excel.

Potential NREs commonly identified include:

» Increase or decrease in operating hours (e.g., 24-hour operations vs. scheduled operations, or change from 6:00 am - 6:00 pm to 8:00 am - 4:00 pm);

» Shift in operating hours (e.g., change from 7:00 am – 7:00 pm to 5:00 am - 5:00 pm);

» Changes in equipment or operations impacting daily base loads or peak loads, durations, or timing (e.g., increase in after-hours lighting loads);

» Changes in load rise or fall time, or slope of load profile (e.g., change in occupant density);

» Seasonal shifts in operations or periodic shut-downs.

Inspecting data in time series charts, scatter plots, heat maps, and surface charts (CUSUM covered later) or tracking load shape characteristics can uncover periods of anomalous use or long-term changes in usage. Although both decreases and increases in energy use are equally important to recognize, a sustained increase in energy use relative to the adjusted baseline is generally a red flag since most M&V projects expect to see sustained decreases in energy consumption.

A sample of possible strategies is covered in this section, including:

» Heat Maps,

» Surface Charts,

» Time-Series Plots, and

» Overlays of daily load-profiles.

Load profile comparisons should be conducted using the same day-type, e.g., weekdays. Although these strategies do not require, including the independent variable data (e.g., outside air temperature), inclusion can help determine if observed variability is related to these key energy drivers.

The heat map in Figure 2 shows one-year of hourly kW data, with one row representing a week of data[19]. A quick review of the chart's color patterns indicates a temporary schedule change occurred at the end of August, shifting operating hours. Heat maps represent an excellent tool for visualizing energy use patterns and can be made in Excel using conditional formatting and pivot charts if needed.

Surface charts that use a three-dimensional format can also be informative. Figure 3 uses 15-minute interval data, which shows a two-week period at the end of August with unusually high peak loads.[20]. Note that in this case (and others), using more data and longer time-periods can obscure usage patterns.
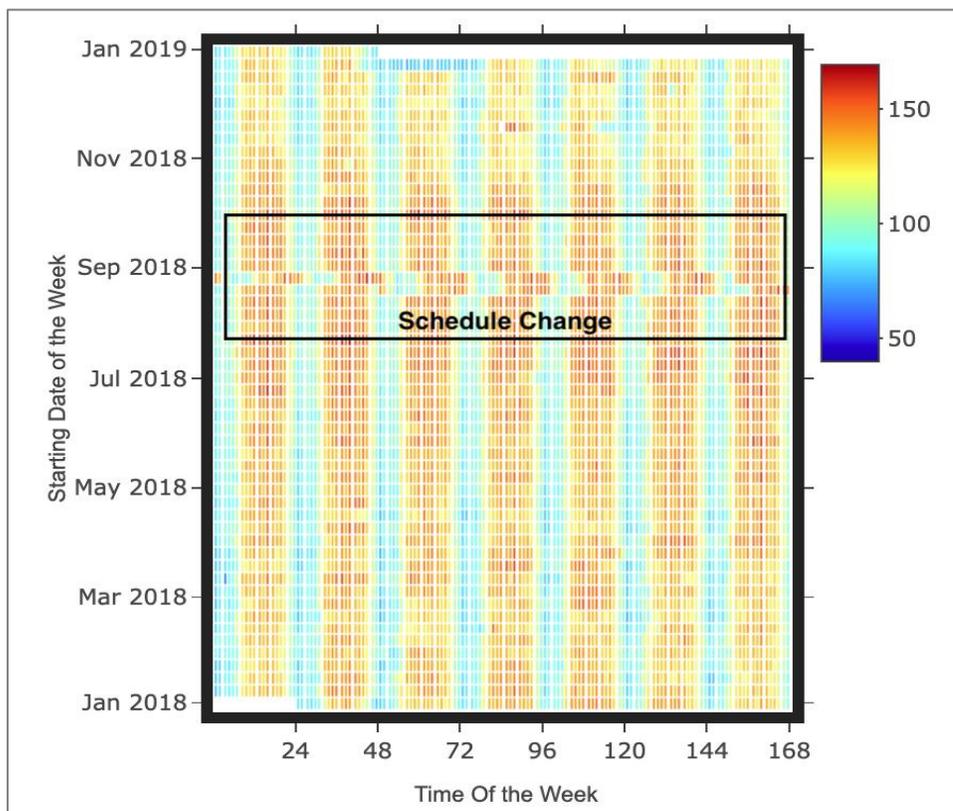
FIGURE 2: HEAT MAP OF ENERGY DATA SHOWING SHIFT IN OPERATING HOURS

---

[19] Graphic is from RMV2.0 package, which is available on Github.

[20] Excel requires a cross-tabular data format for surface charts, which is the format interval data is provided by some utilities.
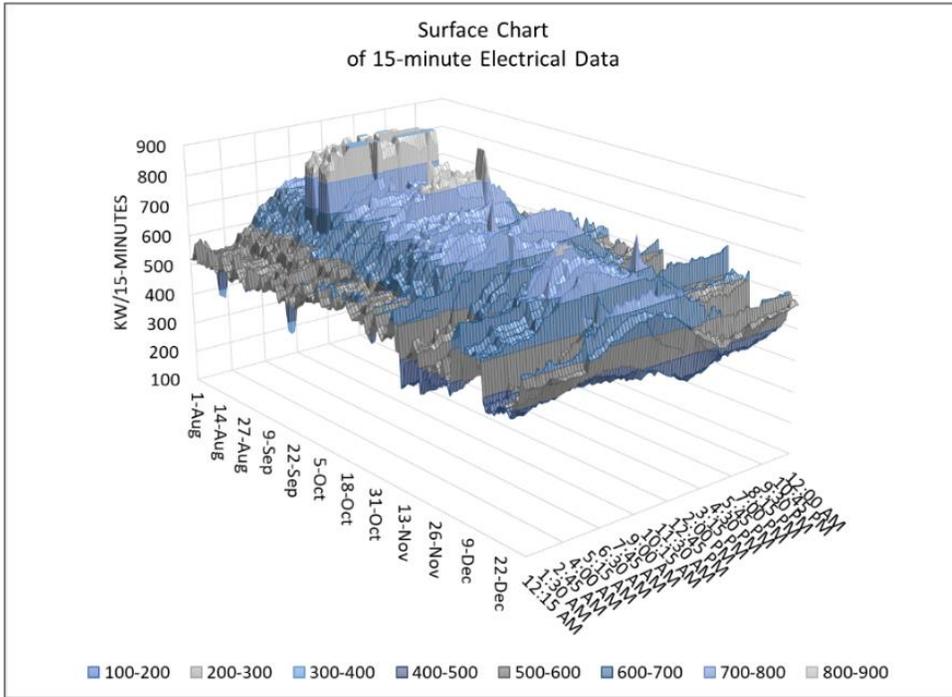
FIGURE 3: SURFACE CHART OF 15-MINUTE ELECTRIC DATA SHOWING UNUSUALLY HIGH PEAK LOADS

Figure 4 shows three-month metered data from a facility. The month of June is a representation of normal conditions. During July and August, the facility fails to shut down at night (shaded periods), and its systems are running additional hours due to an apparent schedule override during the summer.
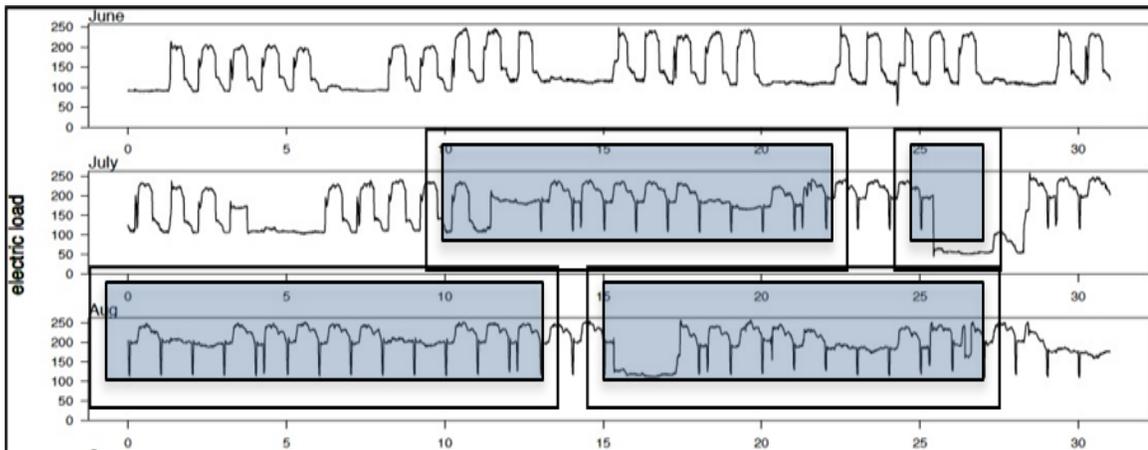
FIGURE 4: QUARTERLY TIME SERIES CHART OF LOAD FOR FACILITY WITH A SCHEDULING CHANGE[21]

The time-series chart of energy consumption in Figure 5 shows an increase in daily peak loads for ten days (May 21st through May 30th). These data show a temporary increase in daily peak loads without a corresponding increase in the driving independent variable, outdoor air temperature.
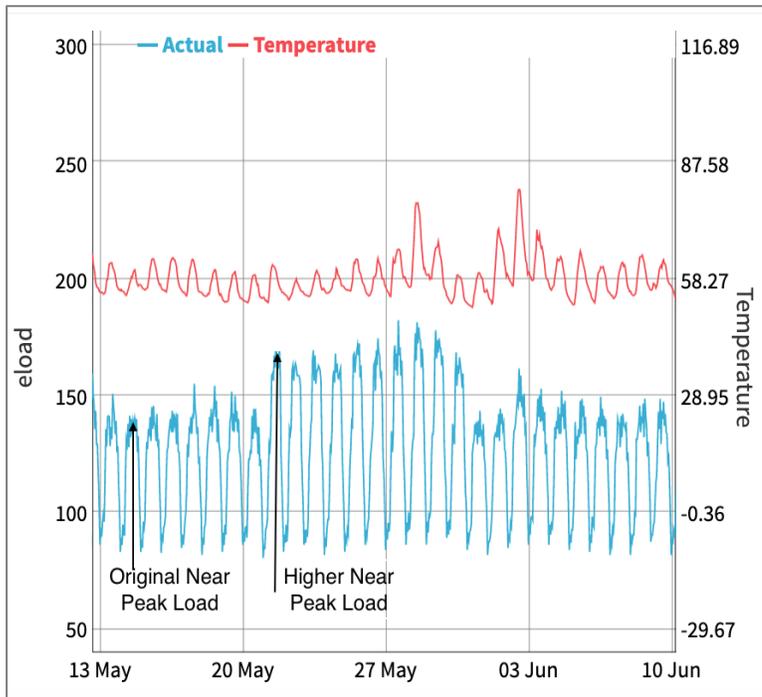
FIGURE 5: MONTHLY TIME-SERIES OF ELECTRIC LOAD AND TEMPERATURE WITH TEMPORARY INCREASE IN DAILY PEAK LOADS (KW)
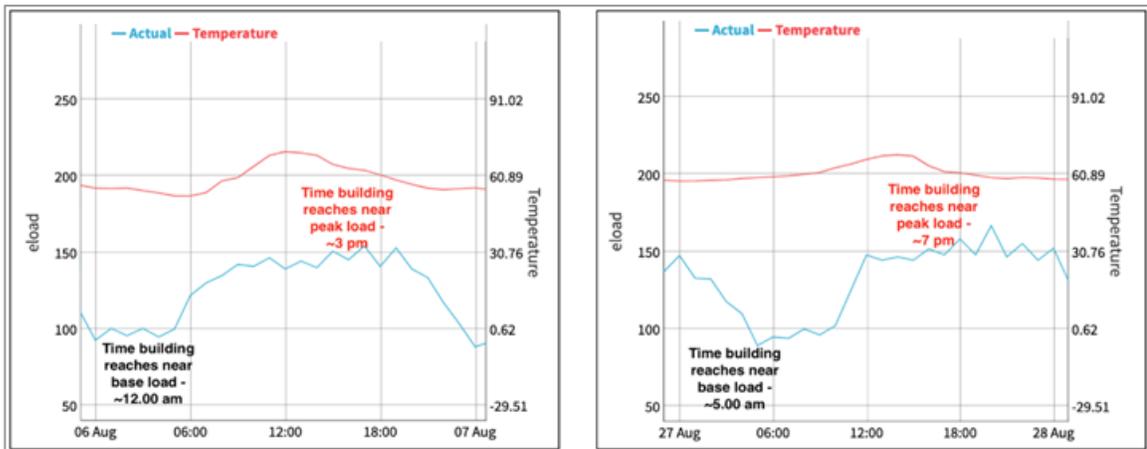
FIGURE 6: TYPICAL DAILY LOAD CURVE (LEFT) AND LOAD CURVE WITH SHIFT IN OPERATING HOURS (RIGHT)

Many facilities, including schools, industrial, and agricultural sites, may undergo substantial variations in both schedules and equipment operations. These periods can be recurring events (e.g., summer school) that are not NREs, or one-off shutdowns (e.g., upgrades to production lines) that would represent an NRE.

Tracking characteristics of load shapes during periodic visual reviews can facilitate identifying changes in energy use patterns over time. Figure 7 identifies the key load profile characteristics in a commercial facility.

Although not all facilities exhibit these load profile characteristics, each does have unique and consistent features across day-types (e.g., Day 1 and Day 2), such as equipment start and stop times.
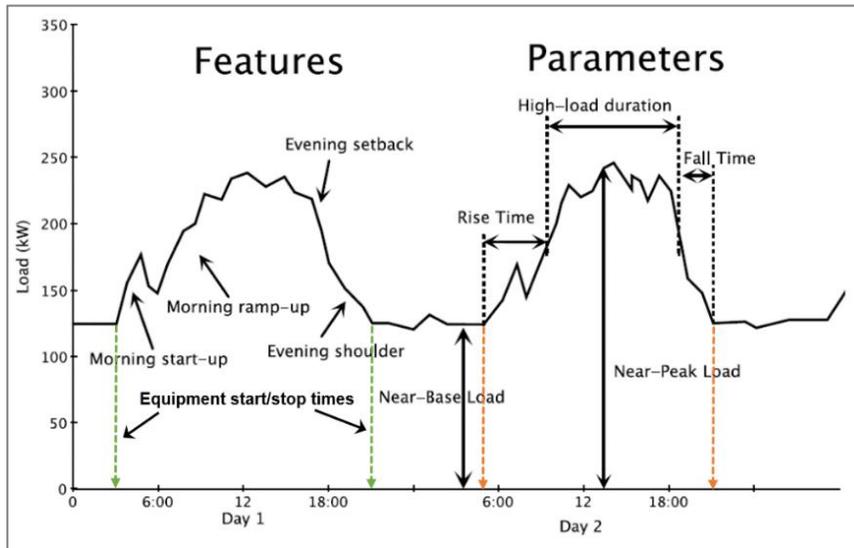
Since these load shape characteristics vary across day-types, identifying changes can be simplified by overlaying daily load-profiles from the same day-type (e.g., Weekends) on a single chart. Comparisons of this type can quickly reveal unexpected variations in load-shapes when a seasonally appropriate reference load-profile is included. Conducting monthly reviews of each day-type included in the baseline energy model is one option for this type of analysis[23].

The example in Figure 8 shows the hourly electric load profiles of a commercial office building for the eight weekend days during February 2017. The three reference days included in the chart (dashed lines) are the average hourly loads (kW) from previous days during the performance period with similar weather conditions and operating modes (fall and winter). The normal weekend loads for this facility have a flat profile near a base load of 285 kW (the building is unoccupied and systems are scheduled off). The loads were as expected for most of the days included, but anomalies are evident in two days (2/12 and 2/17) when the building loads and schedule appear to be those of a weekday rather than a weekend.

---

[22] Adapted from LBNL-4944E Mathieu, Price et al., *Quantifying Changes in Building Electricity Use with Application to Demand Response*, 2011.

[23] Assigning day-types based on periods with similar load-profiles is usually conducted when developing a baseline model using techniques such as cluster analysis.
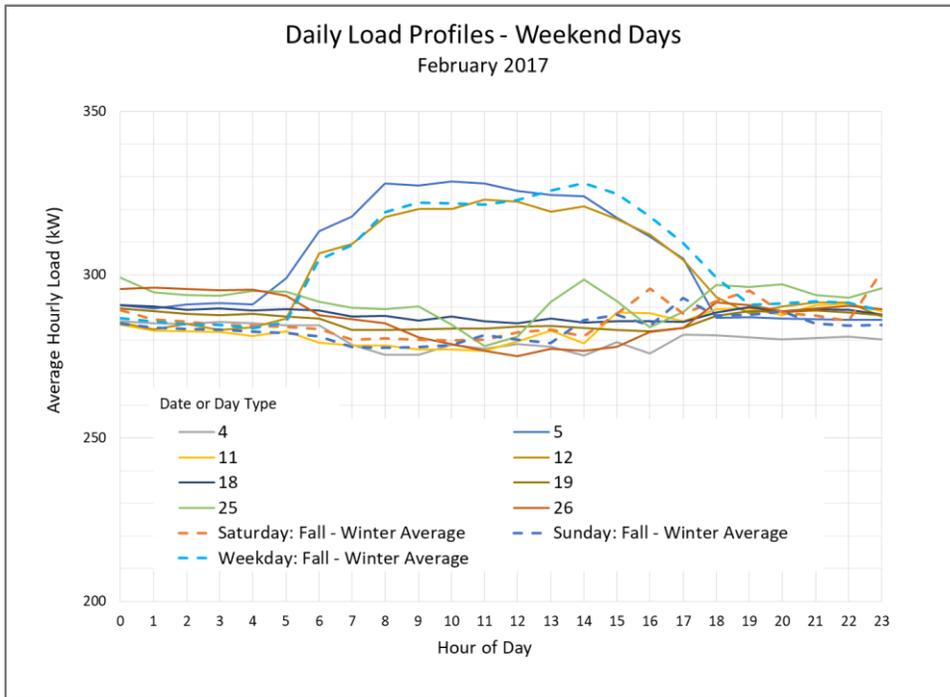
FIGURE 8: MONTHLY REVIEW OF OVERLAID ELECTRIC LOAD PROFILES FOR WEEKEND DAYS HIGHLIGHTS OUTLIERS

Another strategy that can identify subtle changes is quantitatively documenting the key characteristics of a load profile periodically. Because there is limited analysis required, this strategy can be used to reduce engineering time and effectively identify periods with potential NREs, such as those flagged in Figure 9.

Date	Day-Type	Base kW	Time Equipment Starts	Peak kW	Time of Daily Peak	Duration of Peak (hrs)	Time Equipment Stops
5/1/2019	Weekday	75	8:00 AM	248	12:30 PM	3	3:00 PM
5/4/2019	Sat. & Sun	74	6:00 AM	184	12:30 PM	2	7:00 PM
6/4/2019	Weekday	78	6:00 AM	247	12:30 PM	3	7:00 PM
6/8/2019	Sat. & Sun	75	8:00 AM	174	12:30 PM	2	3:00 PM
7/3/20219	Weekday	80	5:00 AM	255	1:00 PM	4	9:00 PM
7/4/2019	Holiday	79	-	130	-	-	-
7/6/2019	Sat. & Sun	74	8:00 AM	174	12:30 PM	2	3:00 PM
7/8/20219	Weekday	82	5:00 AM	258	12:00 PM	3.5	9:00 PM
7/27/20219	Sat. & Sun	77	6:00 AM	238	12:30 PM	2	9:00 PM
8/3/2019	Sat. & Sun	74	8:00 AM	244	12:30 PM	2	3:00 PM

FIGURE 9: EXAMPLE TRACKING WORKSHEET FOR LOAD PROFILE CHARACTERISTICS FOR EACH DAY-TYPE FLAGGING OUTLIERS

3.4 NRE Approach #4 — Analyze Data for Outliers

It is typically good practice to check for invalid data, and a review of the data for outliers can identify potential NREs and other issues. Establishing an expected span for each data set is needed to recognize when values are out of range. Outlier data flagged should be validated (e.g., the sum of interval energy data matches utility billing data) before any groups of outliers should be considered a potential NRE.

Depending on the data being evaluated, one of three similar methods may be applied. In each, a time-series plot is created for an individual variable that includes high and low threshold values based on the data included in the baseline model. Thresholds provide a consistent means to flag data outliers that occur during the reporting period.

In the first two approaches, the reference boundaries for independent variables such as weather are set based on the maximum and minimum values included in the baseline model. Boundaries for the data must be suitable, but between 90% of minimum and 110% and maximum values of the range of data from the baseline period are recommended. The ASHRAE Guideline 14 sets limits of 110% of maximum and 90% of minimum values used in the model. BPA's *MT&R Guide* recommends using the range of values +/- 10%, which can be useful in some circumstances.

