California Industrial SEM M&V Guide

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1. Introduction

Rate-payer funded Strategic Energy Management (SEM) programs are a relatively new approach to saving energy in the industrial sector. These programs seek to:

1. Develop and improve an organization's Energy Management System (EnMS), which are the business practices that help an organization manage and continually improve energy performance
2. Implement energy efficiency projects and save energy
3. Demonstrate and report facility-wide energy performance improvement.

The industrial customer (customer), the SEM implementer (implementer), and utility are the three primary stakeholder who will be engaged in conducting the measurement and verification (M&V) of energy savings in order to demonstrate and report facility-wide energy performance improvements.

While other tools exist for determining facility-wide energy performance improvement as part of an SEM program, this *California Industrial Strategic Energy Management Measurement & Verification Guide* (M&V Guide or Guide) sets forth the requirements with guidance for determining and demonstrating facility-wide energy savings at an industrial facility as part of a utility SEM program in California.

This M&V Guide is meant for use with the California Industrial SEM Design Guide (Design Guide), which provides the detailed process for engaging a customer, reporting progress and influence, and provides the timing of key activities.

The main text of this M&V Guide contains the requirements that must be followed. Annexes contain additional information that may be of value to those seeking additional guidance or have unique challenges regarding energy savings determination. Documentation requirements, which can be used in part to show SEM program influence, are included in this M&V Guide.

If exceptions to this M&V Guide are sought, or clarification is needed, the utility SEM program manager shall be contacted.

The development of this M&V Guide is founded upon the key principles and details of other well-established M&V documents. All of the technical content and much of the language in this Guide has been taken with permission from three M&V documents:

- Bonneville Power Administration Monitoring Tracking and Reporting Reference Guide, Revision 5.0, February 20, 2015
- Energy Trust of Oregon Energy Intensity Modeling Guideline, Version 1.1, January 27, 2016, and
- U.S. Department of Energy Superior Energy Performance Measurement and Verification Protocol, July 2016.

In combination, these three documents have been used to determine facility-wide energy savings at hundreds of industrial facilities in the United States, Canada, and Mexico.

This M&V Guide is consistent with the principles of *ISO 50015:2014 – Measurement and verification of energy performance of organizations – General principles and guidance* and is compatible with *ISO 50047:2016 – Determination of energy savings in organizations*.

In addition, efforts were taken to ensure consistency in technical direction with:

- ASHRAE Guideline 14:2014 – Measurement of Energy, Demand and Water Savings, and

- International Performance Measurement and Verification Protocol – Option C, January 2012.

While the determination of facility-wide energy savings can be performed by any party following this M&V Guide, it is expected that the customer participating in the SEM program and the SEM program implementer (or a supporting party qualified to determine SEM energy savings) will work together to determine savings. Although this Guide is meant to be followed in a linear progression, it is highly recommended that the SEM implementer first read and understand this Guide and then review the key concepts with the customer prior to engaging in the determination of energy savings.

> NOTE: In order to demonstrate competency to use this Guide, it is recommended that the implementer or other individual tasked with determining energy savings be accredited with, or have the equivalent knowledge of an individual accredited with, a Superior Energy Performance - Performance Verifier or Certified Practitioner of Energy Management Systems credentials from the Institute of Energy Management Professionals.[1]

1.1. A Facility-Wide Approach to Energy Savings Determination for SEM

For SEM programs the determination of energy savings is conducted at a facility-wide level. While the determination of facility-wide energy savings does not necessitate or result in the calculation of energy savings of individual energy performance improvement actions (EPIAs or energy efficiency projects), the energy savings of individual energy efficiency projects may be used in a limited capacity to provide confidence in calculated facility-wide SEM energy savings.

The determination of facility-wide energy savings is based upon a “facility boundaries approach” and consists of a process of:

1. As part of an M&V Report, establishing an Energy Data Collection Plan,
2. Accounting for energy consumption and relevant variables that affect energy consumption and collecting and maintaining data,
3. As part of an M&V Report, creating an Energy Data Report to document alterations to data,
4. Normalizing energy consumption values for relevant variables with energy consumption adjustment models (adjustment models) through:
    a. The creation of hypothesis models with historic energy consumption and relevant variable data,
    b. Testing the hypothesis models as reporting period data become available, and
    c. Finalizing the adjustment models,
5. Calculating energy savings values using the finalized adjustment models, and
6. As part of an M&V Report, creating an Energy Savings Calculation Report to document calculated energy savings values and the adjustment models used.