The third approach may appropriate for normally distributed data[24] and uses the standard deviation of the data from the modeled period. The standard deviation of a population indicates the variability in the data and can be calculated in Excel or by using the equation below. A general rule of thumb that data three or more standard deviations (σ) from the mean or average represent outliers[25]. This rule can, however, can sometimes result in a wider than desirable range.

EQUATION 1: STANDARD DEVIATION OF A NORMALLY DISTRIBUTED POPULATION

$$\sigma = \frac{\sum(Y_i - \mu)^2}{(n-1)}$$

Where Y is actual energy use at time-interval if, μ is mean (average) energy use for the population, n is the number of data points, and σ is the standard deviation of the population

The similarities in these thresholds vary based on how the data are distributed. These strategies are best applied to data from consistent operations (e.g., does not include unoccupied periods or zero production days). The analyses and can be used to assess the subsets of data, as appropriate.

The example in Figure 10 is a time-series of weekly customer visits from the baseline period into the reporting period. The three different sets of threshold boundaries shown are set using the baseline data, and all indicate the rate of weekly visits began to exceed the valid range midway into the reporting period.

---

[24] This includes model residuals which are discussed later in this section. Note histograms can illustrate the distribution of data.

[25] Monitoring, Targeting and Reporting (MT&R) Reference Guide Rev 8.0, BPA, November 2019 updated their recommendation from three to four standard deviations.
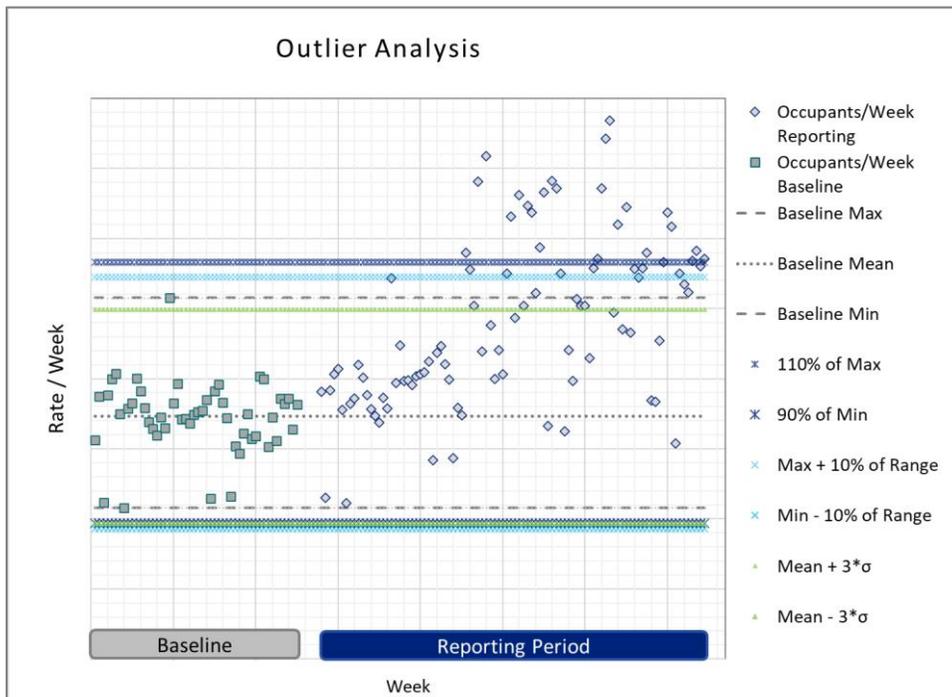
FIGURE 10: OUTLIERS ANALYSIS OF INDEPENDENT VARIABLE DATA USING EXPECTED THRESHOLD VALUES IN A TIME-SERIES CHART

3.5   NRE Approach #5 — Track Energy Savings with a 'CUSUM' of Savings Chart

Requirements:	▪ Reporting period energy savings results data
Identifies:	▪ Changes in the rate savings are accumulating

A cumulative sum (CUSUM) chart is a bar or line chart showing the ongoing cumulative sum over time. CUSUM profiles of energy savings clearly indicate the change in calculated savings over time and can be utilized to detect anomalies in calculated energy savings during the reporting period. As shown in Figure 11[26], the slope of the CUSUM chart reflects the rate energy savings are accumulating, with a steady upward slope indicating a constant amount of savings is added in each time step.

This strategy is best used by periodically calculating the avoided energy consumption during the reporting period and adding data to the chart. The time period covered by each point in a CUSUM of savings chart typically matches the data increment used in the baseline energy model (e.g., daily), and can quickly show a trend in savings. Conducting periodic calculations of avoided energy consumption can add effort but may be warranted. Otherwise, CUSUM charts can be generated at the end of a reporting period[27].

---

[26] The CUSUM savings charts in this section are from Crowe, E. *From Theory to Practice: Lessons Learned from an Advanced M&V Commercial Pilot*, IEPEC 2019.

[27] The CUSUM charts included in this section are from the RMV2.0 analysis package available on Github.
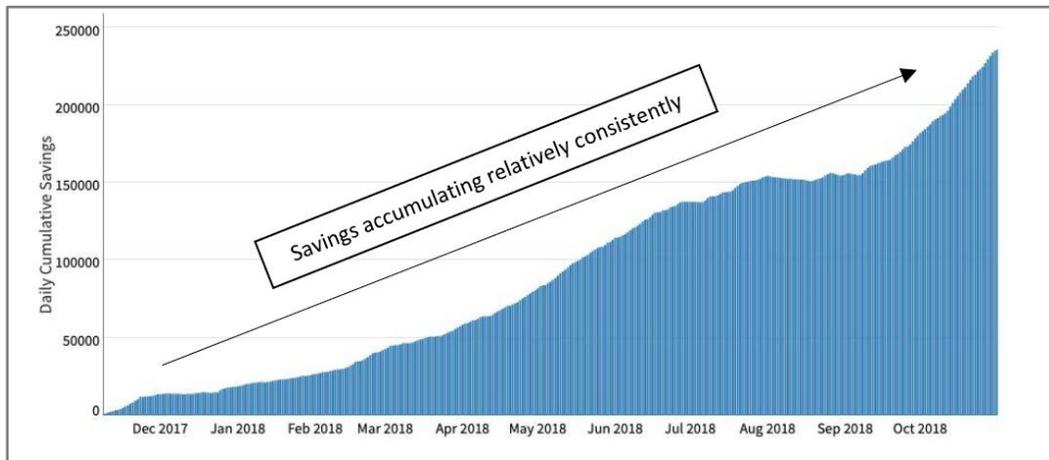
A change in the CUSUM chart slope indicates an increase or decrease in energy savings generated over time and may indicate a *potential NRE*. Key points on the CUSUM of savings graph are where the slope of the line changes, which can reflect an expected variation in the rate of savings based on the installed ECMs, or it can indicate a *potential NRE*.

Any time a CUSUM chart shows an unexpected change in savings, the occurrence of potential NREs should be further investigated. A flat CUSUM chart indicates savings are no longer accumulating. A change in energy savings direction downward reveals more energy is being used than in the baseline period, and energy savings are not accumulating. If a CUSUM chart trends below the horizontal axis, the total accumulated energy savings are zero and trending negative, indicating more energy is being consumed than in the baseline period.

In Figure 12, the energy savings are initially apparent, but the savings stop accumulating in May. An inflection in the CUSUM line is seen in late June as electricity use begins to increase, and by mid-July, the cumulative total of the energy savings is zero. This is a worst-case CUSUM chart since the project has clearly experienced one or more potential NREs that have persisted for months.
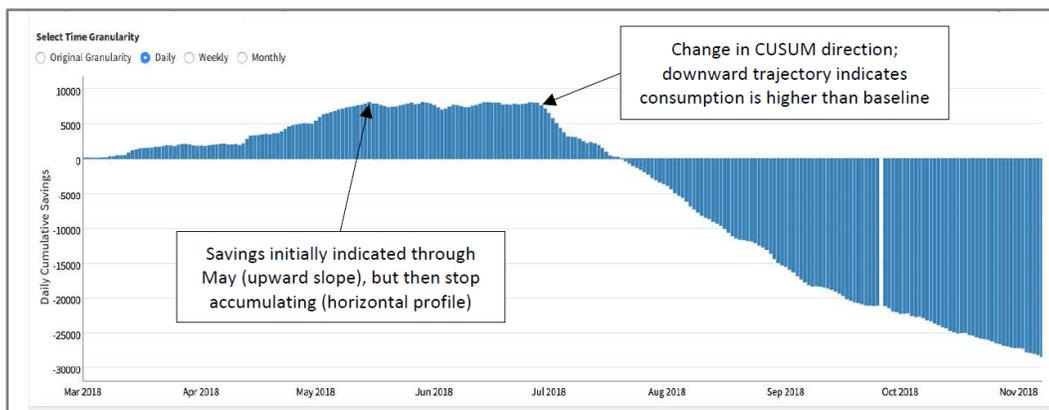
FIGURE 12: CUSUM SHOWING INCREASE IN ENERGY USE (NEGATIVE SAVINGS)

While some efficiency projects save energy consistently throughout the year, many projects are seasonally impacted, and savings can vary throughout the year, including some lighting upgrades. Creating an 'expected

CUSUM' chart from engineering calculations can clarify when savings are expected to occur, as shown in Figure 13. This can be useful if savings are expected to vary substantially by season and are easily created from savings predictions in hourly custom spreadsheets or building simulation models. Since these estimates are usually based on average TMY data, they may not capture variations due to actual weather or site conditions.
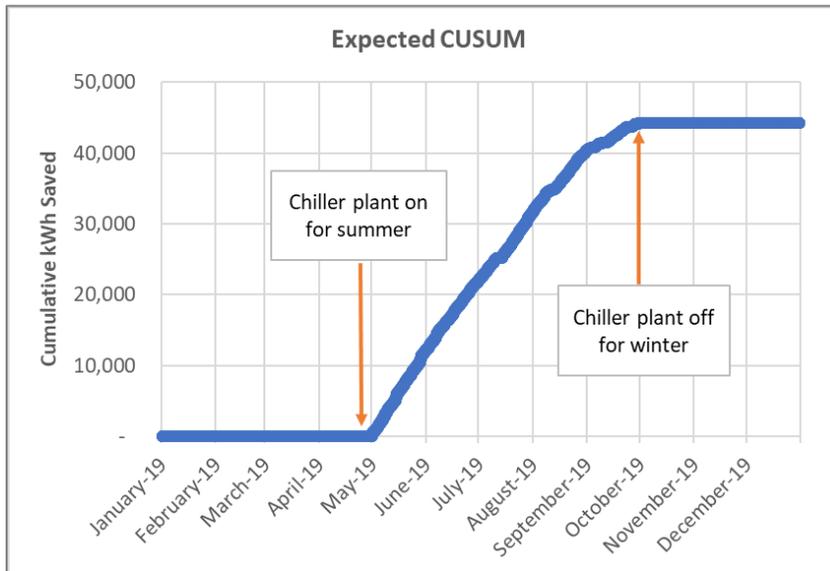
FIGURE 13: EXAMPLE ESTIMATED SAVINGS PROFILE AND CUSUM OF CHILLER PLANT IMPROVEMENTS

3.6 NRE Approach #6 — Analyze Residuals from the Model

Requirements:	- Predicted energy use from the model for the period, and - Actual energy use for the period
Identifies:	- Change in energy use patterns, or - Increasing or decreasing trend in energy use

These strategies can be applied to any baseline energy model or reporting period energy model. Creating a reporting period model would be an extra step for projects using avoided energy consumption.

Analysis of the difference between the actual energy consumption and the predicted energy consumption from a model, or 'residuals', is an important step in validating regression-based models[28] . It may also be used to reveal potential NREs.

If energy consumption patterns change, the effects can be seen in the residuals. Uncorrelated residuals from a non-biased model will sum to zero, and when plotted on a time series plot, are randomly skewed around the x-axis (y = zero). If energy consumption continues to follow the established pattern, the residuals will be

---

[28] These strategies assume the residuals show a normal distribution.

small and uniformly distributed around zero. A change in the residual pattern will occur if there is a change in energy use due to factors outside of the independent variables.

EQUATION 2: MODEL RESIDUALS

$$Residuals = Y - \hat{Y}$$

Where: $Y = actual\ energy\ use$, and $\hat{Y} = predicted$ **energy use**

Many strategies can be used to analyze model residuals for unexpected changes. A sample of strategies is covered in this section, including:

» Use Time Series Charts or Heat Map of Residuals,

» Use Standardized Residuals,

» Use the Probabilities of Residuals,

» Use a CUSUM of Residuals,

» Identify Trends in Residuals.

Outliers in the model residuals may indicate the occurrence of a potential NRE, especially when occurring in clusters. This is similar to the outlier analyses discussed in Section 3.4 above but uses the model residuals rather than the recorded variable data.

Evaluation of residuals is an effective approach to investigate whether data are in range and to identify outliers. This approach, and others, assume the residuals follow a normal distribution, which allows a statistical assessment of the data. In this case, the mean (average) and the standard deviation (σ) of the data are used to identify data that is out of range (see Equation 1).

A typical rule of thumb is data with standard deviations from the mean of more than 3 are outliers[29]. The value of 3 is only a rule of thumb. However, periods of time containing groups of residuals with standard deviations closer to 2[30] can also indicate a potential NRE.

3.6.1 Use Time Series Charts or Heat Map of Residuals

Using a time-series chart or a heat map of residuals is a very effective method for identifying unexpected changes in energy use that can represent potential NREs. In a time-series chart, the appearance of bias or sudden jumps spanning zero can indicate a potential NRE.

The next two examples use data from a site whose operating schedules were extended for two hours in May. Figure 14 uses a time-series chart of residuals to highlight the period where the distribution of the differences around zero becomes less symmetrical.

---

[29] *MT&R Guidelines Rev 8.0,* BPA, November 2019.

[30] In a normal distribution, three standard deviations from the mean includes 99.7% of expected values and two standard deviations includes 95% of expected values,

The same data are shown in Figure 15. In this case, a heat map of the hourly residuals clearly indicates the change in May and illustrates the hours affected by the extended schedule (hours 18 and 19). Note that this chart was created in Excel using a pivot table and conditional formatting, which uses red to highlight residuals that are the most significantly out of range.

FIGURE 14: TIME SERIES CHART OF HOURLY RESIDUALS INDICATE POTENTIAL NRE IN MAY

Date / Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mon, 4/28/2014	15	2	-5	4	0	2	6	-7	-12	-6	5	-2	-1	-1	3	8	-1	3	-3	-17	-1	3	-3	9
Tue, 4/29/2014	-2	-2	3	-6	-3	-11	0	-3	3	-8	-10	-14	2	-1	-4	8	6	-2	-10	-3	5	-6	6	2
Wed, 4/30/2014	4	-1	0	3	0	2	6	-1	1	20	-4	6	11	-5	6	-6	-8	-8	-2	6	0	-10	9	6
Thu, 5/1/2014	3	-5	-11	8	11	-9	1	1	9	-1	-2	10	-4	2	2	-16	7	8	37	33	-2	-9	11	-14
Fri, 5/2/2014	0	4	9	-12	7	-2	5	-11	4	-3	-7	3	-9	1	-2	2	0	-14	28	13	-3	9	-8	-12
Sat, 5/3/2014	-20	4	3	5	-10	-1	5	9	0	-26	-3	2	0	8	-5	10	-14	7	18	9	-7	8	7	5
Sun, 5/4/2014	1	-15	1	5	5	3	-7	9	0	8	-1	-3	10	7	-8	-7	2	3	18	11	-1	-9	-8	1
Mon, 5/5/2014	-12	13	-5	-9	-3	2	-6	4	-18	4	5	-7	18	4	-8	-1	2	-1	28	13	8	-8	14	9
Tue, 5/6/2014	4	11	-2	4	-5	2	9	-2	0	7	-4	-5	13	2	9	2	10	13	2	13	8	-2	-1	-3
Wed, 5/7/2014	19	3	-10	-3	7	9	-11	7	-9	-12	0	2	-8	5	-4	-11	7	3	15	28	5	2	4	4
Thu, 5/8/2014	-8	5	3	0	-6	-6	3	6	18	-7	5	9	5	-2	-8	-2	4	5	20	7	2	-1	5	3
Fri, 5/9/2014	20	-1	0	11	2	6	10	0	16	6	-1	-16	-4	12	4	0	-24	-4	22	7	2	9	4	-9
Sat, 5/10/2014	-8	3	4	1	-12	3	1	12	-6	10	-7	-17	1	-3	9	2	1	10	32	21	-12	10	10	-12
Sun, 5/11/2014	-4	-14	4	2	-4	6	-3	6	7	-7	2	-3	-6	-17	12	-4	-9	-3	30	15	14	-9	-9	-1
Mon, 5/12/2014	2	-1	-20	-13	1	6	6	12	8	3	-1	6	-13	0	9	-14	15	6	42	17	6	-1	4	6
Tue, 5/13/2014	6	-6	-4	-8	7	-3	-7	1	-12	6	15	-7	-3	-8	-2	-3	7	3	45	15	3	-14	-4	-6
Wed, 5/14/2014	16	-12	7	-13	3	-1	0	-21	-7	2	-2	17	3	-13	1	-4	6	18	46	33	-1	-2	13	-3
Thu, 5/15/2014	1	5	5	-2	-4	3	-5	17	-16	-1	-3	-7	-3	-8	-8	3	-8	2	48	45	8	2	-12	1
Fri, 5/16/2014	16	-8	-8	-3	4	4	-10	-4	5	4	-2	-1	-6	-8	-1	1	-5	6	30	22	1	-1	-7	-4
Sat, 5/17/2014	-7	8	-3	0	1	-3	2	-3	-4	-1	2	8	-6	16	-9	12	8	15	34	29	-1	9	-4	6
Sun, 5/18/2014	-4	-8	-7	-11	-5	-11	4	-8	3	-8	-17	2	10	-1	2	9	-3	-4	40	12	-7	0	-1	0
Mon, 5/19/2014	7	-12	0	-5	21	-3	2	2	4	8	-2	-4	-5	-3	16	-17	8	7	15	8	-5	4	-11	6
Tue, 5/20/2014	0	-7	3	-7	-7	2	-6	-6	4	-4	-23	0	-9	-4	-4	-3	-1	-2	19	-7	-1	-9	-4	1
Wed, 5/21/2014	-1	-1	9	-1	3	-5	18	9	-3	6	7	5	2	8	-1	5	11	-3	21	19	-9	-10	-4	2
Thu, 5/22/2014	-2	0	0	0	1	1	-1	-5	-1	6	-7	3	1	5	-1	15	1	2	15	12	-8	-4	7	1
Fri, 5/23/2014	-1	0	-7	11	16	-15	0	2	-8	0	-7	0	12	11	-5	-3	-2	9	31	12	4	-4	2	6
Sat, 5/24/2014	3	-3	-11	11	-2	-3	5	13	1	0	-7	-3	11	1	7	-8	3	-3	41	9	7	0	0	1
Sun, 5/25/2014	-17	-12	-6	7	-2	-6	7	4	14	-5	-5	-3	-10	-3	0	-1	-2	1	26	16	3	-10	10	8
Mon, 5/26/2014	-13	9	13	12	-16	0	19	-1	-3	6	-1	1	6	10	-1	3	6	2	42	28	1	-9	4	8
Tue, 5/27/2014	-2	-2	2	-12	8	-5	4	10	-9	-9	5	-3	7	3	-9	6	9	4	32	16	-5	-6	0	7
Wed, 5/28/2014	-4	-11	-13	-9	-3	21	3	5	9	0	-2	6	11	-2	-6	3	1	-8	24	30	-2	-2	8	2
Thu, 5/29/2014	-8	2	-2	7	-6	-6	-1	-3	-1	16	-17	-2	3	7	-16	7	9	2	30	1	-3	12	-2	2
Fri, 5/30/2014	4	1	4	-6	-6	-2	2	4	11	5	-4	-6	-14	10	-4	-1	4	4	17	16	12	-1	8	-6
Sat, 5/31/2014	4	-4	-3	7	-9	-4	11	13	-6	-6	5	-8	-7	2	12	15	14	3	33	14	4	5	-17	5
Sun, 6/1/2014	9	19	15	4	-6	-8	7	-15	0	-11	7	5	-4	-6	-4	5	-1	-2	7	11	0	-4	-5	-4
Mon, 6/2/2014	6	-6	-11	-6	-12	-3	-1	7	-2	1	1	10	-2	-8	0	-7	5	-9	7	-1	8	-13	8	-4
Tue, 6/3/2014	2	2	3	-6	8	4	-10	1	-3	-3	-7	-7	-4	-6	1	13	4	-11	9	-1	3	-5	0	-4

FIGURE 15: HEAT MAP OF HOURLY RESIDUALS INDICATE POTENTIAL NRE IN MAY 2014

3.6.2 Use Standardized Residuals

Outliers may be flagged by assessing each residual point's standard deviation from the mean, also called the standardized residuals or z-score. Standardized residuals are the residual values expressed in the number of standard deviations from the mean, as shown in Equation 3.