If energy savings values cannot be determined following the above “facility boundaries approach” then facility-wide energy savings can be determined following an “Energy Performance Improvement Action” (EPIA) approach. The EPIA approach aggregates energy savings from non-incented individual energy performance improvement actions (projects).

[1] https://ienmp.org

Additionally, this M&V Guide provides guidance for “netting-out” or reducing the facility-wide savings based on estimated energy saving from other incented custom/capital energy performance improvement actions.

1.2. The Value of Energy Consumption Adjustment Models

The development and use of energy consumption adjustment models serves two primary purposes:

1. *Making energy savings values meaningful.* Energy savings are calculated by comparing energy consumption between two time periods. Because variables that affect energy consumption are ever changing, the operational and external conditions of these time periods do not inherently reflect one another. By adjusting, via a regression model, the energy consumption of one of the two time periods such that the operational and external conditions are comparable, calculated energy savings values depict an accurate representation of the impact energy performance improvement actions implemented at the facility have made.
2. *Provide feedback to customers.* The regression model developed to normalize for relevant variables is a valuable tool, providing industrial facilities with energy performance information over time. It is important that customers understand and trust their models and work closely with the implementer in all steps of the determination of facility-wide energy savings. The ultimate goal is for the customer to own the energy savings determination process and use the process and results as a tool as they continually improve energy performance.

1.3. Supporting Program Influence through SEM M&V

Utilities and implementers seek to demonstrate that the SEM program directly influenced the achievement of facility-wide energy savings. SEM program influence is demonstrated through documented interactions between the customer, implementer, and utility throughout the SEM program engagement. Details on the types and timing of reports are found in the Design Guide.

The determination of energy savings is a process that both the customer and implementer collaboratively conduct throughout the SEM program engagement. Through documentation of a M&V Report the implementer is able to document the program’s impact. The M&V Report is comprised of information taken from the Energy Data Collection Plan, Energy Data Report, and Energy Savings Calculation Report. Raw data collected as part of this effort may be customer sensitive and shall be maintained by the customer and implementer. Raw data are not shared with the utility as a general rule. However, this data shall be made available to the utility upon request and per the requirements of the SEM program.

It is the responsibility of the implementer to finalize the M&V Report and deliver it to the utility as requested or at the conclusion of the SEM engagement. The M&V Report will be used to confirm that the adjustment models created are valid and allowable for use when the utility reports savings to the California Public Utilities Commission.

It is the responsibility of the implementer to ensure the customer understand what types of data will be required and to whom the data will be made available.

2. Terminology and Reference Notation

2.1. Terminology

For the purposes of this M&V Guide, the following terms and definitions apply.

Achievement period: interval between the end of the baseline period and the end of the reporting period
Source: MSE 50021: 2015, 3.1

Baseline period: specific period of time selected as the reference period for the determination of energy performance improvement
Source: MSE 50021: 2015, 3.2 (removed "SEP")

Boundaries: physical or site limits as defined by the organization
Source: ISO 50001:2011, 3.1 - modified (removed "and/or organization limits" and "examples")

Energy: electricity, fuels, steam, heat, compressed air, and other like media
Note 1: for the purposes of this Guide, energy refers to the various types of energy, which can be purchased, stored, treated, used in equipment or in a process, or recovered.
Note 2: energy can be defined as the capacity of a system to produce external activity or perform work.
Source: ISO 50001:2011, 3.5 - modified (replaced "International Standard" with "this Guide", and removed "including renewable" in Note 1)

Energy accounting: system of rules, methods, techniques and conventions used to measure, analyze, and report energy consumption
Source: ISO 50047, 3.2

Energy consumption: quantity of energy applied
Source: ISO 50001:2011, 3.7

Energy use: manner or kind of application of energy
Examples: ventilation; lighting; heating; cooling; transportation; processes; production lines
Source: ISO 50001:2011, 3.18

F-test: A statistical test that can be used to assess how well a regression model fits the data, or how much evidence there is that a particular variable or set of variables belong in the model

Feedstock: raw or unprocessed material used as an input to a manufacturing process to be converted to a product
Example: crude oil used to produce petroleum products

Non-routine adjustment: adjustment made to the energy baseline to account for unusual changes in relevant variables or static factors, outside the changes accounted for by normalization
Note 1: non-routine adjustments may apply where the energy baseline no longer reflects energy use or energy consumption patterns, or there have been major changes to the process, operational patterns, or energy using systems
Note 2: for routine adjustments normalization is used

Source: ISO 50015:2014, 3.16 - modified (added Note 2)

Normalization: process of routinely modifying energy data in order to account for changes in relevant variables to compare energy performance under equivalent conditions
Source: ISO 50006:2014, 3.13 - modified (removed Note 1 to entry)

p-value: value which indicates the probability of observing an outcome at least as extreme given that the null hypothesis was true.
Note 1: In a linear regression model, an estimate's p-value represents the probability of the model producing the estimated parameter value given that the true value was zero.
Note 2: A regression model's F-test p-value indicates the probability that the true model is best represented by an intercept model (i.e., except for the intercept term, all variables are uninformative)

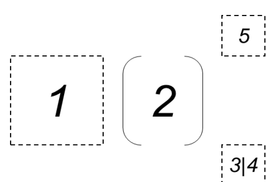
Relevant variable: quantifiable factor that affects energy performance and routinely changes
Examples: Production parameters (production volume, production rate); weather conditions (outdoor temperature, degree days); operating hours; operating parameters (operational temperature, light level).
Source: ISO 50047, 3.18

Reporting period: ending period in which energy performance improvement is measured relative to the baseline period to determine SEP energy performance improvement
Source: MSE 50021: 2015, 3.6

Static factor: Identified factor that affects energy performance and does not routinely change
Source: ISO 50047, 3.21

2.2. Reference Notation

This section describes the notation used in this Guide. The energy consumption and savings notation is designed to distinguish quantities in the format shown below.



1. **Base Notation:** Describes if the energy consumption or savings is for delivered energy and provides the base for energy performance improvement notation.
2. **Energy Types:** Describes the type of energy that is quantified. The asterisk (*) notation is used as a placeholder for a generic or unknown energy type.
3. **Modeled Period:** Indicated in subscripts and defines the time period for which the model is built.
4. **Period/Conditions of Interest:** Indicates the time period or conditions of interest for which the model is being applied to.
5. **Adjustment Indicator:** Indicated in superscripts and describes if the quantity of energy is observed (actual) or adjusted.

1. Base Notation

ECD(*)	Delivered energy consumption of an unspecified energy type
E(*)	Quantity of energy of an unspecified type
ESD(*)	Delivered energy savings of an unspecified energy type
EnPI	Energy Performance Indicator

2. Energy Types

Individual energy type notation replaces the asterisk (*) in parentheses from the base notation above. The following are recommended for clarity of communication.

*	Unspecified energy type
e	Electricity
ge	Grid delivered electricity
pve	On-site generated electricity from on-site photovoltaic panels
ng	Natural gas
st	Steam
ca	Compressed air
d	Diesel
c	Coal
hw	Hot water
Σ	The sigma notation is used to represent summation of all energy types. $\mathrm{ECD}(\Sigma) = \sum_{*} \mathrm{ECD}(*)$ Example: if observed baseline delivered energy types are "ge" and "ng", then $\mathrm{ECD}(\Sigma) = \mathrm{ECD}(\mathrm{ge}) + \mathrm{ECD}(\mathrm{ng})$

3. Modeled Period and 4. Period/Conditions of Interest – (Subscript)

b	Baseline period
r	Reporting period
s	Standard conditions
m	Mean conditions

5. Adjustment Indicator – (Superscript)

o	Observed (actual) value for the indicated time period of condition of interest
a	Adjusted value for the indicated time period or condition of interest

Energy Savings Notation

$\mathrm{ESD}_{\mathrm{TD}}$	Delivered energy savings as determined by the top-down approach

3. Characterizing the Facility

The process of characterizing the facility is conducted prior to the collection of any energy consumption or other data, the creation of energy consumption adjustment models, and calculation of energy savings. This process is conducted in tandem between the customer and implementer and is best done at the facility.