EQUATION 3: STANDARDIZED RESIDUALS

Standardized Residuals $= (Y – Ŷ) / σ$

Where Y is actual energy use, Ŷ is predicted energy use, and σ is the standard deviation of the residuals

Standardized residuals can be analyzed in the same way as residuals but can be more easily used to identify periods of outliers. As discussed in Section 3.4, setting thresholds using the standard deviations of data makes identifying periods of outliers more clear-cut. The example in Figure 16 below highlights a period when the standardized residuals are relatively large and, in this case, exceed the thresholds plus or minus three

standard deviations from the mean, although lower values may be useful. In this case, the periods of unexpected increases in energy use occurred during the weekends.
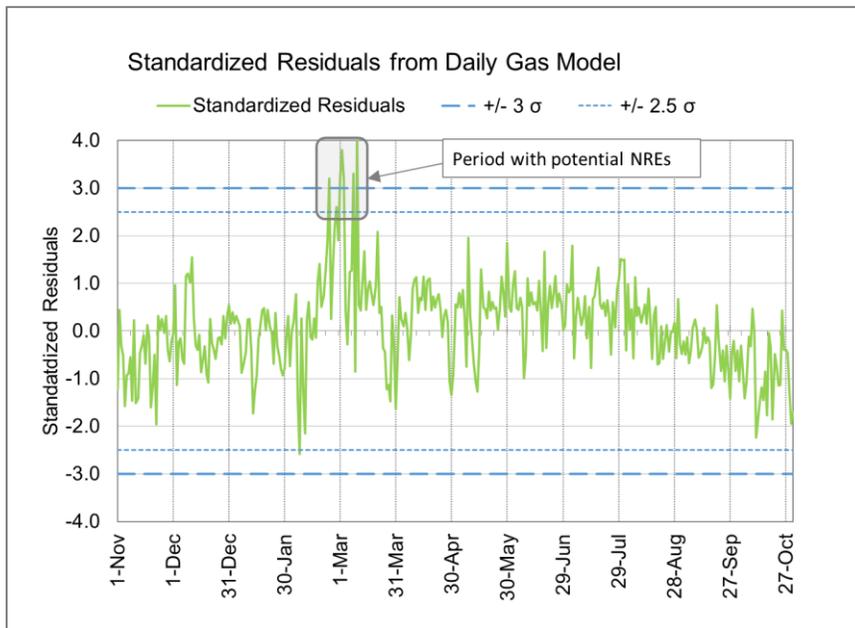
FIGURE 16: TIME-SERIES OF HOURLY STANDARDIZED RESIDUALS INDICATE A POTENTIAL NRE OCCURRED IN FEBRUARY

3.6.3 Use the Probabilities of Residuals

The probability of the residuals provides another metric for interpreting residuals. The probability of the residual, or p-value[31], can be used similarly to residuals to highlight periods with potential NREs. When using probabilities, values approaching zero are likely anomalies and can be flagged as a potential NRE.

P-values[32] can be evaluated using an expected range of values for probabilities, similar to NRE Approach #3[33]. In this case, the rule of thumb commonly used is Chauvenet's Criterion, which suggests data with probabilities of 5% or less (two standard deviations from the mean) may represent outliers.

In the example shown in Figure 17, the 24-hour average probabilities and hourly kW values are plotted to visually smooth the data.

---

[31] A p-value can be calculated in Excel using the T.DIST.2T function.

[32] P-values are calculated from the Z-score and number of points in the sample. Z-score is determined from the mean and standard deviation of the residuals. In Excel, T.DIST.RT(ABS(standardized residual),DOF of the model)*2. In words, T.DIST.RT returns the probability that you will find a standardized residual greater than (i.e. RT = the right-tail of the normal distribution) than your number, given the degrees of freedom (DOF) of the model.

[33] The F-statistic of the residuals is another NRE evaluation metric. See Goldberg, M. and Mahone, T., *Can the Non-Routine become Routine? Dealing with Non-Routine Events in Normalized Metered Energy Consumption,* IEPEC 2019.
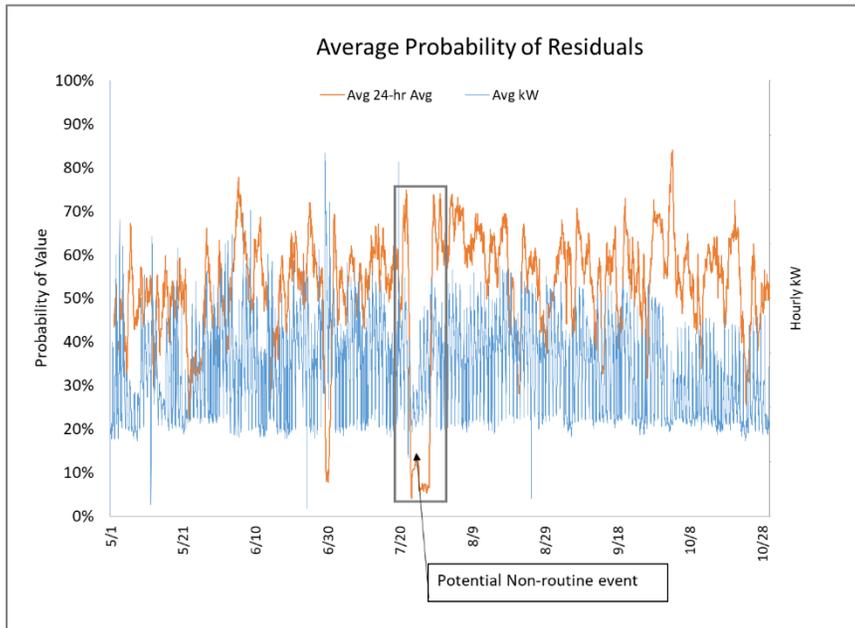
FIGURE 17: TIME-SERIES OF AVERAGE 24-HOUR PROBABILITY OF RESIDUALS

3.6.4 Use Cumulative Sum of Residuals

Using a CUSUM chart of the residuals (or standardized residuals) will clearly show unexpected changes in energy use over time, often more clearly than a review of the residuals themselves. As noted earlier, during normal operations, the residuals from a linear[34] model will maintain a zero-sum over time. Using a CUSUM chart can quickly indicate a shift in energy use that may otherwise not be evident due to the irregular nature of residual patterns.

A change in the slope of a CUSUM chart of residuals indicates a change in the residual pattern and a potential NRE. When the slope changes direction (e.g., from increasing to decreasing), the inflection point indicates another potential NRE with the opposite impact has occurred.

Figure 18 shows a CUSUM of residuals alongside a time-series of the residuals. The CUSUM effectively smooths the data and highlights the ongoing impacts of a potential NRE since it uses the ongoing totals. The time-series of the residuals adds granularity to help evaluate changes in the slope of the CUSUM.

---

[34] For linear regressions using ordinary least squares (OLS) method the sum of the residuals over the entire population will be zero.

CUSUM of Residuals and Daily Residuals

A change in the slope in the CUSUM (★) indicates a potential NRE.

An inflection point in the CUSUM(▲) indicates another potential NRE in the opposite direction
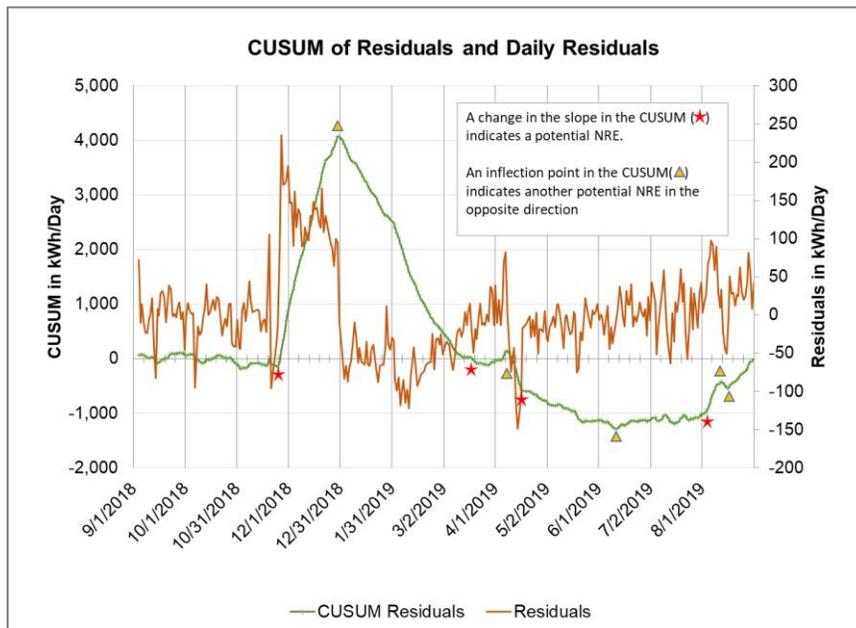
FIGURE 18: TIME SERIES OF DAILY RESIDUALS AND CUSUM OF RESIDUALS INDICATE SEVERAL POTENTIAL NRES

Note there are several changes in the slope of the CUSUM line. Initially, the CUSUM hovers around zero, as expected, but begins to rise at an even pace at the end of November through the end of December 2018, at which point energy use had increased by approximately 4,000 kWh. The CUSUM then trends steadily down, again reaching zero in mid-March; after a short stable period near zero, the CUSUM decreases from April to June (a decrease of ~ 1,200 kWh) when a series of potential NREs increases energy use back to the expected daily level. The frequency of the potential NREs shown by these residuals indicates there is likely a problem with the model, such as missing independent variables.

3.6.5   Identify Trends in Residuals

A significant slope in the residuals plotted over time can show long-term trends in energy use. Still, it can also show bias in the model due to seasonality or holidays, the inclusion of NREs at the beginning or end of the period, or as a result of a missing independent variable. In these cases, the model should be closely evaluated.

Possible causes of long-term trends in residuals include:

» **The model is missing a day-type variable.** Models with deficiencies, including unspecified day-types (e.g., holidays) or modes of operation (e.g., production type, can sometimes appear as trends. This is an important possibility that should be investigated.

» **The model is missing independent variables**. Potential additional independent variables should be considered and added to the model where appropriate (e.g., occupancy levels increased slowly over time due to company growth).

» **Weather patterns and seasonal extremes**. These can appear as trends in energy use (or model residuals), especially since most models use limited parameters for the weather[35].

» **Non-routine events**. NREs occurred during the baseline period, especially at the end or beginning of the period, which can appear as an overall trend. Ongoing performance improvements can also appear as an ongoing trend.

EXAMPLE 6: OMISSION OF HOLIDAYS IN MODEL APPEARS AS A LONG-TERM TREND

A baseline model for an office building that uses a year of data, starting in February and ending after the succeeding January, may show a trend if holidays are not treated separately from weekdays. Since most of the holidays are at the end of the baseline, the residuals may show a decrease in energy use over the baseline period. Accounting for holidays will result in a better model with lower uncertainty. However, assuming the reporting period(s) use the same holidays, the savings estimate should show little impact by incorporating holidays, even though the trend in residuals may be significant.

In an unbiased model, the average of the residuals is always zero. A trend may appear if the residuals are negative at the beginning of the model period and positive toward the end of the period, or vice versa. The end of a trend may be identified as a point when the values of the residuals hover above and below a new average value.

The example in Figure 18[36] indicates a significant trend that exists during the baseline period, with a 3.6% decrease in energy consumption. However, these are the same data previously presented in Figure 18, and the trend is caused by a series of potential NREs identified by the CUSUM of the residuals.

---

[35] Including weather metrics such as dewpoint in addition to temperature may improve models in hot and humid climates.

[36] Chart is from the Energy Charting and Metrics (ECAM) analysis tool which is available here.
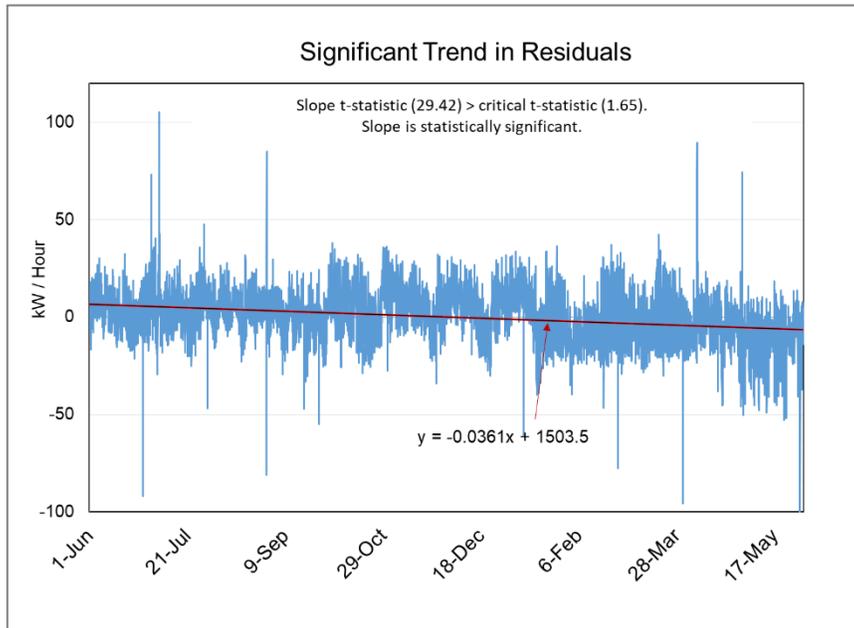
FIGURE 19: SIGNIFICANT TREND IN BASELINE PERIOD RESIDUALS IS DUE TO NREs IDENTIFIED IN FIGURE 18

To identify trends in residuals, create a linear regression of the residuals over the period and determine if the trend is significant. Select a confidence level and determine if the t-statistic for the slope of the trend line is greater than the critical t-statistic for the selected confidence interval (e.g., greater than 1.65 at 90% confidence). The t-statistic for the slope can be calculated from the regression analysis results, as shown in Equation 4.

EQUATION 4: T-STATISTIC FOR SLOPE OF TREND

$$T - statistic\ for\ Slope\ of\ Trend\ = (Slope)/\ (Standard\ Error\ of\ Slope)$$

EXAMPLE 7: OMISSION OF OCCUPANCY AS AN INDEPENDENT VARIABLE IN MODEL APPEARS AS A LONG-TERM TREND

Occupancy impacts may become significant over time. Occupancy variables such as the number of rooms occupied for a hotel or the percent of space leased for an office building can be important to include in the model as an independent variable rather than making NRAs. Since there can be daily changes in the number of rooms occupied for a hotel, it should be treated as an independent variable. Even when there is little change reported, e.g., near-constant 100% occupancy, including the detailed information as an independent variable (e.g., 0-100% of the conditioned area leased), the baseline model may be warranted to avoid NRAs from future changes. For any trend identified as significant by the t-statistic, the missing independent variable will likely also be significant.

3.7   NRE Approach #7 — Reporting Period Energy Savings are Higher or Lower than Expected.

Requirements:	▪ Expected energy savings, and ▪ Reporting period energy savings
Identifies:	▪ Reporting period energy savings not as expected

Reporting period energy savings results that are either higher or lower than initial project estimates can indicate an NRE occurred. However, the viability of this method depends on the accuracy of the originally estimated savings, which can vary widely.

If a potential NRE has occurred in the reporting period, the impacts on savings may not be immediately apparent since impacts from NREs will accrue over time. In some cases, the effects from NREs might be masked by the savings from the ECMs installed at the site and appear only as a reduction in calculated savings.

A time-series of the calculated hourly savings is shown in Figure 20. A period of negative savings occurred during April 2019, indicating the occurrence of a potential NRE.
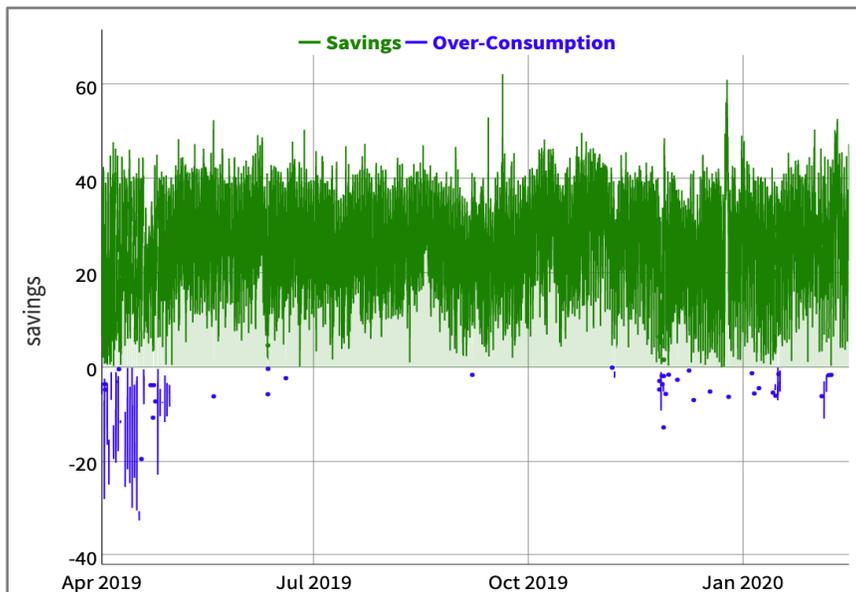
FIGURE 20: TIME-SERIES CHART SHOWING HOURLY kW SAVINGS WITH PERIOD OF NEGATIVE SAVINGS IN APRIL 2019

Realized and estimated savings may differ for multiple reasons besides an NRE either enhancing or obscuring the calculated savings, such as:

» Initial energy estimates based on flawed engineering assumptions,

» ECMs were not installed and commissioned correctly, or

» High level of uncertainty in the model(s), e.g., due to poor choice of the model form, missing variables, limited frequency or missing data, or unpredictable energy use.

With these alternate possibilities in mind, use additional methods to look for and validate the occurrence of a *potential NRE*.

4 MAKING NON-ROUTINE ADJUSTMENTS

This section covers key considerations for making non-routine adjustments (NRAs) using meter-based methods.

> *'Non-routine adjustments'* (NRAs) are defined in the IPMVP Core Concepts as individually engineered calculations to account for the energy effects due to changes in the Static Factors within the Measurement Boundary.
>
> To clarify, non-routine adjustments are made to energy data to compensate for changes not associated with the ECMs or due to expected changes in independent variables such as outdoor temperatures, which are accounted for by making routine adjustments.

NRAs modify <u>energy data</u> so that calculations continue to properly represent the savings from the targeted project. Although not explicitly shown in the IPMVP savings equations (see Appendix 2), NRAs are typically executed after routine adjustments have been made. In the case of avoided energy consumption, the NRA is determined by one of the recommended NRA methods and applied to the *adjusted baseline energy*. Similar modifications are made to data from model outputs for normalized energy savings or backcasting methods. Under some circumstances, NRAs are made directly to metered energy use, and the baseline or reporting period model is re-determined using the updated data.

Methods to determine impacts to savings are detailed in Section 5. However, the strategy selected to make an NRA will depend on the specifics of the situation, including:

> » The M&V option used for the project,
>
> » The need to report or value savings based on time of use,
>
> » The basis of adjustment used to determine savings (e.g., normalized energy savings),
>
> » Characteristics of the non-routine event (covered in Section 2), and
>
> » The NRA's contribution to savings uncertainty (covered in Section 7).

These project-specific considerations are discussed in this section below, except as noted above.

4.1 NRA Follows M&V Option for Project

In general, the original IPMVP M&V option (A, B, C, or D) used in a project is the preferred approach to make an NRA. If possible, the methods used to estimate an ECM's energy savings should be used to value an associated NRA and include similar measurement and calculation techniques. This ensures the NRA is consistent with the calculated savings, maintaining uniformity in the savings estimates.

EXAMPLE 8: NON-ROUTINE ADJUSTMENT FOLLOWS M&V OPTION FOR PROJECT

> If the savings estimates for a lighting upgrade are based on measured fixture power(s) and estimated run hours based on the facility's operating schedule, a non-routine adjustment due to a change in the number of fixtures installed should use the same calculation methodology. The NRA would use the estimated change in scheduled run hours and established fixture power(s), rather than use measured energy use from the lighting panels. This ensures the NRAs are in line with the reported energy savings for the project.