3.1. Establishing Facility Boundaries

3.1.1. Initial Development of Facility Boundaries

Facility boundaries are used as the point at which energy types (e.g. electricity, natural gas, propane, and diesel) are accounted for, as this is where these types of energy enter or leave the facility. In the majority of situations energy consumption of any energy type will not need to be submetered within the facility boundaries. Examples of when metering of energy consumption and generation metering is required within the facility boundaries are presented in Section 1.

The facility boundaries shall align with production lines, process systems, buildings and/or utility meters and submeters as appropriate. All energy consumed within the buildings and by operations which are included within the scope of the EnMS being developed as part of this SEM engagement must be included inside the facility boundaries.

The customer is responsible for initially identifying the facility boundaries. Documentation of facility boundaries shall include one or more line drawings of the facility with the facility boundaries clearly marked. The line drawing(s) shall include demarcation of buildings and major equipment and processes within the facility boundaries. Process flow diagrams, energy maps, piping and instrumentation diagrams, and value stream maps can be helpful in creating the line drawing(s). Energy maps are used as part of the implementation of the facility's EnMS.

> NOTE: Facility boundaries are considered three-dimensional, thus energy accounting shall include energy that enters the facility boundaries from the sky (e.g. rooftop solar PV) and ground (e.g. on-site natural gas extraction) if consumed at the facility in the form of an energy type for which energy savings are being determined. This requirement is needed to address the energy accounting of onsite solar generated electricity as well as natural gas extraction, consumption, and exportation as a product. See Section 1 for more information.

The facility boundaries shall not change between the baseline and reporting periods. Subsequent steps in the energy modeling process may reveal a need to revisit facility boundaries. Changes to the facility boundaries made after the baseline period will result in the need for a documented non-routine adjustment to the baseline energy values (Section 7.5.1).

3.1.2. Utility and Submeter Boundary Considerations

Use of existing utility meters may be sufficient to conduct the energy consumption portion of energy accounting at most facilities. However, if utility meters serve buildings, equipment, processes or other energy using systems outside the boundaries of the SEM program for which energy savings are being determined, submeters are required to net out the energy consumption of these energy uses.

The customer shall identify all utility and other relevant meters for all types of energy delivered to or away from the facility boundaries. Serial numbers or other unique identifiers of these meters shall be recorded as part of the Energy Data Collection Plan. The location of these meters shall be recorded on the line drawing(s) showing the connection between the meters and the energy uses.

Data regarding the quantity of energy delivered into or away from the facility boundaries (delivered to the facility, delivered away as energy export, delivered away as energy product, or feedstock) may be available directly from meters (utility or submeters) or taken from a supplier invoice (see Section 6 for more information). Meters (utility or submeters) may directly report energy consumption values or physical properties such as pressure, temperature, mass, volumetric flow, and heating value that can be used to calculate energy consumption by using engineering equations and conversion factors. Equation and conversion factors shall be documented as part of the Energy Data Collection Plan.

3.1.3. Energy Flows

Energy flows for the energy types for which energy savings are to be determined shall be documented on the line drawing(s). The energy flows trace the "path" energy takes from the point it is delivered to the facility boundaries and to the energy end uses. If applicable, the energy flows will include the "path" energy may take into and out of on-site storage, delivered away from the facility as an energy product or energy export (see Section 6 for more information). Additionally, if energy is used as a feedstock this shall be noted as part of the energy flow. The energy content of the energy flows that do not terminate in energy end uses within the facility boundaries will need to be netted out of the delivered energy value as part of the energy accounting (Section 5).

3.1.4. Finalization of Facility Boundaries

Using the initial line drawing(s) as well as the information regarding utility meters and submeters, the customer and implementer shall finalize and document the facility boundaries. The finalized line drawing(s) shall show the facility boundaries, buildings, major equipment and processes, energy flows, and utility and relevant variable data meters and submeters. This documentation is to be reviewed by the customer with the implementer and be documented as part of the Energy Data Collection Plan.

3.2. Identifying Relevant Variables

Relevant variables are factors that may or may not be in the control of the customer and which directly affect the amount of energy consumed within the facility boundaries.