When using meter-based M&V methods, this means using metered or sub-metered energy data to define an NRA is preferred. This also avoids combining methods where the uncertainty in estimates is known (meter-based methods) with methods where the uncertainty is unknown. Maintaining consistency in the assessment of uncertainty in estimated savings increases confidence in savings estimates that include NRAs.

If a different approach such as engineering calculations (including IPMVP Option A) is used, which is not recommended, additional steps should be taken to ensure that appropriate levels of rigor are applied to site-level verification of the NRE and to the estimated energy impacts and that savings estimates are conservative.

> *Essential to adhering to IPMVP is following the key principles in M&V:* **Accurate, Complete, Conservative, Consistent, Relevant, and Transparent**.

4.2   Time of Use Savings

Since one of the key benefits of meter-based methods is accounting for time of use impacts from energy savings, the energy impacts from an NRA often need to be quantified in the same time interval as the model. This allows time-based energy savings to be reported and valued according to complex energy rate schedules, if required. (Hourly models are especially useful for assessing the time of use energy impacts.)

Maintaining granularity in NRAs can add complexity to some NRAs, but is needed if:

» The value of savings is based on time of use energy rates, or utility incentives require granular estimates of energy impacts;

» The baseline or reporting period energy data need to be updated after an NRA is applied so the regression-based energy model for the period can be re-determined, often appropriate after a permanent NRE; or

» Electrical peak demand savings (kW) are estimated in addition to energy consumption (kWh).

4.3   Basis for Adjustment Used

Another consideration when making an NRA is the basis for adjustment used in determining savings, either *avoided energy consumption*[37] or *normalized energy savings*, as defined in the IPMVP. The application of some of the NRA valuation methods presented is limited in calculating normalized energy savings.

In general, NRAs are applied in a similar manner as routine adjustments, as indicated in the simplified savings equations from the IPMVP Core Concepts in Appendix 2 (IPMVP Equations 3, 6, and 7). Avoided energy consumption is the simplest savings determination approach and is similarly the most straightforward to apply NRAs. In avoided energy consumption, shown in Equation 16, the *non-routine adjustments* are applied to the adjusted baseline energy, after making routine adjustments to reflect reporting period conditions. Hence the popular term "baseline adjustment." In normalized energy savings, however, an NRA is made to both the adjusted baseline energy and the adjusted reporting period energy, representing a standard set of conditions, as shown in Equation 18.

4.4   Timing & Duration of the NRE

Both the *project period* and *duration* of an NRE can affect the suitability of using some NRA methods. Specifically, baseline period energy data must be obtained from measured data, and the regression-based methods (NRA Methods #4 – 9) do not apply. Additionally, the methods in Section 5 are limited when calculating normalized energy savings.

Some general considerations regarding the timing and duration of an NRE follow.

4.4.1   NREs Occurring during Baseline Period

When addressing baseline period NREs, adhere to IPMVP's guidance to not use any <u>estimated</u> energy data in the baseline period. Because of this requirement, the NRA methods to address baseline period NREs are limited to Method #s 1 – 3.

> *IPMVP's M&V Issues and Examples document states*[38]*:*
>
> **Baseline data consists of real facts about energy and independent variables as they existed during the baseline period.** *Therefore, baseline data problems should not be replaced by modeled data, except when using Option D. Where baseline data are missing or inadequate, seek other real data to substitute, or change the baseline period so that it contains only real data.*

4.4.2   NREs Occurring during Implementation Period

Temporary NREs can be ignored if they end before the reporting period begins. If not, the start of the reporting period should be delayed until the NRE has ended.

---

[37] Avoided energy consumption is typically based on 'forecasting' a baseline model but also includes 'backcasting' a reporting period energy model.

[38] *Measurement and Verification Issues and Examples for IPMVP*, Energy Valuation Organization (EVO), 2019. See Section 4.13 - Data Collection Errors and Lost Data.

Permanent NREs are challenging since it is difficult to differentiate between impacts from the NRE and those from the targeted energy project. Similarly, NREs occurring early in the reporting period can obscure or inflate the impacts from the targeted project. In these cases, the preferred method would be energy sub-metering (NRA Method #2), if possible. Calibrated simulation (NRA Method #9) is a secondary option. If the cumulative impact from an NRE over time is small relative to the energy project engineering calculations (NRA Method #10) may be reasonable. If these options are not suitable, using an alternate or back-up M&V option should be considered.

4.4.3   NREs Occurring during Reporting Period

Temporary NREs can be relatively straightforward to evaluate, and most of the methods covered for making NRAs can apply. IPMVP allows reporting period energy data to be estimated, but limits are the same as when omitting data (NRA Method #1).

NREs occurring at the beginning or end of a project period prevents the period of the NRE from being bridged for analysis (for data interpolation) as recommended in IPMVP. This bridging of the NRE period is the basis of NRA Method #5 — Create an 'NRE Adjustment Model' below.

5 Methods to Make Non-Routine Adjustments

In meter-based M&V approaches, there are three general options for making non-routine adjustments (NRAs):

> » Omit the data from the non-routine event period in the performance period model,
>
> » Redefine the baseline model using new variables, or
>
> » Determine the impacts to project savings using metered data and apply an NRA to offset those impacts.

As discussed in Sections 3 and 4, the NRA methods presented do not apply to all situations. NRA methods' applicability is limited by the project period[39], duration of the NRE, and the basis of adjustment used to calculate savings (i.e., avoided energy consumption or normalized savings). The summary of NRA methods in Table 6 shows the applicability of each method based on these categories.

It is important to note that IPMVP adherent methods to address baseline period NREs are limited to NRA Methods # 1 – 3 (see Section 4.4.1). Similarly, NRA Method #10 does not typically adhere to IPMVP (see Section 5.10 below).

As with other M&V efforts, selecting an NRA method may require trade-offs between accuracy and level of effort (or costs). The NRA methods, in general order of preference, are to:

1. Omit data (NRA Method #1) or use sub-metered energy data (NRA Method #2),

2. Redefine the baseline model (NRA Method #3),

3. Use a regression-based method (NRA Methods #4 – 8)[40],

4. Use a calibrated building simulation model (NRA Method #9), or

5. Use engineering calculations (NRA Method #10) only if necessary.

In some circumstances, however, non-routine adjustments may not work, and changes to the M&V approach are required. Alternate methods to consider (Alternate Methods #1 – 3) are covered in Section 6.

Before making any adjustments, the reasons for the change in energy use must be validated, as discussed above in Section 2.3.

---

[39] As noted earlier, baseline energy data should <u>not</u> include estimates, and. This includes using NRA Methods #4 – 5, 9 and 10.

[40] These approaches generally follow the method referenced in IPMVP. See *IPMVP Issues and Examples* Section 4.13, which states "The M&V Plan should also establish a methodology by which missing or erroneous reporting period data will be re-created by interpolation for final analysis. In such cases, reporting period models are needed to interpolate between the measured data points so that savings can be calculated for each period." Additionally, tests indicate this method is effective at reducing savings uncertainty. See Touzani, S. et al., *Statistical Change Detection of Building Energy Consumption: Applications to Savings Estimation*, 2019.

TABLE 6: SUMMARY OF NRA METHODS AND ALTERNATE M&V APPROACHES BY APPLICABILITY TO PROJECT PERIOD, DURATION OF NRE, AND BASIS FOR ADJUSTMENT

#	Project Period / Duration of NRE / NRA Method	Baseline Temporary	Baseline Permanent	Implementation Temporary	Implementation Permanent	Reporting Temporary	Reporting Permanent	Avoided Energy Consumption	Normalized Energy Savings
1	Omit Data	X				X		X	X
2	Use Sub-Metered Energy Use	X	X		X	X	X	X	X
3	Redefine Baseline Model Using New Variables	X	X		X	X	X	X	X
4	Use Model Residuals from the NRE Period					X	X	X	X
5	Create an 'NRE Adjustment Model'					X		X	
6	Use 'Mini' Models					X	X	X	X
7	Develop a 'Pre-Post NRE' Model					X	X	X	X
8	Adjust for Significant Trends in Residuals						X	X	X
9	Use Calibrated Simulation	X	X		X	X	X	X	X
10	Use Engineering Calculations*		X		X	X	X	X	X
#	**Alternate M&V Approaches**								
1	Use Backcasting							X	
2	Apply Chaining							X	
3	Use a New M&V Option	X	X		X	X	X	X	X

*Methods are not adherent to IPMVP

5.1   NRA Method #1 — Omit Data

Omitting data from periods that do not reflect normal operations is a simple NRA that can be used in the baseline or reporting period, but only applies to temporary events. This approach is straight-forward and should be considered, but applications are limited and should be used with care.

Omitting data from the NRE period(s) can be an appropriate means to addressing an NRE, such as a short periodic demand-response event, or if power systems were offline for periods due to an emergency, such as a wildfire. Reasons for omitting data must be clearly documented.

Considerations for excluding data include:

» Gaps in reporting period energy data may be considered a period of no savings (e.g., avoided energy consumption), or data may be replaced with estimated values.

» The number of data points (%) omitted should be small relative to the data set (e.g., a <u>maximum</u> of 25% is recommended in ASHRAE Guideline 14[41]).

» Confirm the impacts on the coverage of independent variables and operating modes are limited[42]:

▪ Less than one-year of data can result in model bias from under- or over-represented operating scenarios;

▪ A complete range of independent variables in comparison to other project period or standard conditions (e.g., TMY data) is needed. (See related discussion in Section 3.4 - NRE Approach #4 — Analyze Data for Outliers.)

Given the above considerations, data should be omitted with care. If possible, use a different continuous 12-month period for the baseline period either before or after the period when the NRE occurred. Shorter time-frames (e.g., nine months) can be used to develop viable advanced M&V models in some cases, usually to accelerate the development of the reporting-period model and the reporting of normalized energy savings but can also be used to create a baseline energy model if necessary. When a baseline model is based on less than a year (or one full cycle) of data, backcasting may be considered when calculating avoided energy consumption.

If data are omitted, the energy model may be redetermined if needed, and savings are calculated as planned. If data are omitted or less than a year of data used, the rationale and details of the analyses should be reported[43] and documented as an NRA.

---

[41] *ASHRAE Guideline 14-2014 Measurement of Energy, Demand, and Water Savings*. Also see discussion on coverage factors in *Normalized Metered Energy Consumption Savings Procedures Manual*, 2017 by Southern California Edison <u>available here.</u>

[42] Koran, B. '*Potential Analytics for Non Routine Adjustments*' <u>found here</u>.

[43] As per ASHRAE Guideline 14-2014 Section 4.3.2.2, "Reasons shall be reported for data gaps, data elimination, or estimation of any actual measured data in the baseline or reporting periods."

5.2 NRA Method #2 — Use Sub-Metered Energy Use

Sub-metering energy consumption is a solid option to quantify some NRAs when using meter-based methods and should be used where viable. Advanced planning will reduce metering costs, and sites using meter-based M&V methods should be encouraged to sub-meter energy use of any loads that may change after a project's baseline period.

Energy metering may be appropriate if the NRE can be isolated and the change in energy use measured separately. This includes NREs related to equipment or systems whose energy use can be isolated and measured, such as updates to an exterior lighting system or the replacement of older mechanical equipment, as well as substantial site-level modifications.

EXAMPLE 9: ENERGY DATA FROM BOTH UTILITY METER AND SITE SUB-METER USED TO MAKE NRA

A small office building was added at a plastics manufacturing plant where a whole-facility M&V effort was underway for a recently completed process-related improvement. This addition increased electrical and natural gas use and chilled water loads at the main facility.

Since a new electric sub-meter from the utility was installed, the metered data will be utilized to make an NRA directly to the adjusted baseline energy; the increase in natural gas consumption is not relevant to the M&V effort. A sub-meter at the new facility meters the energy provided from the central plant to the new facility for space cooling, and time-of-use efficiency of the chiller plant is available from existing sub-meters to determine this portion of NRA. These meters effectively capture all of the energy impacts, and the totals can be applied to the adjusted baseline energy.

Site changes that are structural, such as a facility expansion, or those related to energy generation or energy storage, such as a new solar PV system, are also likely candidates for using directly metered energy data. These types of projects may include the installation of a new utility-grade meter, which is ideal. Third-party energy meters can also be utilized and should be selected to provide a high level of accuracy.

Sites using substantial long-term energy sub-metering may be able to directly pinpoint and effectively quantify decreases or increases in loads and run-times.

Sub-metered data should be collected at least as frequently as the energy data used in the savings analyses and should include the recording of likely independent variables. Using metered data for the duration of the reporting period will increase accuracy and may allow for metered energy to be directly applied as an NRA. For normalized savings, a regression model of the sub-metered energy use and independent variables can be developed to routinely adjust the NRA impacts as needed.

EXAMPLE 10: SUB-METER DATA USED IN NON-ROUTINE ADJUSTMENT

Midway into the first year of the reporting period, an industrial facility using whole-facility M&V for a comprehensive retrofit was required to install a new scrubber system in one area for regulatory compliance purposes. The system consisted of one 500-hp variable speed fan and one constant speed 10-hp pump. Since the system had limited interactive effects with other facility energy loads, a measurement boundary around the new equipment was possible.

Energy sub-metering equipment was installed, and 15-minute data were collected along with key operating parameters (% fan speed, pump flow rate), shown in Figure 21. The load was constant with an average fan motor load of 372.7 kW and the average pump motor load of 6.3 kW, totaling 379 kW.
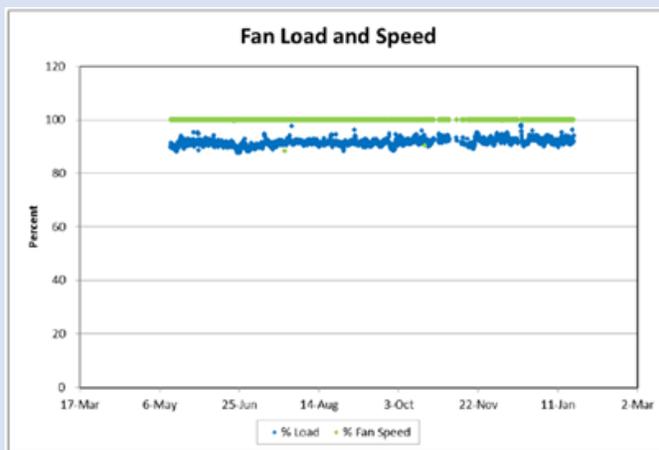
Figure 21: Sub-metered Fan Power and Speed for New System Data Used for Making NRA

It was agreed that the fan speed and pump flow rates would be checked quarterly for changes for the duration of the reporting period. The quantified energy use of the new equipment was added to the adjusted baseline energy as an NRA.

5.3   NRA Method # 3 — Redefine Baseline Model Using New Variables

Revising the baseline energy model by identifying and including additional significant independent variables is the most robust analytical NRA method. In some cases, it may help limit the need for future NRAs

Identifying all relevant independent variables to use in a baseline energy model is a critical step. If important variables or other details are suspected to be missing - either overlooked, identified as static factors, or operating conditions changed - the baseline energy model should be revisited.

This approach may be effective in scenarios such as:

» Permanent changes make a baseline model invalid;

» Additional independent variables are needed to explain reporting period energy use;

» The omission of significant operating modes (e.g., holidays) or other deficiencies are identified in the baseline model;

» Uncertainty in models is higher than desired and can be improved by adding one or more statistically relevant variables to the model(s).

In these cases, updates may be warranted to both baseline and reporting period models if applicable.

Redefining a model can include several possible modifications, such as:

» **Defining a new day-type.** A common model deficiency includes the omission of specific day-types (e.g., holidays) or modes of operation.

» **Change model form.** Improvements may relate to the amount of data included in a single model, the frequency of the data used, the number of changepoints assumed, or data relationships.

Potentially relevant variables[44] that may improve a model include:

» **Facility occupancy or load variables.** A metric such as the percent of facility that is occupied or leased, the number of occupants per day, number of classes per week may be needed to account for unexpected changes during the reporting period. This metric may not be flagged as a variable until occupancy changes occur during the reporting period, creating challenges in collecting adequate data.

» **Additional weather variables**. Regression-based models may possibly be improved by including other uncorrelated weather variables in addition to the dry-bulb temperature. In some cases, the dew point[45] might improve a temperature-based model of energy loads that are also affected by outdoor air humidity[46].

» **New production-related variable.** New variables may become important in the reporting period.

The goal is to include all significant independent variables that influence energy use. In addition to key variables such as weather, the model can be revised to include one or more additional variables that reflect the impacts related to any known NRE. These additional variables may describe occupancy levels, specific operating parameters, process loads, or another metric. Examples of site-specific metrics for static factors that may be evaluated for significance as independent variables are included in Appendix 1.

Any additional variable data used to redefine the baseline must be available throughout the project — from the start of the baseline period through the reporting period. This allows the new baseline model to be used to estimate savings consistently through the reporting period.

If data from a new significant variable only covers the reporting period, it can be utilized to make an NRA to the existing baseline instead. The new independent variable can be included in the 'mini' models, as appropriate, described in NRA Method #6.

---

[44] Model parameters require validation through statistical analyses. It is strongly recommended that a full year of data is used for additional independent variables beyond outside air temperature. Otherwise, it becomes very difficult to know that an adequate range of each operating condition is included or if bias may be present.

[45] Correlated variables such as dry-bulb temperature and wet-bulb temperature or relative humidity should not be used together.

[46] For example, air-conditioning loads in hot and humid climates can be significantly affected by the absolute humidity of outdoor air used for ventilation.

5.4   NRA Method #4 — Use Model Residuals from the NRE Period

Residuals from an energy model can provide a quantitative valuation of the energy impacts from temporary NREs. This method is simple to apply and can be accurate in certain applications. For temporary NREs, a sum of the residuals for the NRE period can be used to estimate the energy impacts.

Since the residuals directly reflect the energy impacts of an NRE, they can be used to establish regression-based relationships with appropriate independent variables such as a weather parameter. This allows the energy impacts to be estimated and applied to other time periods (e.g., standard weather conditions).

This approach may be preferred when addressing:

» Temporary NREs affecting less than 5 to 10% of data in a reporting period[47] model used to calculate normalized savings. The method is accurate if the NRE period is relatively short compared to the modeled period.[48]

» Temporary or permanent NREs during the reporting period when calculating avoided energy consumption (using a reporting period model for detecting NREs).

» This method does not apply if the NRE changes the relationship of energy use to weather or other independent variables (e.g., envelope upgrades or change in chiller staging)[49].

If a temporary NRE occurs during the baseline period, this method should not be used, and it is better to select another baseline period or omit the data from the NRE period.

5.4.1   Procedure

1. Identify the start and end dates of the NRE period(s).

2. Create a new reporting period model including the NRE period (generally with the same independent variables used in an earlier model but new coefficients) and ensure the NRE period affects less than 5 to 10% of data points used in the energy model.

3. Calculate the residuals for each interval during the NRE period. (Residuals are the differences between measured energy use and predicted energy use as shown in Equation 2.)

4. Evaluate the change in the residuals during the NRE. (See Section 3.6 - NRE Approach #6 — Analyze Residuals from the Model). Use regression analysis to establish statistically valid relationships with independent variables, if appropriate.

5. Determine the total value of the NRA. The sum of the residuals during the NRE period(s) corresponds to the total energy impact of the NRE. Note that this sum can be positive or negative. (It will be positive if the NRE causes increased energy use.)

---

[47] As noted earlier, baseline energy data should not include estimates.

[48] If the model includes the data from the NRE period this method will somewhat underestimate the impacts. Estimates will be biased by the length of the NRE relative to the overall model.

[49] NRA Method #7 — Use a 'Pre-Post NRE' Model should be considered in this situation.

6. Make the NRA. Update the adjusted baseline energy data to account for the impacts from the NRE by adding the residuals (they may be positive or negative) to the energy value for that data point.

Either:

   a. Calculate avoided energy consumption using the updated energy data that includes the NRA, or

   b. Redetermine the reporting period model to calculate normalized energy savings or keep the reporting period model accurate so NREs can continue to be detected.

7. Review the uncertainty in the estimated NRA to ensure the estimate is valid and should be used, as discussed in Section 7.

8. Document method, details, and results.

EXAMPLE 11: EXAMPLE NON-ROUTINE ADJUSTMENT USING NRA METHOD #4

A project using a daily model verified a non-routine event in the reporting period that appeared as a change in the value of the residuals. At the beginning of September, the residuals increased and remained above the expected rolling average of zero.

The change at the site was due to the addition of several booster fans in the return air system. The NRE was ongoing and indicated an increase across all day-types.
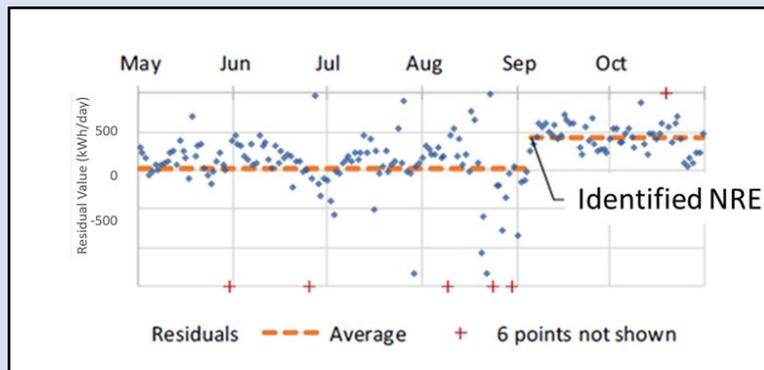
Figure 22: Times series chart of Daily Residuals Showing Step Change from NRE

A simple linear regression was used to determine the average daily energy impact from the site changes. The regression statistics on the model in Excel showed an RMSE of 20 kWh, but the residuals during the NRE had an average value of 480 kWh. This result was deemed valid since the resulting error relative to the impact at any given point is small at 4.2%[50]. (Note the coefficient of determination (R^2) was close to zero because the slope of the line is zero.) Based on these results, the increase in the model residuals (480 kWh) would be added to the adjusted baseline energy as an NRA beginning the first day of the NRE for the duration of the project.

---

[50] See additional uncertainty analysis procedures in Section 7.

5.5   NRA Method #5 — Create an 'NRE Adjustment Model'

This method omits the data during an NRE and then creates a model of energy use during the impacted project period (i.e., reporting period). This 'NRE Adjustment Model' is used to determine what the energy use would have been without the NRE, which is then compared to actual energy use to determine the NRA.

This method can be appropriate for:

» Temporary or permanent NREs, and

» NRAs, when calculating avoided energy consumption.

The process may leverage an existing model from the reporting period to create a new '*NRE Adjustment Model*' that uses all data from the affected project period (e.g., reporting period) <u>except</u> data from the NRE period. The model accuracy should be verified and then routinely adjusted using the independent variables recorded during the NRE period to predict what energy use would have been during the NRE period if the NRE had not occurred.

The value of the NRA is the difference in the energy use measured during the NRE period and energy use predicted by '*NRE Adjustment Model*'. The predicted energy use during the NRE is added to the adjusted baseline energy use (Note that this sum can be positive or negative — positive indicates energy use increases.) and avoided energy consumption can be determined. Models used for NRE detection should be re-determined after the energy data are updated.

For normalized energy savings, update the data to offset the impact from the NRE and then re-create the model before conducting routine adjustments. This step ensures the reporting period energy model continues to measure savings from targeted measures.

5.5.1   Procedure

1. Identify the start and end dates of the NRE period(s).

2. Gather data from the project period with the NRE, e.g., metered energy use, independent variables, and adjusted reporting period energy.

3. Ensure a range of independent variables during NRE are included in the range of variables covered during the non-NRE period.

4. Exclude the data from the NRE period. Create an 'NRE Adjustment Model' from the energy and independent variables using advanced modeling strategies.

5. Use independent variables from the NRE period in the new 'NRE Adjustment Model' to predict what the energy consumption would have been during the NRE period(s) if no NRE was present.

6. Determine the total value of the NRA. Compare metered energy use for the NRE period with the energy use estimated by the 'NRE Adjustment Model'. Calculate the value of the NRA using a time-series of energy impacts, if appropriate.

7. Make the NRA. Update the adjusted baseline energy data to account for the impacts of the NRE. This step creates an energy use time series without the NRE

8. Calculate avoided energy consumption using the updated energy data that includes the NRA, or redetermine the reporting period model. This is required for normalized energy savings and advised to keep reporting period models accurate, so NREs can continue to be detected.

9. Review the uncertainty in the estimated NRA to ensure the estimate is valid and should be used, as discussed in Section 7.

10. Document method, details, and results.

5.6   NRA Method #6 — Use 'Mini' Models

In this method, the 'mini' model(s) are created within the project's reporting period. A 'mini pre-NRE' represents the time period before the occurrence of the NRE and is used to forecast what the energy use would have been during the NRE period.

When calculating normalized energy savings, a 'mini NRE' model is developed from data when the NRE was present. The differences in these models are due to the impact of the NRE. This is the same general procedure used in meter-based M&V methods to determine energy savings.

This method is appropriate for:

» Temporary or permanent NREs affecting more than 15 to 20% of data in the reporting period (where Method #4 would not be appropriate, as noted above), and

» NRAs, when calculating avoided energy consumption or normalized energy savings.

The key limitation in applying this method is having adequate coverage of independent variables and operational modes during the 'mini' period(s). The range of coverage in the 'mini pre-NRE' model needs to be applicable to the NRE period to determine avoided energy consumption or to standard conditions (e.g., TMY weather) for normalized energy savings[51]. (If the range of variables during the NRE period is not covered, consider using NRA Method #7 — Use a 'Pre-Post NRE' Model.)

5.6.1   Procedure

1. Gather all energy and independent variable data from the project's reporting period and flag or separate the data into two data sets based on the presence of the NRE.

2. Evaluate the range of independent variables in both periods. If the coverage requirements described above are not met, do not proceed.

3. Create a regression model using advanced M&V methods with the data from the data set before the NRE period ('mini pre-NRE').

4. If calculating an NRA for normalized energy savings, create another regression model using advanced M&V methods with the data from the NRE period ('mini NRE').

5. Use the independent variable data during the NRE period in the 'mini pre-NRE' model to estimate the energy use without the NRE for the NRE period.

---

[51] Models made from durations of less than a year may include seasonal bias, as discussed in 5.1 - NRA Method #1 — Omit Data.

6. For avoided energy consumption:

    a. The NRA is the difference between the estimated energy and the actual energy during the NRE period.

    b. Make the NRA. Adjust the baseline energy model to reporting period conditions. Offset the adjusted baseline energy with time-based impacts (the NRA). The offset can be either positive or negative, depending on if the NRA increases or decreases savings.

    c. Calculate avoided energy consumption using reporting period conditions: (Adjusted Baseline Energy + NRA) – (Actual Reporting Period Energy).

7. For normalized energy savings:

    a. Adjust both the 'mini' models to standard conditions.

    b. The NRA is the difference between the adjusted 'mini pre-NRE' energy and adjusted 'mini NRE' energy.

    c. Make the NRA. Adjust the baseline model to normal conditions. Offset the resulting adjusted baseline energy using the time-based energy impacts from the NRE (the NRA).

    d. Calculate normalized energy savings using standard conditions: (Adjusted Baseline Energy) – (Adjusted 'mini pre-NRE' Energy).

8. Re-determine the model for the reporting period, if appropriate (which may alter the form and/or the model coefficients). This is required to report future normalized energy savings and is advised to keep reporting period models accurate if used for NRE detection.

9. Document method, details, and results.

5.7   NRA Method #7 — Use a 'Pre-Post NRE' Model

Creating a '*pre-post NRE model*' is appropriate for addressing all types of NREs but is preferred for NREs with large impacts relative to overall meter data. However, it is not as frequently used since it requires advanced statistical software or additional work in Excel[52].

This method should be considered when:

» **NRA Method #6 is not viable**. If the 'mini pre-NRE' or 'mini NRE' periods described above do not include the range of independent variables and operating conditions recorded during the NRE period, a pre-post model using all of the information from the affected project period data can be used.

» **NRA is for permanent NREs with large variable loads**. These types of NREs can invalidate existing models due to changes in the underlying relationships between temperature or other variables and whole-facility energy use. This approach captures any changes in interactions with independent variables due to the NRE.

---

[52] The analysis requires solving for coefficients in a model with a prescribed complex form.

> » **Need to calculate normalized savings**. These models[53] allow an NRA to be 'routinely adjusted' so the NRA can be applied to normalized energy savings.

Note: The approach outlined does not create a comprehensive pre-post model [54] , and it does not include the savings from the ECMs.

5.7.1 Procedure

A pre-post NRE model is applied similarly to the 'mini' models in NRA Method #6 — Use 'Mini' Models where the 'pre' is the time within the project period without the NRE, and the 'post' is the time when the NRE was present (it may be ongoing). NRA's value is estimated using the data from the entire project period that includes the NRE (e.g., reporting period).

The selected model needs to describe the energy consumption for the affected project, including the NRE and should include all relevant independent variables. A simple form of a *'pre-post NRE'* model is shown in Equation 5. [55]

EQUATION 5: 'PRE-POST NRE' EQUATION USING A SINGLE INDEPENDENT VARIABLE

$$kWh_i = [\beta_o + \beta_1(X_i)] + (NRE\_Flag_i) \times [\beta_2 + \beta_3(X_i)] + \epsilon_i$$

Where:
- kWh_i is the total energy used during time interval i
- NRE_Flag_i, is an indicator variable (equal to 1 in the NRE period and to 0 in the non-NRE period)
- β_o = Non-NRE constant
- β_1 = Non-NRE coefficient [to the Independent variable]
- X_i is the independent variable at time interval i (e.g., weather or production);
- β_2 is the change in the intercept (between Non-NRE period and NRE period);
- β_3 is the change in the slope [e.g., weather or production]
- ϵ_i is error term[56]

This example uses a simple linear relationship between energy use and one independent variable (e.g., *[$\beta_o + \beta_1(X_i)$]*)[57]. An indicator variable is used to identify the period that includes the NRE (note the form of the model is consistent during the NRE period (e.g., *[$\beta_2 + \beta_3(X_i)$]*)).

This type of model requires the coefficients in the model to be solved using regression analyses. The value of the NRA is determined by the second part of the equation (e.g., *(NRE_Flag_i) $\times$ [$\beta_2 + \beta_3(X_i)$].*

---

[53] Not all forms of pre-post models allow for normalization of independent variables such as weather.

[54] A comprehensive pre-post model combines the baseline through the reporting periods into one model and impacts from both NREs and ECMs are accounted for using additional indicator variables.

[55] Adapted from Uncertainty Guide for IPMVP, 2019.

[56] Error term should sum to zero using linear regression based on least ordinary squares.

[57] More complex equation forms are typical (e.g., a 6-paramter change-point model).

Once the model form is defined and coefficients determined, the NRA can be estimated for other conditions (e.g., routinely adjusted to TMY data for normalized energy savings), and the NRA may be applied to the adjusted baseline energy and the adjusted reporting period energy, as appropriate.

Variations include:

» The form of the model may be complex (e.g., 6-parameter change point model);

» The model form may be simplified if the NRE is a constant load, and an indicator variable[58] with a coefficient can represent the NRE;

» Additional independent variables may be included as needed.

Assess the uncertainty from the NRA as described in Section 7 to ensure results are valid. In a pre-post NRE model, the uncertainty in the NRA is the standard error (SE) of the indicator variable (NRE_Flag).

5.8   NRA Method #8 — Adjust for Significant Trends in Residuals

As discussed in Section 3.6, the most important use of trends in residuals is to help identify flaws in the model, including the inclusion of NREs. These flaws should be corrected if they impact the energy savings estimates or, if needed, to reduce uncertainty. An NRA based on trends should only be made if there are data available to support the basis of an ongoing trend or identified as the cause of the trend that could be included in the model.

If a trend is non-linear or is composed of multiple steps, again, the cause(s) should be sought so that the relevant independent variable can be identified and the model updated.

Long term trends in energy use during the baseline or reporting period may occur due to various reasons, but they may or may not be sustained. NRAs should only be considered for sustained trends in the baseline period that are expected to extend into the reporting period after the root cause has been confirmed to justify an NRA. The identified cause of the trend can be tracked to validate it is ongoing.

As noted earlier (Section 3.6.5), possible causes of long-term trends in residuals include:

» Model deficiencies such as not including holidays or accounting for other day-types,

» Missing independent variables (e.g., occupancy variable),

» Weather patterns and seasonal extremes, or

» Inclusion of non-routine events.

Since the residuals from an unbiased model will average zero, a shift in a model's residual values can indicate a step change that shows up as a long-term trend. If the end of a trend is identified as a point in time at which the values of the residuals hover above and below a new average value, the adjustment should not be applied

---

[58] Categorical or indicator variables, e.g., NRE_Flag$_i$, indicate that portion of the equation ($[\beta2 + \beta3(Xi)]$) only applies during the NRE period, and is otherwise zero.

as a trend but as a step-change. Step-wise changes in energy use can be addressed by combining this approach with another NRA Method (see Example 11 using Method #4).

EXAMPLE 12: NON-ROUTINE ADJUSTMENT FOR CHANGES IN RESIDUALS APPEARING AS A TREND

Assume the residuals for an hourly reporting-period model are -10 kW at the start of a baseline period. The residuals gradually increase, and nine months later, the residuals are about +6 kW. They vary randomly around +6 kW for the last three months of the baseline period, and it is clear that the trend ended after nine months. The model was underestimating the energy use at the end of the baseline by 6 kW.

After the site confirmed they had re-sheaved the HVAC ventilation fans, it was determined that the trend was actually a small step-change in energy use affecting all occupied hours. Therefore, the adjusted baseline energy values for the affected hours were increased by 6 kW before estimating the savings (note this is NRA Method #4).

5.8.1 Procedure

The first three steps were detailed previously in Section 3.6.5.

1. Establish confidence level and determine critical t-statistic.

2. Create a linear regression of the residuals over time in the period.

3. Evaluate if the trend is significant. A trend in energy use is significant if the t-statistic for the slope of the trend line is greater than the critical t-statistic for the selected confidence interval (e.g., greater than 1.282 at 80% confidence).

4. Re-estimate the trend during the first and second portions of the period to see if slope or significance changes, or to confirm the trend is consistent and ongoing. The lowest percent trend value observed should be selected to ensure the adjustment is conservative.

5. Re-evaluate the project period for potential NREs and review the baseline model for deficiencies.

6. Confirm the source of the trend. If possible, identify criteria to validate if the trend is ongoing during the reporting period. The adjustment can be applied to only a part of the reporting period if the cause of the trend ends.

7. If there is a confirmed basis to substantiate the estimated trend, re-evaluate the model with consideration of cause. Ideally, a baseline model that includes all relevant variables, both continuous and discrete (e.g., indicator variables), would be developed to explain the trend (NRA Method #3).

8. All parties involved in the M&V effort must agree upon how specific trends are handled. Possible outcomes include:
   - There is no real trend because no cause can be identified.
   - The trend ceases, and the rate of energy use at the end of the modeled baseline period will be used for estimating savings.
   - The trend will be ongoing in the reporting period.
   - The trend will continue in the reporting period, but only up to a specified increase or decrease in energy use.
   - The trend will continue in the reporting period, but only under explicit conditions or for a specified period.

9. In the case of the first two outcomes, an NRA would not be applied. Otherwise, to account for an ongoing ramp-up or ramp-down in energy use, modify the adjusted baseline energy by the rate of change of the estimated trend for the affected portion of the reporting period. The adjusted baseline period energy is ratcheted up or down by the change in the trend to compensate for the expected trend in the reporting period.

10. Review the uncertainty in the estimated NRA to ensure the estimate is valid and should be used, as discussed in Section 7.

11. Document method, details, and results.

5.9   NRA Method #9 — Use Calibrated Simulation

When using meter-based M&V methods, some NREs may require simulation modeling to estimate the impacts on savings. In this approach, the impacts of the NRE are determined using simulation models in a similar fashion as valuing an ECM. This method would also be adapted for projects using IPMVP Option D: Calibrated Simulation as the project's M&V method.

This method should be considered for:

» Permanent NREs when other recommended methods are not viable, and a high level of accuracy in the estimated non-routine adjustment is needed.

NREs occurring during the implementation period, where sub-metering does not exist or cannot help to quantify the NRE effects. Creating a calibrated energy simulation model can be more costly than other methods, often requiring more engineering time than other methods. The *NRA threshold criteria* and the initial estimated impacts on savings may need to be revisited to confirm the analysis required to make sure the adjustment will be within the M&V budget and available resources.

5.9.1   Procedure

1. Establish model calibration criteria based on allowable uncertainty in the estimate. See IPMVP Core Concepts Equation 16 and the discussion on savings uncertainty in Section 7 of this document.

2. Create a 'pre-NRE' simulation model of the facility before the occurrence of the NRE (within the same project period, e.g., reporting period).

3. Using relevant independent variables (e.g., local weather conditions for the period), calibrate the 'pre_NRE' model to the whole-facility energy use or the sub-metered energy use for the same time period.

4. Create an 'NRE' simulation model by updating the calibrated 'pre-NRE' model to include the changes related to the NRE (as if the NRE were an ECM).

5. Using local weather conditions for the NRE period, calibrate the NRE model to the whole-facility energy use or the sub-metered energy use for the same time period.

6. Update the pre-NRE energy model and NRE models with either reporting period or normalized conditions data, as appropriate for the basis of adjustment. The energy use profiles predicted by the simulations are the 'adjusted pre-NRE energy' and the 'adjusted NRE energy', respectfully.

7. Determine the value of the NRA. The difference between the adjusted simulation models will be the total impact of the non-routine adjustment:

$$\text{NRE\_Impact} \ = \ +/- \ (\text{adjusted pre} - \text{NRE energy} \ - \ \text{adjusted NRE energy})$$

12. If time-of-use reporting is needed, or a reporting period model is used for detecting NREs, use the granular energy impacts to modify the adjusted baseline energy use.

13. Review the uncertainty in the estimated NRA to ensure that the estimate is valid and should be used, as discussed in Section 7.

14. Document method, details, and results.

5.10   NRA Method #10 — Use Engineering Calculations

Engineering calculations are often considered the most straight-forward and cost-effective approach to quantifying an NRA. These types of adjustments may not be IPMVP adherent and should generally be avoided when using meter-based methods[59]. It is included herein, but the use of this method should be limited[60].

Engineering estimates may be appropriate when:

» **Permanent NREs occur during the implementation period or early in the reporting period**. The impacts of changes during these periods are difficult to discern from the targeted energy savings and may otherwise require sub-metering or calibrated simulation.

» **Estimating the interactive effects of an NRE**. Impacts from the NRE to other energy sources (e.g., heating penalty) are often estimated using engineering calculations.

» **Sub-metered data used for NRA require some modification.** Sub-metered energy data used to make NRAs can sometimes include or omit loads or require other refinements that need to be estimated using engineering calculations.7

» **Impacts from NREs are small when evaluated over the life of the project**. If the cumulative impact from an NRE over time is small relative to the energy savings, using engineering estimates may be reasonable.

» **Using a recommended 'NRA Method' is not feasible due to resource constraints.** M&V needs to be cost-effective relative to savings, which can require a trade-off with the accuracy of reported savings. When using meter-based methods, a sufficient budget should be allocated to address NRAs using recommended methods.

---

[59] Engineering estimates are useful for making an initial rough estimate of the impact from an NRE as discussed in Section 2.3.2.

[60] A recent review of SEP projects requiring an NRA indicated engineering calculations were used in only 25% of NRAs, and in all cases were used with sub-metered energy or system-level trend data. See Earni, S. *Non-Routine Adjustments - Towards Standardizing M&V Approach for Quantifying the Effects of Static Factors,* EEPC 2020.

Ideally, sites using meter-based M&V will sub-meter related energy data before and after any significant site changes, including implementing additional ECMs. Without sub-metering, it is best to wait until the energy impacts from an NRE can be observed and quantified using one of the other NRA Methods.

5.10.1 IPMVP Adherence

Often, engineering calculations used to make an NRA do not adhere to IPMVP requirements. These adjustments should meet the minimum level of rigor established for *IPMVP Option A – Retrofit Isolation with Partially Measured Parameters,* which includes field measurement of the key parameter(s), as well as confirmation that operational verification activities were conducted.

Additional specific IPMVP criteria discussed in Section 4 relates to the basic mechanics of making a non-routine adjustment. NRAs should modify the energy consumption data, not directly change calculated energy savings. For example, savings from additional ECMs that are accounted for by subtracting the anticipated energy savings from the savings determined through the meter-based M&V is not an IPMVP adherent NRA.

If estimates from engineering calculations are necessary, a profile of the expected impacts from the NRE over time[61] should be used instead of just an annual energy consumption value[62]. Although some NREs will affect energy consistently throughout the year and annual energy savings can be evenly parsed, the impacts from many types of changes vary seasonally[63].

An expected energy-saving profile can be used to make the NRA directly to the adjusted baseline energy consumption and to the adjusted reporting period energy for normalized savings if needed. If possible, the energy savings profile should be based on site-specific data and determined in the same increment as the data used in the whole-facility energy model so energy impacts to each time-period can be subtracted from (or added to) the adjusted baseline energy data.

Applying the NRA to the energy data ensures the estimated savings from the new ECMs are not greater than the total metered energy consumption[64]. Updating the energy data can also help maintain NRE detection capabilities and prevent energy savings from new ECMs from being identified as a potential NRE in the future if estimates are accurate[65].