> EXAMPLES: Production quantities, equivalent products, number of batches, heating degree-days, humidity, occupancy, hours worked, and raw material characteristics.

Relevant variables shall be physical quantities, characteristics, or conditions. Financial metrics or metrics that include a financial component, such as product price or energy costs are not allowed as they lack a physical relationship to energy consumption.

Relevant variables are used to normalize energy consumption as part of an adjustment model. In order to develop robust and meaningful adjustment models, care shall be taken to avoid:

- Omitting relevant variables that affect energy consumption, and
- Including variables that do not directly affect energy consumption.

The customer and implementer shall work together to identify a list of potential relevant variables that may or may not be included in the adjustment models developed as part of the energy consumption normalization process, using engineering judgment to identify potential relevant variables. For each potential relevant variable included on this list the energy type the relevant variable is suspected to affect shall be noted. This list shall be included as part of the Energy Data Collection Plan.

A metric of production is often a relevant variable, but is likely not the only relevant variable for an industrial facility. It is important to understand how many product types are manufactured in a facility and whether there is likely to be a difference in energy consumption based on operating parameters such as product type, process flow, or batch size. Facility personnel who work closely with energy end uses typically have insight into what variables shall be considered. By thinking openly about not only which variables may affect energy but how those variables compare to one another, the chances of developing a robust energy consumption adjustment model will be increased.

> EXAMPLE: A facility that produces two types of products, one of which is very energy intensive to produce and the other is not, may consider including production levels from both products rather than an aggregated production value.

The following variables shall be considered for inclusion as relevant variables:

- Activity level (e.g., operating hours, operating mode (weekend/weekday), production level, product mix, and equivalent products, occupancy)
- Weather (e.g., heating degree-day, cooling degree-day, ambient temperature, and humidity)

See Annex B for more information on selecting production based relevant variables.

The list of variables will be reviewed by the implementer with the customer prior to their use in developing hypothesis model(s). This review will include discussions about adding and removing variables. Variables are excluded from the initial list if there is no logical mechanism by which the variable would affect the consumption of energy types for which energy savings are being determined.

Additionally, a discussion on how data related to relevant variables will be collected shall be included in the Energy Data Collection Plan. Relevant variable data will be collected as part of the energy accounting process (Section 5).

A reduced list of relevant variables which have been chosen for inclusion in the energy accounting shall be included in the Energy Data Collection Plan.

> NOTE: In the process of selecting relevant variables for energy accounting, there exists competing objectives of capturing the full subset of variables which will prove statistically significant for inclusion in adjustment models, while aiming to limit the number of relevant variables to a level that is easy to maintain yet meaningful. No single analytical technique will provide the perfect solution, so the customer and implementer must rely on their own experience and engineering judgment to decide which relevant variables shall be included as part of the Energy Data Collection Plan.

4. Establishing Time Periods

For each two-year SEM engagement cycle, the determination of energy savings is based upon the energy consumption of the baseline and selected reporting periods. Together, two annual reporting periods comprise the achievement period.

Energy savings are determined using a baseline period that is valid for two years (the duration of an achievement period). As such, a progression is made of every second reporting period becoming the new baseline period.

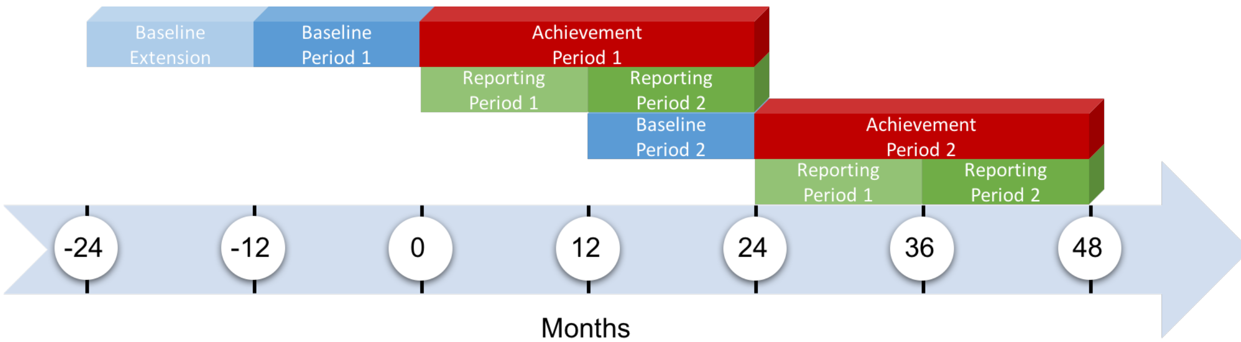


Figure 1. Relationship between time periods.