Using engineering calculations is especially problematic for NRAs that are large relative to the project's savings due to the impact on overall savings uncertainty. Since consideration of uncertainty is required by IPMVP and often quantified when using meter-based methods, other approaches are preferred.

---

[61] This is similar to the 'expected CUSUM' chart discussed in NRE Approach #5 in Section 2.5.

[62] Savings profiles can require detailed analysis with a level of effort likely equivalent to or higher than applying a meter-based method.

[63] Lighting retrofits, for example, often include daylighting controls whose performance will vary with season. Accounting for time-of day variations may or may not be warranted.

[64] Poorly estimated energy savings can sometimes be vastly exaggerated, exceeding whole-building consumption.

[65] Parameters such as equipment run-times, electrical power factors, and equipment load factors can vary dramatically and have substantial impact on estimated energy use. Estimates can be improved by including sub-metered energy data and confirming assumptions using field measurements and trend data.

Significant discrepancies can arise when engineering estimates of energy use, including Option A approaches, are co-mingled with metered energy use. Assumptions commonly used in engineering calculations can sometimes cause significant inaccuracies in estimates. Parameters such as equipment run-times, electrical power factors, and equipment load factors can vary dramatically and have a substantial impact on estimated energy use. Estimates can be improved by including sub-metered energy data and confirming assumptions using field measurements and trend data.

When using engineering estimates, it is advisable to double-check the feasibility of results based on facility-specific factors such as transformer size and capability of the facility to use the amount of energy reflected in the adjusted baseline energy after the NRA is applied.

In addition to potentially increasing uncertainty in reported savings, applying inaccurate NRAs to the adjusted energy data may reduce the ability to detect future NREs.

EXAMPLE 13: ENGINEERING CALCULATIONS BASED ON FIELD MEASURED DATA USED IN NRA

An increase in the amount of air exhausted in specific sections of two industrial food processing machines was identified and completed by the O&M staff at a plant where a whole-facility M&V effort was underway for a recently completed process-related improvement. The two exhaust fans and motors were modified with new belts and sheaves to increase fan speed and exhaust air by approximately 10% based on a request from system operators.

This change was made by the O&M team without the knowledge of the energy team, and measurements of the baseline electrical power used by the fans were not made. The increase in exhaust fan electrical energy was estimated to be significant enough to warrant consideration. (The related increase in steam consumption was not a concern.) Since the M&V effort had been underway only a few weeks, engineering estimates were needed to offset the energy impacts from the fan modifications.

The technicians who modified the fan sheaves had measured and recorded details of the operating parameters on the units before and after the adjustments. Due to the medium-voltage power supply to the fan motors (>2k volts), the measurement of true electrical power was not feasible for cost and safety reasons.

Due to these limitations, engineering calculations based on the manufacture fan curve and data from the test and balance reports were constructed to estimate the change in fan motor energy. Power consumption was estimated using core engineering principles, field measurements, and assumptions related to efficiency shown in the equation below.

$kW = (BHP\_Fan)*(0.746)/(\eta\_belt*\eta\_motor)$

The recorded operating parameters included fan pressures, air flows, temperature, humidity, tachometer readings, and fan nameplate speeds (RPMs), as well as system-level amperage readings (from amperage gauge on the MCC instrumentation panel, which includes some other loads). The fan curve was used to determine the brake horsepower (BHP) for each fan before and after the change in sheave configurations.

The rotational speed of the two motors pre- and post-retrofit determined using a tachometer were not entirely conclusive, but along with the magnitude of the BHPs, confirmed the loads on the motors were above 60% in all cases, and the nameplate motor efficiencies of 94% should be accurate. The belt efficiencies were estimated at 97% (drives were regularly maintained and used cogged v-belts), and no variable frequency drives (VFDs) were used.
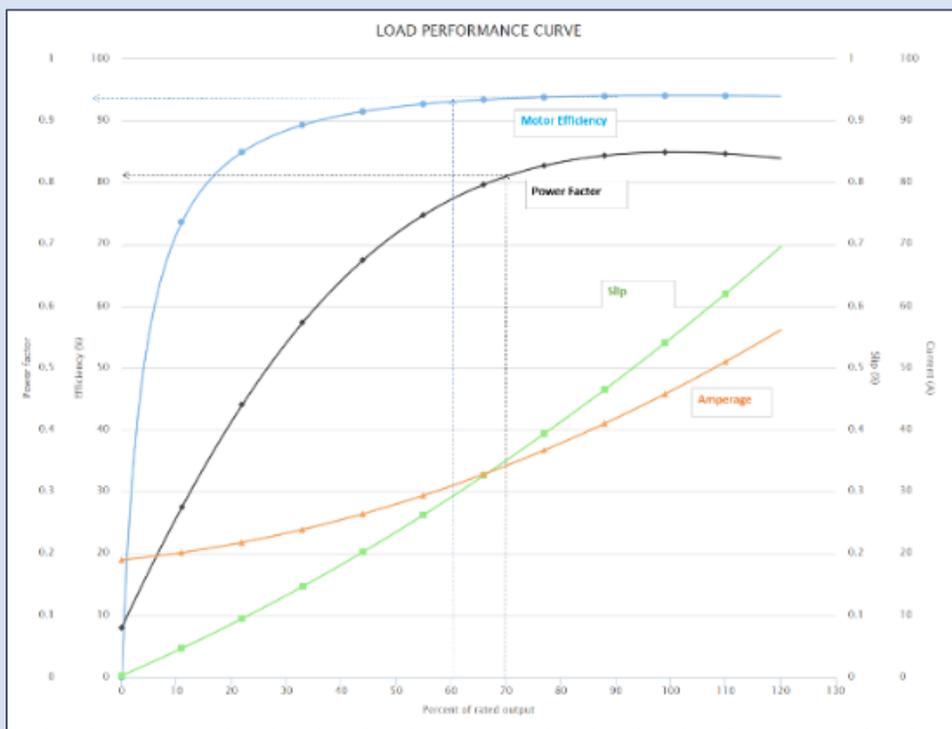
FIGURE 23: POWER FACTOR AND MOTOR EFFICIENCY VARY BY UNIT AND MOTOR LOAD

The increase in Exhaust Fan kW per affected time interval is then:

$\Delta kW = (\Delta BHP\_Fan) *.746 /(.97 * .94)$

$\Delta kW = (163 - 123)*.746/(.97*.94) =$ **32.7 kW (~33 kW per fan)**

Since both food processing machines (FP1 and FP2) operate during all plant hours, the adjustment should apply to December – April from 6:00 am – 6:00 pm, and May – November: 6:00 am – 8:00 pm, Mon-Sat, excluding Thanksgiving, Christmas, New Year's Day, Memorial Day, Independence Day and Labor Day. This NRA is estimated to affect 4,044 hours/year, a total of 266,904 kWh/year (5.0% of annual estimated savings), and $10,676/ year at $.04/kWh over the next year.

To double-check this estimate, the three-phase electrical power formula was applied. The recorded change in amperages measured at the MCC, which include other loads, was used along with an assumed constant voltage of 2,400 volts AC. Power factor values were estimated from the manufacturer's motor performance curve shown in Figure 23[66].

MCC Reading	Notes
44.2	FP1 Exhaust Fan Motor Pre MCC Amperage
54.2	FP1 Exhaust Fan Motor Post-Adjustment MCC Amperage
10.000	Δ amps
46.2	FP2 Exhaust Fan Motor Pre MCC Amperage
56.7	FP2 Exhaust Fan Motor Post-Adjustment MCC Amperage
10.5	Δ amps

The input power or kW for each motor = 1.732*Volts*Amps*PF/1000 and the estimated increase in each exhaust fan motor's input power or ΔkW = 1.732*Volts* ΔAmps*PF/1000.

The increase in FP1's exhaust fan's power = 1.732 * 2400 * (10.0) * 0.80/1000 = **33.2 kW (~33 kW).**

Similarly, the increase in FP2's exhaust fan power = 1.732 * 2400 * (10.5) * 0.80/1000 = **34.9 kW (~35 kW).**

The change in fan motor input power estimates from three-phase electrical power formulas compared well with those calculated from the fan performance curve data and indicated the previous estimate is reasonable and more conservative. Therefore, the NRA should be made by adding the total impact of **66 kW** to the adjusted baseline energy data for all hours subsequent to the retrofit when the equipment operates.

---

[66] More refined power estimates can be made by using precise amp readings and recording an input voltage reading from existing instrumentation from the MCC.

6 WHEN NON-ROUTINE ADJUSTMENTS DO NOT WORK: CHANGE THE M&V APPROACH

A planned meter-based M&V approach can prove ineffective, and a different strategy may become necessary (and is hopefully prescribed in the M&V plan). This section describes alternative meter-based M&V methods that can be considered if the recommended NRA methods in Section 5 are not feasible or do not apply.

Contract-based agreements require consensus on any change in the savings calculation approach outside of the M&V plan, and many project circumstances may not have flexibility. The effort required to conduct the M&V in the context of the savings may need to be reconsidered.

For meter-based methods, an alternate approach may be needed for several reasons, such as:

> » **The project results in less energy savings than expected, and the baseline model accuracy is not sufficient.** If savings are less than expected (e.g., all ECMs not installed), a lower fraction of whole-building savings will result, and savings may be fully or partially obscured by the error in the model.

> » **NREs occur during the implementation period.** Discerning the impacts of concurrent site changes from the targeted energy project is problematic when using meter-based M&V methods.

> » **Changes to the range of independent variables in the reporting period.** Key independent variable(s) can extend significantly beyond the baseline period coverage range, making the baseline and/or the reporting period model(s) invalid.

> » **Changes that cannot be managed by making non-routine adjustments (NRAs)**. This includes past NREs that cannot be validated or whose impacts cannot be estimated and NREs with ongoing impacts that are not predictable. (For example, a facility's new tenant changes the basic use from an office to light manufacturing fundamentally changed energy consumption patterns and rendered the baseline energy model invalid.)

Options for the M&V effort moving forward in these cases are limited. The use of the methods outlined below is not typical, and approaches adopted in these circumstances may not adhere to IPMVP requirements.

These alternate approaches include:

> » **Backcasting** when the reporting period model is superior to the baseline period model;

> » **Chaining** for baseline model(s) invalidated due to reporting period conditions, when a 'Pre-Post NRE' model is not feasible;

> » **Using a different IPMVP Option** if NREs are unmanageable, or savings are cannot be effectively detected in the energy model; and

> » **Redefining or canceling the project** if M&V efforts prove ineffective, and other alternatives cannot be developed.

These alternate approaches are discussed below.

6.1   Alternate Method #1 – Backcasting

Backcasting is a form of estimating *avoided energy consumption* that utilizes the baseline period as the basis of adjustment to determine savings. In this case, a reporting period model is created and routinely adjusted to baseline conditions. Savings are calculated as the difference between the measured baseline energy and the adjusted reporting period energy. For longer-term projects, a reporting period model would be developed each year.

This approach uses a regression model of the reporting period energy rather than one of the baseline period energy to calculate avoided energy consumption. It is not commonly specified since most projects using meter-based methods focus on having a robust energy baseline model.

Generally, backcasting applies if the reporting period model is significantly better than the baseline period model. Specific scenarios include:

» Reporting period energy has improved data granularity over the baseline period, such as when new interval meters are installed;

» Energy use in the reporting period is more predictable due to improvements in controls (e.g., after a retro-commissioning project);

» Energy savings are less than expected and cannot be fully discerned in the original baseline model;

» The range of independent variables in the reporting period includes baseline values but significant periods fall beyond the baseline model's coverage.

  ▪ Note this could also be addressed by limiting the range of independent variables in the reporting period (also called 'capping')[67]. For example, if production levels in the reporting period exceed baseline levels by 20%, a maximum allowable value may be set and used in place of any higher values.

Backcasting adheres to the IPMVP and is typically used as an alternate method to the planned meter-based approach. Since most projects initially plan to use the baseline energy model developed early in a project, backcasting is not specified in most meter-based M&V plans but may be a good contingency approach.

Backcasting is effective for determining avoided energy consumption but cannot be applied to normalized energy savings since only one model is used. IPMVP's equations for applying adjustments when backcasting are included in Appendix 2 (Equations 16 and 17).

6.1.1   Procedure

1. Create a regression-based energy model for the reporting period.

2. Routinely adjust the reporting period model to baseline conditions to determine adjusted reporting period energy use.

---

[67] This is a conservative and consistent approach, which follows IPMVP's principles.

3. Synchronize the adjusted energy data increments from the baseline and reporting periods to the smallest common interval. If necessary, fill any gaps in the baseline period energy data using estimated values from the original baseline period model. True-up these estimates as needed so that the period totals align with the metered monthly utility data, which may be an iterative process.

   o Replace no more than ~30 days across two utility billing periods[68]. (Also see project-specific M&V plan requirements for procedures on missing data.)

4. Calculate avoided energy consumption using IPMVP Equation 6 (EQUATION 15 in Appendix 2), or

   Avoided energy consumption = Baseline energy use – Reporting period energy use adjusted to baseline conditions

5. Evaluate savings uncertainty to ensure results are valid.

6.2 Alternate Method #2 – Chaining

Chaining applies IPMVP adherent methods (forecasting and backcasting) sequentially to estimate avoided energy consumption[69] and applies to projects that report savings for multiple years. Chaining may be needed when the conditions during a targeted year in the reporting period are out of the range of the independent variable(s) included in the baseline period (e.g., production rates).

When the independent variable(s) in a portion of the reporting period falls beyond the valid range of the baseline energy model, the model should not be used to forecast what the energy use would have been without the project. Similarly, a reporting period model based on a narrow range of independent variable(s) should not be routinely adjusted (backcast) to a broader set of baseline conditions.

Chaining relies upon an interim period that includes the full- range (or near full-range) of the independent variable(s) encountered in both the baseline and reporting period. This 'chaining period' is a portion of the reporting period before the targeted year, ideally comprised of one (or more) full years or periods. Using the data from this period, a regression-based model is created and used to 'chain' together the dissimilar project periods to determine the avoided energy consumption in the subsequent targeted period(s).

The chaining model is backcast (see Section 6.1) to baseline conditions to determine the avoided energy consumption during the interim or chaining period. The chaining model is then forecasted to the targeted reporting period's conditions, which determines the savings relative to the chaining period. The savings for the targeted period relative to the baseline are the total of the avoided energy from backcasting and forecasting periods.

---

[68] Adopted from *Simplified Processing Method for Meter Data Analyses, 2015* PNNL which was based on sub-metered energy use specifies no more than 45 days of data should be replaced. For utility meter day, using 30 days, which should span 2 utility billing periods, is more appropriate if using billing data.

[69] Chaining is IPMVP adherent if models are not used to predict energy beyond their valid range.

A manufacturing facility participating in a multi-year energy management program determines the avoided energy consumption each year using an energy model of the baseline period. Avoided energy consumption was reported for Year 1 as planned. During year two, the production rates rose steadily, and by the end of the year, they exceeded the maximum rate seen during the baseline by more than 10%. The Year 2 savings were calculated by limiting or 'capping' the production rate at the maximum valid rate for the affected period of six weeks, which was a consistent and conservative approach.

During Year 3, production rates remained at these higher levels, and the baseline model could not be applied. Rather than continue to cap the production rate (and savings), a reporting period model from Year 1 and 2 data were created. As illustrated in Figure 24, this model was backcast to baseline conditions to determine the average annual avoided energy consumption for the two-year interim period (Year 1 and Year 2) of 620,000 kWh/year. The model was then forecasted to Year 3 conditions. These results showed 140,000 kWh savings were achieved in Year 3 relative to the interim period, which was expected due to efficiency improvements.

The Year 3 avoided energy consumption relative to the baseline period is the total of the avoided energy savings calculated, or 620,000 kWh + 140,000 kWh or 760,000 kWh.
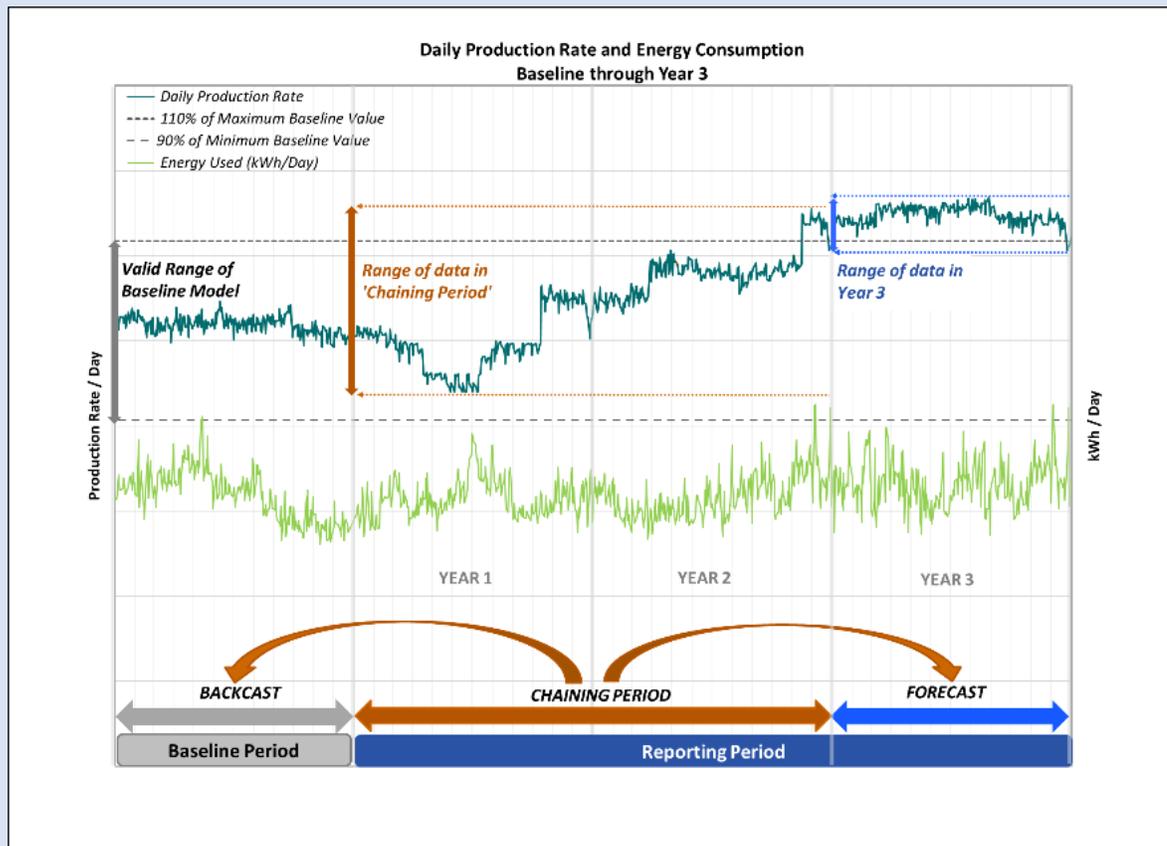
FIGURE 24: CHAINING USES AN INTERIM PERIOD MODEL TO "CHAIN" TOGETHER REPORTING PERIODS

6.2.1 Procedure

Chaining procedures[70] may vary depending on circumstances. The general approach determines annual savings for a period occurring at least one year into the reporting period.

1. Identify a chaining period that includes the full range of baseline and reporting period conditions during the reporting period (but not including the period of savings determination). The length of the chaining period should be based on a full cycle or year to avoid bias, if possible.

2. Evaluate the chaining period for potential non-routine events and address if needed.

3. Create a regression-based model of energy use and independent variables in the chaining period using advanced modeling strategies.

4. Routinely adjust the model to baseline period conditions (backcasting) to determine the avoided energy consumption during the chaining period. The results are the annual[71] avoided energy consumption in the chaining period.

5. For subsequent periods, annual avoided energy consumption can be determined by adjusting the chaining period model to the subsequent period's conditions (forecasting), which determines the savings relative to the chaining period. (A result of zero would indicate there has been no change in energy consumption (avoided energy consumption) relative to the chaining period.

6. Since avoided energy use for the forecasted period relative to the baseline is typically needed, the results from backcasting and forecasting are combined:

    $$\text{ANNUAL AVOIDED ENERGY CONSUMPTION} =$$
    $$(\text{AVOIDED ENERGY CONSUMPTION}_{\text{BACKCAST}} + \text{AVOIDED ENERGY CONSUMPTION}_{\text{FORECAST}})$$

7. Evaluate uncertainty in the results to ensure the results are valid.

6.3 Alternate Method #3 – Use a Different IPMVP Option

When a different M&V approach is needed, determine savings using a different (hopefully pre-planned) IPMVP Option.

As discussed in Section 2, designating a back-up M&V method in the project's M&V Plan is useful. It provides a path forward for determining project results in case NRAs are not viable or savings are too low to discern from the uncertainty in the model. Preparing for this potential outcome includes documenting sufficient details of the baseline conditions and installed ECMs to support an alternate M&V approach.

Projects that adhere to IPMVP methods will already include many of the specifics needed, including documented static factors, details on the installed ECMs, and data from the operational verification activities conducted. Extra details documenting the baseline conditions for a back-up method (e.g., Option A) may be

---

[70]*SEM Energy Modeling Method Selection Guide*, Northwest Strategic Energy Management Collaborative 6/14/2019 adapted the procedures outlined in *Superior Energy Performance (SEP) Measurement and Verification Protocol for Industry,* 11/19/2012.

[71]Assuming the baseline period is based on one year of data.

warranted. Some additional data collection during the baseline and implementation period can provide flexibility and lower project risk from unforeseen circumstances.

6.4   Redefine or Cancel Project

If any specific M&V effort proves ineffective, the project may need to be redefined or abandoned. In these circumstances, assigning value to any energy savings may or may not be appropriate.

Redefining a project can be effective if it is part of a long-term effort. A reporting period energy model can be developed, if needed, and used to verify stable energy performance and to track future energy changes[72].

EXAMPLE 15: CHANGE IN M&V APPROACH DUE TO NRE THAT INVALIDATES MODEL

> Due to a downturn in a business market, a steady decrease in the observed levels of production well outside the range of the baseline model were observed in reporting periods Year 2 and 3. The development of a new regression model was necessary. Engineering calculations based on Option A and end-use metering following Option B were used to quantify the completed energy-specific measures in Years 2 and 3 to date. Going forward, the continuous energy improvement program agreed to create a new baseline model and use it to evaluate avoided energy consumption from all future projects.

Unfortunately, some energy project efforts will not have a path forward and will be canceled. Contractual terms and conditions of individual projects will determine related financial details.

---

[72] This approach is sometimes referred to as re-baselining.

7 UNCERTAINTY ASSESSMENT FOR NON-ROUTINE ADJUSTMENTS

IPMVP requires consideration of uncertainty[73] in energy savings estimates, including non-routine adjustments (NRAs). This assessment is necessary to ensure that estimated NRAs are valid.

When evaluating the uncertainty for NRAs, ensure:

1) The estimated uncertainty in the NRA should be much less than the value of the NRA (i.e., relative uncertainty);

2) The NRA is valid (the range of possible NRA values does not include zero); and

3) The total uncertainty in the reported savings, after including the uncertainty in the NRA, is acceptable.

The uncertainty in NRAs estimated using meter-based M&V methods can be quantitatively assessed since the error in the regression-based energy model is propagated to the non-routine adjustment. (As noted in IPMVP Core Concepts, uncertainty from validated utility meter data is not typically included, but uncertainty in sub-metered energy data would be considered.)

When using regression energy models to estimate an NRA, the statistical prediction error of the model being used needs to be considered to ensure the estimated non-routine adjustment is valid. Although all NRAs are estimates, uncertainty analysis shows some are better than others. When an estimated NRA from a model is invalid, as shown in one example below, a different NRA method should be considered.

Unfortunately, accurately estimating the uncertainty of advanced M&V models is a challenging problem[74]. The approach included here is aligned to the industry's current standard practice and key industry guidelines (IPMVP and ASHRAE Guideline 14). The uncertainty in the results is underestimated even after correction factors are applied due to the autocorrelation[75] of the residuals. This is an issue with meter-based M&V methods using frequent (e.g., hourly, daily) energy data.

> *Correction factors will improve results, but the uncertainty in models using hourly or daily data are underestimated, even after an auto-correlation correction factor is applied[76].*

Since the model errors are *higher* than calculations indicate, evaluations need to be very conservative. Because autocorrelation effectively overstates the confidence level in results, one approach to ensure

---

[73] For more information see IPMVP Core Concepts, 2016 and Uncertainty Assessment for IPMVP, 2019.

[74] This is an area of active industry research.

[75] Autocorrelation, also known as serial correlation, is of the residuals is when the value and sign of a residual is correlated with the value and sign of the prior residual.

[76] This is because the common correction factors are designed for lag-1 autocorrelation, where a residual is correlated with the prior residual, but not with residuals two or more time-intervals earlier. Models built on higher frequency data often have higher lag order autocorrelation (i.e., autocorrelation with residuals from many earlier time intervals).

estimates are conservative may be to use a higher confidence interval than otherwise might be specified, such as 90% instead of 50%[77].

The procedures that follow will apply if an NRA is estimated using a linear regression-based model[78], including NRA Methods #4 through #8. Regardless of the method used, this type of uncertainty assessment should be made before making an NRA.

The method in this section represents a simplified method based on ASHRAE Guideline 14 that is less accurate than other methods but is easy to apply. The analysis approach described is appropriate for linear regression models, including piecewise linear models such as change-point and temperature and time-of-week models, but may not apply to other methods. The simplified analysis method includes:

» Step 1: Evaluate absolute uncertainty in the non-routine adjustment;

» Step 2: Determine total uncertainty in the savings;

» Step 3: Decide if the estimated NRA should be applied.

These steps are detailed in the following sections.

7.1   Step 1: Evaluate Absolute Uncertainty in the NRA

Non-routine adjustments determined by regression models typically use a model to determine what the energy consumption would have been without the NRE. For the uncertainty analyses below, this is considered the 'baseline period', and the NRE period is the 'post-period'.

For linear and piecewise linear models (including change-point and temperature and time-of-week models), the root mean square error (RMSE[79]) of the model can typically be used for this assessment. The RMSE measures the average magnitude of the error in each prediction and is equivalent to Standard Error (SE) if adjusted for degrees of freedom[80], which is typical in analysis tools such as Excel.

7.1.1   Adjust the RMSE for Autocorrelation[81]

A. Determine the autocorrelation coefficient (ρ) for the lag-1 residuals (values range between -1 and 1) of the model. This is often given in the model's statistical summary, or it can be calculated directly from the model's residuals[82].

B. Calculate the appropriate autocorrelation correction factor (f) using Equation 6 or Figure 25.

---

[77] This has impact of increasing t-statistic used in the uncertainty assessment procedures.

[78] The analysis approach described is appropriate for linear regression models, including piecewise linear models, but may not be applicable to other regression methods.

[79] The RMSE is equivalent to equivalent to one standard deviation of the residuals.

[80] Degrees of freedom = n − p, where n is number of data points and p is the number of parameters included.

[81] NW SEM Collaborative's *Tools and Methods for Addressing Autocorrelation in Energy Mode*ling, October 2013.

[82] ρ is the lag-1 autocorrelation coefficient of the model residuals (ρ) can be determined in Excel using the 'CORREL' function to compare the residuals to those from the next time increment.

EQUATION 6: AUTOCORRELATION CORRECTION FACTOR (F)

$$f = \sqrt{\left(\frac{(1+\rho)}{(1-\rho)}\right)}$$
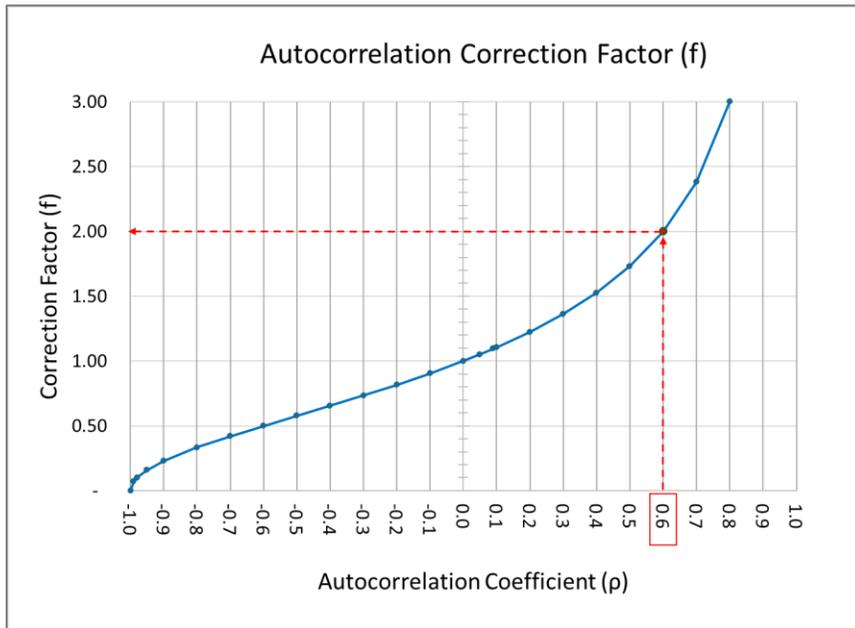
FIGURE 25: AUTOCORRELATION COEFFICIENT (P) AND CORRESPONDING CORRECTION FACTOR (F) FOR RMSE

C. Calculate the 'Adjusted RMSE' by multiplying the RMSE of the model by the autocorrelation correction factor (f) determined previously.

EQUATION 7: ADJUSTED RSME ACCOUNTING FOR AUTOCORRELATION[83]

$$\text{Adjusted RMSE} = f \times \text{RMSE}$$

7.1.2   Calculate the Total Error in the Estimated NRA

Calculate the total of the cumulative errors in the estimated NRA[84]. First, determine the cumulative standard error of the model using Equation 8 and the cumulative standard error of the noise using Equation 9. In this

---

[83] This approach applies the autocorrelation correction to the standard error of the individual point, which gives a corrected standard error for an individual point prediction.

[84] For details see Koran, Boyer, Khawaja, Rushton, Stewart: *A Comparison of Approaches to Estimating the Time-Aggregated Uncertainty of Savings Estimated from Meter Data*, IEPEC 2017. Note that model and noise uncertainty aggregate differently. The model uncertainty aggregates directly with m_post whereas the noise uncertainty aggregates with the square root of m_post.

case, the 'baseline' is the period used to model what the energy consumption would have been without the NRE, and the 'post' is the NRE period.

Cumulative standard error (RMSE) of the model
$= \text{Adjusted\_RMSE} * m_{post}/\sqrt{(m\_baseline)}$

Cumulative error of model noise $= \text{Adjusted\_RMSE} \times \sqrt{m\_post}$

Where:
- Adjusted RMSE = RMSE from the baseline model adjusted for autocorrelation
- m_baseline = number of points used in the baseline model
- m_post = the number of data points in the non-routine event period

Combine these errors in quadrature, as shown in Equation 10.

A. Select a confidence interval (e.g., 80%) to evaluate the uncertainty in the estimated NRA. Lookup the critical t-statistic for the specified confidence level from a reference guide. Some critical t-statistics appropriate for hourly or daily data (i.e., degrees of freedom>120) are shown in Table 7.

TABLE 7: CRITICAL t-STATISTICS FOR MODELS WITH DEGREES OF FREEDOM > 120

Confidence Interval	50%	68%	80%	90%	95%
Critical t-statistic	0.674	1.000	1.282	1.645	1.960

B. Determine the range of error at the selected confidence interval by multiplying the total error by the appropriate t-statistic (e.g., 1.28). Note the results are '+/-', which provides a range of expected errors.

EQUATION 10: TOTAL UNCERTAINTY IN THE NON-ROUTINE ADJUSTMENT

$$\text{Total Error in NRA} = \pm\, t - \text{statisitic} \times$$
$$\sqrt{(\text{Cumulative standard error of the model})^2 + (\text{Cumulative error of model noise})^2}$$

EXAMPLE 16: TOTAL ERROR (UNCERTAINTY) IN NON-ROUTINE ADJUSTMENT

Residuals from an annual hourly model (8760 hours) during a non-routine event in the baseline period averaged 50 kW for 100 hours. The RMSE of the hourly regression model is +/- 15 kW, and the correlation coefficient of the lag-1 residuals is 0.4. Determine the range of absolute uncertainty in the NRA at an 80% confidence level.

First, adjust the RMSE for autocorrelation. Using the autocorrelation coefficient, the correction factor f is 1.528, so the Adjusted RMSE is 15*1.528 or +/- 23 kW.

Next, estimate the total error in the NRA. In this case, m_baseline is 8,760, and m_post is 100. Where: m_baseline = number of points used in the baseline model, and m_post = the number of data points in the NRE period.

Using Equation 8, the cumulative standard error in the NRA is 24.5;

Using Equation 9, the cumulative error from model noise in the NRA is 229.1;

Using the selected confidence interval of 80%, the critical t-statistic is 1.28.

Using Equation 10, the total Uncertainty in NRA

= +/- 1.28 * [(24.5)^2 + (229.1)^2]$^{0.5}$ = +/- 295 (round to 300).

Based on the residuals, the estimated impact of the NRA is 50 kW * 100 hours = 5,000 kWh. Therefore, the NRE increased energy consumption by 5,000 kWh +/- 300 kWh, and the relative uncertainty in the NRA is 300/5,000 or 6%. We are therefore 80% confident the actual value of the non-routine adjustment falls between 4,700 kWh and 5,300 kWh.

7.1.3   Evaluate the Estimated Non-Routine Adjustment for Validity

When the level of uncertainty is high in an estimated NRA, the estimate may be invalid[85]. This is evident when the range of possible values for the NRA includes zero. An estimate may also be unacceptable if the uncertainty relative to the value of the NRA is high. This metric is called relative uncertainty or fractional savings uncertainty.

Evaluate the estimated non-routine adjustment for validity based on the level of uncertainty estimated. If the average change in residual values during the NRE is less than or equal to the adjusted RMSE at a specific confidence interval, the results will be inconclusive by including zero in the range of possible values.

---

[85] ASHRAE Guideline 14 suggests the level of uncertainty should be less than 50% at a 68% confidence interval.

Consider the example above, but the RMSE is +/- 40 kW (instead of 15), and the average value of the residuals during the NRE was 5 kW (instead of 50).

First, adjust the RMSE for autocorrelation. Using the autocorrelation coefficient, the correction factor f is 1.53, so the Adjusted RMSE is 40*1.53 or +/- 61.1 kW.

Using Equation 8, the cumulative standard error in the NRA is 65.3; Using Equation 9, the cumulative error from model noise in NRA is 611.0; Using the selected confidence interval of 80%, the critical t-statistic is 1.28.

Using Equation 10, the total Uncertainty in NRA

$= +/- 1.28 * [(65.3)^2 + (611.0)^2]^{0.5}$

= +/- 786.5 (round to +/- 790).

The estimated value of the NRA is 5 kW * 100 hours = 500 kWh

Therefore, the NRE increased energy consumption by 500 kWh +/- 790 kWh, and therefore falls between (-290 kWh and 1,290kWh. The relative uncertainty in the NRA is 790/500 or 158%.

This example resulted in an invalid estimate since the range of possible values for the NRA (-290 kWh to 1,290 kWh) includes zero.

7.2 Step 2: Determine Total Uncertainty in the Savings

The absolute error in the non-routine adjustment can be combined with the standard error in the original model(s) to determine total uncertainty in the reported savings. Estimated uncertainties that are unrelated combine in quadrature,[86] as shown in Equation 11.

EQUATION 11: TOTAL SAVINGS UNCERTAINTY FOR UNRELATED ELEMENTS COMBINED IN QUADRATURE, INCLUDING CONTRIBUTION FROM NON-ROUTINE ADJUSTMENT

$$\text{Error in Savings} = \sqrt{(\text{SE\_adjusted baseline})^2 + (\text{SE\_adjusted reporting period})^2 + (\text{Total Error in NRA})^2}$$

---

[86] ''Quadrature' is short for the square root of the sum of the errors squared. For more information see Uncertainty Assessment for IPMVP, July 2019.

EXAMPLE 18: TOTAL SAVINGS UNCERTAINTY WITH NRA FROM SUB-METERED DATA

> Avoided energy consumption was determined to be 50,000 kWh +/- 5,000 kWh, but a non-routine adjustment is calculated from sub-metered data that lowers the baseline energy use by 4,000 kWh +/- 500 kWh.
>
> The standard error in the savings includes those from the baseline model and from the non-routine adjustment, which are unrelated, and there is no reporting period model. Using Equation 11, at 80 % confidence, the
>
> Avoided Energy Consumption = $(50,000 \text{ kWh} - 4,000 \text{ kWh}) \pm 1.28 * \{(5,000)^2 + (500)^2\}^{0.5}$
> $\qquad\qquad\qquad = 46,000 \pm 6,432 \text{ (round to 6,400)}$
>
> The absolute uncertainty in the savings is 6,400 kWh, and we are 80% confident savings are between 39,600 and 52,400 kWh. The relative uncertainty is 6,400/46,000 kWh or 14%.

However, when using regression models to determine the NRA, the model uncertainty and the NRA uncertainty may not be independent (e.g., the same or very similar model and just a slightly different time period of data from the same facility and project period are used for the model and the NRA.) In those cases, quadrature should not be used; instead, the uncertainties would just be added together, as shown in Equation 12[87].

EQUATION 12: TOTAL SAVINGS UNCERTAINTY FOR RELATED ELEMENTS, INCLUDING CONTRIBUTION FROM NON-ROUTINE ADJUSTMENT

$$\text{Error in Savings} = (\text{Total Error in NRA}) + \sqrt{(\text{SE\_adjusted baseline})^2 + (\text{SE\_adjusted reporting period})^2}$$

---

[87] See JCGM 100:2008(E), Joint Commission for Guides in Metrology, _Evaluation of measurement data — Guide to the expression of uncertainty in measurement_, Section 5.2, Correlated Input Quantities: "For the very special case where all of the input estimates are correlated with correlation coefficients $r(x_i, x_j) = +1$ the combined standard uncertainty $u_c(y)$ is thus simply a linear sum of terms representing the variation of the output estimate y generated by the standard uncertainty of each input estimate xi."

Also see Reddy, T. A., J. K. Kissock, and D.K. Ruch, Feb. 1999. "Prediction Uncertainty of Linear building Energy Use Models with Autocorrelated Residuals" Journal of Solar Energy Engineering: "A common but incorrect practice for computing prediction error bounds of the sum of daily predictions is to sum in quadrature the prediction error bounds of the daily predictions…This amounts to assuming that the daily prediction errors are independent… However, this is not generally the case because all of the daily predictions of energy use are based on the same estimated regression coefficients and are therefore correlated. Consequently, summing in quadrature will underestimate the correct prediction error bound."

EXAMPLE 19: TOTAL UNCERTAINTY FROM RELATED ELEMENTS

Example 16 above determined the NRA increased baseline energy by 5,000 kWh +/- 300 kWh based on residual analysis of the baseline model (RMSE = 15 kW). If avoided energy consumption after 6,500 hours is 72,500 kWh, calculate the range of total savings and savings uncertainty at 80% confidence.

First, determine the uncertainty in avoided energy consumption, then calculate the total uncertainty in savings after making the NRA:

Using a confidence interval of 80%, the *critical t-statistic* is 1.28.

In this case, *m_baseline* is 8,760, and *m_post* is 6,500.

Using Equation 8, the cumulative standard error in the avoided energy is 1,591;

Using Equation 9, cumulative error from model noise in the avoided energy is 1,847;

Since the errors are residuals and the model, use Equation 12 for related elements. The combined uncertainty is = +/- 1.28 *{[(1,591) ^{2} + (1,847)^2]$^{0.5}$ } = +/- 3,121 (round to 3,100).

Therefore, savings after making NRA = (72,500 – 5,000) +/- (Total Uncertainty).

Then determine the total uncertainty in the savings, including the NRA, use Equation 12 since the uncertainties in the NRA and the model are related. The total error in savings or absolute uncertainty is 300 + (3,100^2)$^{0.5}$ = ± 3,400 kWh.

Savings with the NRA = 67,500 ± 3,400 kWh. Savings are between 64,100 and 70,900 kWh with a relative savings uncertainty of 3,400/67,500 or 5%.

7.3   Step 3: Decide If Estimated NRA Should Be Applied

A non-routine adjustment may be applied after an analysis of the impacts from uncertainty if:

» Estimated NRA is valid, and

» The total uncertainty in the reported savings, including the NRA, is acceptable.

Consideration of uncertainty[88] in energy savings estimates is required by IPMVP, which includes non-routine adjustments. This assessment is necessary to ensure that estimated non-routine adjustments are valid.

When evaluating the uncertainty for NRAs:

» The estimated uncertainty in the non-routine adjustment should be much less than the value of the NRA (ensuring the range of possible NRA values does not include zero); and

» The total uncertainty in the reported savings, after including the uncertainty in the non-routine adjustment, should be considered.

A non-routine adjustment that results in unacceptable uncertainty levels should not be made.

---

[88] For more information see Efficiency Value Organization's (EVO's) Uncertainty Assessment for IPMVP, 2019.