4.1. Baseline Period

The length of the baseline period shall be 12 consecutive months (1 year) to account for variations in operations and seasonality. The baseline period does not have to coincide with a calendar year.

For the initial baseline period, if valid adjustment models cannot be created and it is suspected that the 12-month baseline period is a limiting issue, a 24-month long baseline period may be used. Baseline periods established for subsequent achievement periods must be the same 12-months as the prior year two reporting period.

> EXAMPLE: February 1 through January 31 of the following year.

For the initial baseline period, the customer and implementer shall work together to establish the start date of the initial baseline period such that it ends within plus or minus of one month of the first date of actions related to developing and implementing the EnMS as part of the current SEM engagement.

> NOTE: It may be helpful to select a baseline period start date that coincides with utility billing data (e.g., if billing data starts on the 15th of each month, starting the baseline period on that data may help create a more meaningful model)

4.2. Achievement Period

The achievement period is 24-months (2 years) long and begins immediately upon the conclusion of the baseline period.

4.3. Reporting Periods

The achievement period is comprised of two 12-month long reporting periods. The two reporting periods sequentially follow one another. As such, the first reporting period begins immediately following the conclusion of the baseline period and is the same as the first half of the achievement period. The second reporting period begins immediately following the conclusion of the first reporting period and ends at the conclusion of the achievement period.

The implementer shall confirm the proposed start and end dates of the baseline, achievement, and reporting periods with the customer. The confirmed dates will be documented as part of the Energy Data Collection Plan.

5. Energy Accounting

Energy accounting is a system of rules, methods, techniques and conventions used to measure, analyze, and report energy consumption and relevant variable data.

The quantity of a particular type of energy that is consumed within the facility boundaries is defined by the net energy flow of that energy type across the facility boundaries. For each energy type included in the energy accounting, energy consumption shall be equal to or greater than zero. If energy consumption is calculated to be a negative value, it shall be accounted for as zero. In such cases, care shall be taken to ensure energy export and energy product are correctly accounted for.

The below equation describes how to calculate energy consumption. Figure 2 graphically illustrates this relationship.

$$
\begin{aligned}
&\mathrm{ECD}(*) = \ \mathrm{E}(*)\ \text{delivered to the facility}\ \ \mathrm{E}(*)\ \text{onsite generation/extraction} - \\
&\mathrm{E}(*)\ \text{delivered away as export}\ - \\
&\mathrm{E}(*)\ \text{delivered away as product} + \mathrm{E}(*)\ \text{drawn out of storage} - \\
&\mathrm{E}(*)\ \text{added to storage}\ - \ \mathrm{E}(*)\ \text{used as feedstock}
\end{aligned}
$$