8 NON-ROUTINE ADJUSTMENTS FOR PROJECTS USING OTHER M&V OPTIONS

This section covers non-routine adjustments (NRAs) for M&V approaches using IPMVP Options A, B, or D.

For all M&V Options, unexpected site changes can affect the accuracy of energy savings calculated, and circumstances may arise that warrant a non-routine adjustment (discussed in Section 2.1.3).

All static factors that could affect the energy use within the ECM's measurement boundary need to be identified and documented in the baseline period and tracked through the reporting period. Since retrofit isolation projects using Options A & B are focused on equipment-level performance, they will have fewer key static factors than those projects using whole building Options C & D (discussed in Section 2.1.5).

Retrofit isolation methods must consider the factors that influence the energy use of the equipment related to the specific ECMs. For simple measures, such as a motor efficiency upgrade for a constant speed hot water pump, the annual run-hours of the boiler plant may be the only static factor that is relevant so that the project would track the facility's scheduled operating times.

Savings estimates for retrofit isolation M&V approaches focus on the performance of specific equipment, so savings may be unaffected by some site changes (e.g., a heating hot-water pumping system using retrofit isolation Option B is unchanged by a chiller plant efficiency upgrade). In many cases, NRAs are limited in the M&V plan (e.g., calculated energy savings for a motor retrofit using Option A with estimated run-hours) may not allow for NRAs due to changes in operating schedules, depending on contract requirements. Methods measuring the ongoing energy use of equipment (Option B) are more likely to be affected by site-level changes that require making an NRA.

As discussed in Section 4, the strategy used to make an NRA will depend on the specifics of the situation, including:

> » Characteristics of the NRE,
>
> » M&V option used, and
>
> » The basis of adjustment used to calculate savings (e.g., avoided energy consumption).

8.1 Retrofit Isolation Approaches (IPMVP Options A & B)

The need for NRAs when using retrofit isolation methods (IPMVP Options A & B) varies by project. These M&V approaches apply to equipment or system-level ECMs. NRAs may be needed when:

1. Site changes affect the performance of the ECM (e.g., for an ECM based on installing VFDs to modulate motor speeds, and VFDs were manually taken off-line).

2. Site changes did not affect the performance of the ECM but did affect the accuracy of the calculated savings (e.g., for a lighting retrofit using measured fixture Watts and estimated run-hours (Option A), a change in occupancy schedules resulted in increased lighting run-hours.

8.1.1 Option A – Retrofit Isolation with Key Parameter Measurement

ECMs using Option A methods do not typically require NRAs, but that depends upon the M&V plan. In IPMVP under Option A, there may be no need for adjustments, routine or non-routine, depending upon the location of the measurement boundary, the nature of any estimated values, the length of the reporting period, or the amount of time between baseline measurements and reporting period measurements.

Option A methods are typically selected to reduce costs or allocate project risks, and contracts may not allow for NRAs. In this method, measured and estimated values are used in the savings calculations, with changes in the 'key parameter' being measured.

Option A is typically applied to lesser value projects or lower risk projects where there is limited uncertainty in key variables (e.g., fixture wattages). The costs of making NRAs may not be warranted depending on the magnitude of individual project savings. When an NRA is required, the original engineering calculations and related measurements should be updated. The change in energy should be determined using the original M&V approach and may leverage the project's original measurements if those parameters are unaffected.

8.1.2 Option B – Retrofit Isolation with All-Parameter Measurement

Option B methods use equipment-level energy measurements and may employ routine adjustments similar to Option C methods that use whole-facility or system-level energy data and independent variables. ECMs using Option B may require NRAs for savings calculations to remain accurate. In general, the strategies to make NRAs described for meter-based methods can be applied to Option B.

In the simplest case, an ECM's baseline energy use may be relatively constant, and the reporting period energy use is variable, such as when installing a VFD on a constant speed motor. In this case, an NRE affecting the reporting period motor energy use would require the baseline energy use to be adjusted to compensate for the change in calculated energy savings. In this case, there are several options for making an NRA:

» Use sub-metered energy data of the affected motor (NRA Method #2),

» Establish regression models of the reporting period energy consumption before the NRE and after the NRE (NRA Method #5),

» Develop a model using an indicator variable for the NRE (NRA Method #7), or

» Create simulation models to estimate impacts (NRA Method #9).

8.2 Option D – Calibrated Simulation Approaches

M&V efforts based on calibrated simulation models (Option D) often use whole-facility energy consumption, and similar to Option C methods can require NRAs to account for changes unrelated to the ECMs being measured. Similarly, all of the NRE detection methods described in Section 5 can be used. If an NRA is required, NRA Methods #1 and #9 can be adapted or applied as needed.

Calibrated simulation software uses complex physics-based models of a facility's structure, equipment, and operating conditions to estimate hourly energy-use at both system and whole-facility levels. These energy models are "calibrated" when their predictions closely match the actual site conditions and energy used through adjustment of the model variables to actual conditions.

As in Option C methods, the simulation model is updated with actual data on independent variables such as weather (i.e., routinely adjusted). Statistical criteria are used to assess if the accuracy of the energy use predicted by the model is sufficiently close to the actual energy use. Modifications to the model are made based on site-level details and may include tuning the model to system-level operational data or sub-metered energy use.

Considerations for NREs and approaches to making NRAs vary significantly between existing facilities and new construction projects.

8.2.1 Existing Facilities

NREs are handled differently in existing facility projects and new construction projects. There are also different considerations for temporary and permanent NREs.

8.2.1.1 Baseline Period NREs

For projects in an existing facility, IPMVP requires calibrating the baseline model to baseline energy use. Calibration is achieved by adjusting various model parameters to reflect known or measured site conditions, including static factors. The baseline data should be screened for potential anomalies using strategies discussed in Section 3 and the root cause of potential NREs identified and validated, as mentioned in Section 2.3. There would be no NRAs required if the operations in this period were normal and expected to repeat in the reporting period. The calibration process would fine-tune the model to capture all "real" variations in energy use.

Investigating and adequately accounting for baseline period NREs is a critical step since the calibrated baseline model is the basis for the savings analyses. This step is best practice and can improve savings estimates[89].

As described in the NRA Method #9, the calibrated baseline model is used to calculate avoided energy consumption. A second model, updated to include the ECMs, can be constructed and used as a "target" when tracking savings, similar to the approach described in NRE Approach #5.

In the reporting period, changes in static factors may precipitate a need for an NRA. Once the root cause of an NRE is understood, non-routine adjustments to the baseline energy use (adjusted baseline model) may be needed.

Temporary NREs. For temporary NREs, omit data during the NRE period or determine impacts through simulation analysis, as described above. Operations during specific portions of time (e.g., schedules and setpoints) can be set at the hourly level. Alternatively, the baseline energy use can be adjusted during the NRE period to compensate. This ensures the accuracy of savings calculations and allows model calibration requirements to be addressed.

Permanent NREs. The simulation model should be updated to accurately reflect any permanent changes made that are significant NREs during the baseline period.

---

[89] Significant discrepancies were found in the savings results from side-by-side execution of Option C and Option D methods. Three of the five sites were found to have significant NREs in the baseline which were accounted for in the simulation models. SBW Consulting, *Commercial Whole Building Demonstration Joint Study Report*, May 2019 (available on Calmac.org).

Permanent NREs that occur during the baseline may shorten the period of energy use available for model calibration. Similar to regression energy models, the post-NRE condition should be considered normal conditions. Using unadjusted data from a pre-NRE period in the baseline is not appropriate when NREs are permanent. However, the pre-NRE baseline energy use can be adjusted by modeling the pre-NRE condition as if it were an ECM to determine energy impacts on measured energy consumption. These results can be used to adjust the baseline energy use before the NRE.

Unfortunately, models can sometimes be 'calibrated' arbitrarily to match energy profiles but not actual equipment operations (e.g., adjusting plug loads instead of identifying exact discrepancies between model and site conditions). Best practice requires that all calibration activities are based on actual field measurements or observations.

8.2.1.2   Reporting Period NREs

NREs that occur during the reporting period can be identified from unexpected differences between actual and modeled energy use using the NRE Methods detailed in Section 3. (Assuming no permanent NREs occurred during the implementation period or early in the reporting period.) Sometimes, reporting period calibrations are not conducted, which leaves the reporting period NREs undetected.

Like Option C, the models and energy data are compared under the same set of conditions. Once routinely adjusted, the reporting period model[90] (the calibrated baseline model that includes the ECMs) should accurately reflect the site's energy consumption within a similar tolerance as the original calibrated baseline model. If the statistical accuracy has declined or is not within calibration tolerances, the variances in predicted and actual energy use indicate a potential NRE.

Any changes made to the model or reporting period energy use are non-routine adjustments. As with all NRAs, verifying and documenting the changes to static factors is required, except in some instances where system-level sub-metered energy data are used.

8.2.2   New Construction Projects

Calibrated simulations can be used to verify the performance of new facilities. These models use hypothetical baselines to represent the facility without the targeted energy improvements, often based on minimum code requirements. The baseline simulation model is based on the planned facility designed 'to code'. That model is updated to include the 'above code' energy features (e.g., better windows and levels of wall insulation). Once operations have stabilized, the reporting period model can be calibrated and adjusted to standard conditions if needed. This is a useful benchmark since some utility energy efficiency programs will provide monetary incentives based on percent improvement over code minimums. However, several critical issues related to non-routine adjustments exist with this approach.

When calibrating new construction models, the *reporting period model* is used to capture changes made during construction. As-built conditions can vary widely from design. Specific consideration is needed to reconcile project changes since design (e.g., facility layout, facade details, equipment selected, post-construction occupancy, production variables, and/or operations).

---

[90] Described in Section 6.6.4 of IPMVP Core Concepts, 2016.

If the model is not updated to match the as-built conditions, including any changes in the details of the ECMs, the reported savings results may be flawed. Additionally, monitoring for potential NREs may not be effective[91].

8.2.2.1 Reporting Period NREs

An as-built calibrated simulation model is an excellent tool for tracking energy performance and making NRAs on an ongoing basis. Simulation models that are periodically updated with the weather (or other independent variables) and compared to energy use data from the site are effective in identifying NREs. For M&V efforts, conducting frequent true-ups (e.g., monthly) allows NREs to be identified and investigated while they are still fresh in mind. Making the non-routine updates to the simulation model in a timely way maintains the predictive quality of the model and allows for ongoing screening for potential NREs. Although this approach is not commonly used, it offers substantial benefits in validating suspected NRE root cause and addressing non-routine adjustments. This is an especially useful tactic for sites that undergo frequent operational changes (e.g., operating schedules). This strategy was demonstrated in a high-profile net-zero building in Seattle[92].

Some calibrated simulation projects can transition to the Option C method in the reporting period and adopt related NRE detection and adjustment strategies. (The weather and/or other independent variable data and energy use predicted by a calibrated simulation model can be used to establish a regression-based baseline energy model. Reporting period energy use can be used to calculate avoided energy consumption or to create a reporting period model that can be used to determine normalized energy savings.)

8.2.3 Costs

Calibrated simulation can be a powerful M&V tool for calculating savings and making NRAs. However, constructing a high-quality calibrated simulation model requires significant time and engineering experience. Once developed, however, the model can be used with significantly less effort to make non-routine adjustments if needed. The costs for making NRAs may include both simulation modeling and field data collection.

8.3 Uncertainty in NRAs Using Other Methods

Retrofit isolation using IPMVP Option A does not typically report savings uncertainty, although considerations regarding uncertainty are made. Option A requires the impact of the uncertainty in the estimated values to be considered to minimize uncertainty in the savings estimates.

Option B methods can follow an analytics-based methodology to calculate uncertainty in savings. Still, it is not often reported with the same level of detail as Option C. However, uncertainty can be determined using regression statistics.

---

[91] A study of *LEED-NC high-performance buildings* by New Buildings Institute available here showed large differences between actual and expected energy performance based on calibrated simulation models.

[92] The Bullitt Center used *DeltaMeter*, a M&V tool based on a simplified simulation model, to track energy performance and make NRAs. Updating design-phase simulation models to track actual energy use is an area of interest to assess the effectiveness of code compliance efforts.

Calibrated simulation using IPMVP Option D can quantify savings uncertainty by comparing simulation results with actual energy use. Uncertainty in avoided energy consumption is reported as calibration error between the model and the utility metered or sub-metered energy use, as shown in Equation 16 from IPMVP (

EQUATION 19 in Appendix 2). Similarly, this calibration error is the uncertainty in a non-routine adjustment determined using simulation.

The overall uncertainty in the energy savings then includes the uncertainties from the baseline, the post, and any non-routine adjustment using Equation 11: Total Savings Uncertainty for Unrelated Elements Combined in Quadrature, including Contribution from Non-Routine Adjustment above (square root of the sum of the errors squared).

A. APPENDICES

Appendix 1 – Example Static Factors

Table 8 provides examples of metrics that may be considered to quantify and track static factors. Depending on the project, some items noted below as *static factors* may instead be independent variables included in the models or elements directly affected by the ECMs.

TABLE 8: EXAMPLE METRICS FOR STATIC FACTORS

#	Category	Example Metrics
1	Structural	Facility size - gross sq. feet or sq. meters
2		Conditioned sq. ft or sq. meters (Total amount of space being heated or air-conditioned (also called occupied area)
3		Facility envelope conditions (Level of insulation, window types/configuration, infiltration levels, levels of external shading)
4	Qty. Occupants	Total qty. of occupants (e.g., The total of workers & average Qty. of visitors; Qty. work-stations/chairs), Totals per area/schedule
5		Aux. rental hours, number of occupants, type or use, additional equipment/loads
6		% facility leased, leased square feet
7		Qty. classes/month, Qty. of occupied rooms/beds
8	Hours of Use	Schedule of occupants/area requiring occupied setpoints.
9		Equipment operating hours, which may exceed hours of occupancy, above, (e.g., Qty. hours per week, holiday schedule, after-hours/weekend operations for HVAC system).
10	Heating	Installed heating capacity (Qty. & size of Furnaces, Boilers, HPs, electric preheat & reheat kW), equipment staging, operating temperatures, % combustion efficiency
11	Ventilation	Carbon dioxide levels, CFM for make-up air units, Qty. of dedicated outdoor air units, Qty. fume hoods, HP of exhaust fans
12	Cooling	Installed cooling capacity (Chillers plant capacity, equipment staging, operating temperatures, ton-hours, peak tons), Water-side economizer capacity & setpoints
13		DX/HP/RTU/AHUs equipment, the area served, capacity, space temperature setpoints, schedules, air-side economizer use
14	Lighting	Qty. & type of installed fixtures, Qty. lamp burn-outs, Qty. controllers off-line
15		Lighting levels, Qty. occupancy/daylighting sensors, control settings
16	Plug Loads	Qty. and power use of large printers, coffee makers, electric vehicle chargers, engine heaters
17		Qty. of computers, Qty. laptops, Qty. and type of monitors, Qty. and type of TVs, Qty. small printers, other smaller electrical loads
18		Auxiliary loads (e.g., space heaters, temporary cooling systems)

#	Category	Example Metrics
19	Refrigeration	The capacity of installed refrigeration equipment, compressor & condenser operating pressures, VFDs, equipment staging, peak load
20		Linear feet of open and closed cases, Use of anti-sweat heaters, type of evaporator fans
21	Controls	Space heating and cooling setpoints for occupied and unoccupied periods, Qty. zones
22		Type of controls, Key control strategies by end-use, Calibration of key sensors
23	Domestic Hot Water	Domestic Hot Water (DHW) water temperatures, loads (e.g., Qty. showers/week)
24		DHW Installed heating capacity, Distribution pumps, Storage, Qty. point of use water heaters
25	Steam	Steam pressure supplied, end uses, steam leakage rates, makeup water used
26	Water	Domestic water end-use inventory (e.g., Type and Qty. of toilets, urinals, sinks, showers)
27		Details of other water end-uses (e.g., Irrigation, injection water, production water, process water, wastewater, tank cleaning water, make-up water)
28		Qty. of dishwasher and clothes washer types and use rates
29		Make-up water rates for swimming pools, spas, cooling towers, other evaporative processes
30		Gallons/day from water deionization systems, ultra-pure water systems, other
31	Information Technology Equipment (ITE)	Air & water temperature setpoints, level of hot-aisle containment, economizer use
32		Size/type/redundancy of uninterruptible power supply (UPS) equipment, ITE loads (kW), tons of air-conditioning required, cooling system used
33	Co-Generation	Size and use of cogeneration systems (e.g., Emergency generator capacity and use; integrated solar system average daily kWh; battery storage kW-hours and schedule
34	Combined Heat and Power	Total system efficiency, Net thermal output, Net electrical output, Total fuel consumption
35	Kitchen / Food	Kitchen operating hours/food sales / Qty. meals
36		Capacity and Qty. of walk-in coolers/freezers, operating temperatures
37		Kitchen equipment installed
38		Qty. of walk-in refrigeration units, length of open and closed refrigerated cases
39	Production	Inventory of installed production-related equipment, total nameplate horsepower
39		Type, rate, or volume of products produced, Number of weekly production shifts; Process temperatures and/or process pressures
40		Sales volume, Qty. of registers, Qty. customers/day
41	Pumping Systems	Pumping system details (pump and motor specifications, system pressures, fluids used)
42		Motor BHPs, runtimes, end uses

#	Category	Example Metrics
43	Materials Handling	Qty. and size of forklift chargers
44		Conveyance system details (Length, speed, throughput, drive configuration, motor/vacuum/pneumatic BHP, runtimes)
45		Compressed air system details (system pressures, compressor HP, types, end-uses, leak rates, use/day)
46	Medical Equipment	Qty. of MRIs, X-ray units, ultrasound, EKG machines, spotlights, powered tables, patient monitors, etc.
47	Pools	Inventory of related equipment (e.g., water heating, filtration, and pumping equipment) operating hours, temperatures
48		Pool related HVAC, heat recovery and dehumidification equipment, air-changes per hour, other controls

Appendix 2 – Related Equations from IPMVP Core Concepts 2016

EQUATION 13: IPMVP EQ. 3 FOR AVOIDED ENERGY CONSUMPTION USING FORECASTING

Avoided Energy Consumption =		(Baseline Period Energy
	±	Routine Adjustments to Reporting Period Conditions
	±	Non-Routine Adjustments to Reporting Period Conditions)
	−	Reporting Period Energy

This equation simplifies to:

EQUATION 14: IPMVP EQ. 4 IS SIMPLIFIED EQUATION FOR AVOIDED ENERGY CONSUMPTION USING FORECASTING

Avoided Energy Consumption =		Adjusted Baseline Energy
	−	Reporting Period Energy
	±	Non-Routine Adjustments to Reporting Period Conditions

EQUATION 15: IPMVP EQ. 5 FOR AVOIDED ENERGY CONSUMPTION USING BACKCASTING

Avoided Energy Consumption =		Baseline Period Energy
	−	(Reporting Period Energy
	±	Routine Adjustments to Baseline Period Conditions
	±	Non-Routine Adjustments to Baseline Period Conditions)

This equation simplifies to:

EQUATION 16: IPMVP EQ. 6 IS SIMPLIFIED EQUATION FOR AVOIDED ENERGY CONSUMPTION USING BACKCASTING

Avoided Energy Consumption =		Baseline Period Energy
	−	Adjusted Reporting Period Energy
	±	Non-Routine Adjustments to Baseline Period Conditions

EQUATION 17: IPMVP EQ. 7 FOR NORMALIZED ENERGY SAVINGS

Normalized Energy Savings =		(Baseline Period Energy
	±	Routine Adjustments to Fixed Conditions
	±	Non-Routine Adjustments to Fixed Conditions)
	−	(Reporting Period Energy
	±	Routine Adjustments to Fixed Conditions
	±	Non-Routine Adjustments to Fixed Conditions)

This equation simplifies to:

EQUATION 18: SIMPLIFIED EQUATION FOR NORMALIZED ENERGY SAVINGS[93]

Normalized Energy Savings =		(Adjusted Baseline Period Energy to Fixed Conditions)
	±	Non-Routine Adjustments to Fixed Conditions)
	−	(Adjusted Reporting Period Energy to Fixed Conditions)
	±	(Non-Routine Adjustments to Fixed Conditions)

EQUATION 19: IPMVP EQ. 16 FOR SAVINGS USING OPTION D OR CALIBRATED SIMULATION

Savings =		(Baseline Period Energy from the Calibrated Model [baseline without ECM])
	−	Actual Reporting Period Energy
	±	Calibration Error in Corresponding Calibration Reading

---

[93] This equation is not included in IPMVP Core Concepts 2016.

EVO

Corporate Address:
1629 K Street NW, Suite 300

Washington, DC 20006, USA

Phone:

+1 202-738 4639

Email:

EVO.Central@EVO-world.org

www.evo-world.org