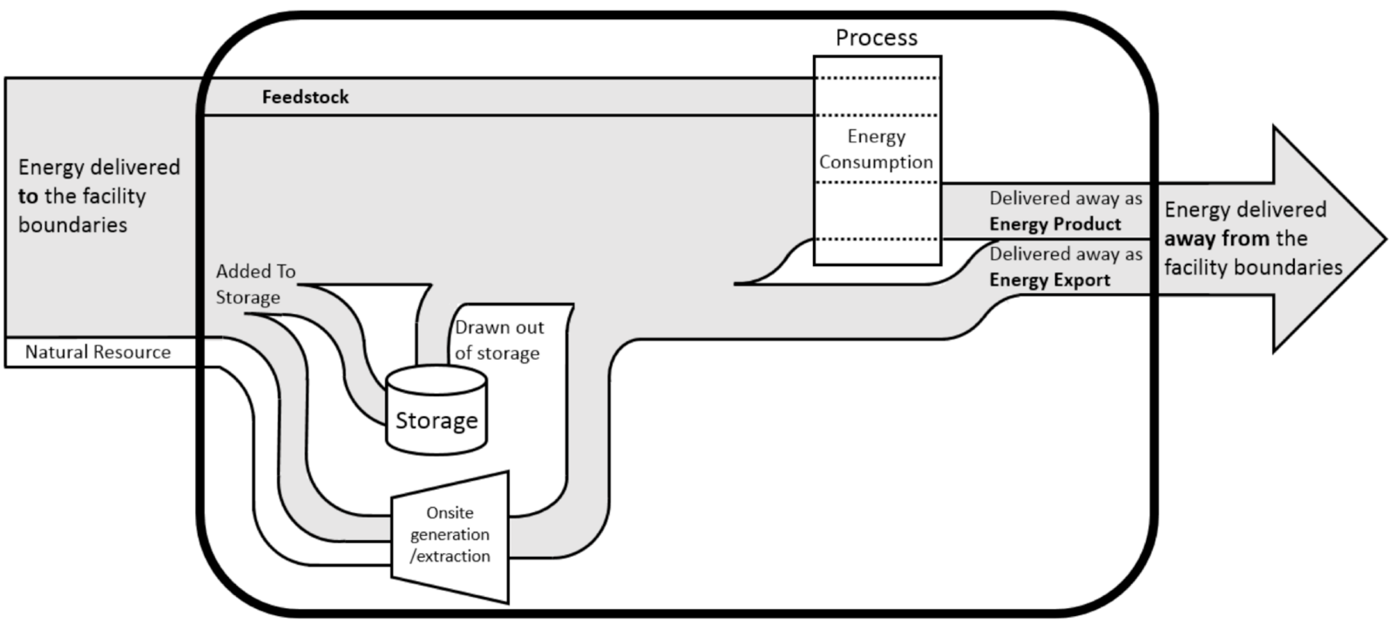


Figure 2: Generic energy consumption accounting flow diagram.

Special cases and requirements of energy accounting are presented in Section 1.

5.1. Types of Energy with Relatively Insignificant Consumption

All energy types that cross the facility boundaries during the baseline and reporting periods shall be included in the energy accounting. Types of energy may be omitted from the energy accounting if these energy types account for in aggregate 5.0 percent or less of the facility's total delivered energy consumption in each of the baseline and reporting periods. In calculating the percent of total consumption represented by an omitted energy type, both the energy consumption of the omitted energy type and total facility energy consumption shall be calculated on a delivered energy basis. The determination to omit energy types may be based on measured or calculated data.

> EXAMPLE: A facility that produces and freezes large quantities of processed foods uses propane for two forklifts.

If the energy consumption of an energy type has been determined to be insignificant and will be omitted from the energy accounting, then it shall be omitted in both the baseline and reporting periods. The omission of an energy type shall be noted in the Energy Data Collection Plan along with justification for the omission.

5.2. Developing the Energy Data Collection Plan

To support the energy accounting, the customer and implementer shall work together to develop an Energy Data Collection Plan. The basis of the Energy Data Collection Plan will have already been established as part of the actions taken in Section 4. In addition to the Energy Data Collection Plan documentation requirements included in Section 4, the Energy Data Collection Plan shall include the items specified in this section as well as by the utility.

The Energy Data Collection Plan shall be utilized to collect data for the baseline and achievement period. In cases where historic data are needed, such as when establishing a baseline period that extends prior to the current date, data shall be collected from utility bills and other records in line with the Energy Data Collection Plan (e.g., data are collected at the same frequency and from the same meter or another source).

The Energy Data Collection Plan may need to be updated during the SEM engagement if it is found to be ineffective, identified meters are removed, additional relevant variables are identified, or other extenuating circumstances arise. The customer and implementer shall work together to make and document changes to the Energy Data Collection Plan. The updated Energy Data Collection Plan shall be put into place and used to retroactively collect data for the baseline and reporting periods.

Requirements and considerations for the Energy Data Collection Plan are presented below.

5.2.1. Frequency of Data Collection

Energy and relevant variable data shall be collected at least monthly if not more frequently (e.g., weekly, daily, and 15-minute interval). In general, more frequent data collection can be beneficial in the development of a robust energy consumption adjustment model. Daily or weekly time interval data typically provide better insight into the process being modeled, and thus more accurate adjustment models may be created when compared to data of longer durations such as monthly data.

The recommended minimum standard for the number of data points needed for use in the creation of an adjustment model is six times the number of relevant variables that will be used in the adjustment model. As at this point it is unknown how many relevant variables will ultimately be used in the development of adjustment models, the expected number of relevant variables that will be used should be selected.

> EXAMPLE: Production output, HDD, CDD, and shift hours have been selected as relevant variables for inclusion in the Energy Data Collection Plan. It is expected that production output, CDD, and shift hours will be used in the electricity adjustment model. It is expected that HDD will be used in the natural gas adjustment model. As such, at a minimum, 18 data points are recommended for use as part of the electricity adjustment model and, at a minimum, 6 data points can be used for the natural gas adjustment model. These recommendations can be used to specify that electricity consumption, production output, CDD, and shift hour data should be collected on at least a weekly basis and that natural gas and HDD data should be collected on at least a monthly basis. This is just a

recommendation and the customer and implementer can agree upon other data collection frequencies understanding that with having more data points will provide more information to arrive at a useful model.

Potentially overriding the equation based guidance, the frequency of data collection shall take into consideration the frequency at which energy consumption data and relevant variable data can be obtained and be meaningful. If production is a relevant variable and data can only be collected on a weekly basis, then there is limited benefit to collecting energy consumption on a 15-minute basis. This should not prohibit a customer from collecting data more frequently as data can be aggregated together when creating energy consumption adjustment models. (e.g., 15-minute interval electricity consumption data can be aggregated to a weekly basis if the relevant variables associated with electricity are only available on a weekly basis.)

5.2.2. Options for Facilities with Multiple Meters

When a facility needs to use more than one meter for a given energy type, consider the following options, selecting one for use as part of the energy accounting for each type of energy.

- Aggregate energy data (preferred option). Sum the data from two or more meters to create an aggregate of facility meter data. If meter data is collected at different intervals, aggregate to the largest sampling interval. This method is appropriate when:
  - Meters have the same interval, or the largest meter has the largest sampling interval.
  - The resulting adjustment model created by using the aggregate data is simple and understandable.
- Build separate energy adjustment models (option used only if aggregation does not work). Build an individual energy adjustment model for each meter. Energy savings calculated for each model will be aggregated. This method is appropriate when:
  - An aggregate energy adjustment model will have large a number of relevant variables. Guidance is that if there are eight relevant variables in a model it should be split if possible by using data from multiple meters.
  - Meters serve different areas or processes with different relevant variables.
  - Meters have different measurement intervals, especially if a meter with the largest energy consumption has much finer granularity than the other meter(s).
  - The facility prefers separate models for greater context of energy savings.

5.2.3. Meter Calibration

All data used as part of the energy accounting, including those for energy consumption and relevant variables, shall be taken from precise measurement systems, such as utility meters and regularly calibrated submeters. Quantification of energy consumption or of a relevant variable via subtraction of readings from two or more calibrated meters is acceptable.

If energy consumption data are taken from a source other than the utility meter, calibration of that meter must follow the manufacturer's recommendations. Calibration records and records of repairs to calibrated meters shall be maintained by the customer and available for the implementer to review if requested. Calibration records for utility meters are not the responsibility of the customer or implementer and do not need to be maintained.

Weather data shall be actual weather data from the baseline and achievement period, from published government sources, such as primary National Oceanic and Atmospheric Administration (NOAA) weather stations, the National Climate Data Center (NCDC) database, or from a calibrated weather meter within close enough proximity to the facility to reflect the weather conditions at the facility.

NOTE: As part of the energy accounting, accurate records will need to be maintained regarding the data source of all energy and relevant variables data. Changes made to the data set, such as the removal of outliers (see Section 5.3.2) will need to be documented. Data continuity is critical to maintaining adjustment model accuracy throughout the SEM engagement

5.3. Implementing the Energy Data Collection Plan

The implementation of the Energy Data Collection Plan is a continuous process conducted throughout the achievement period. The Energy Data Collection Report is the second section of the M&V Report and provides details regarding alterations to the collected data.

5.3.1. Collecting Data

The Energy Data Collection Plan shall be implemented to collect energy consumption and relevant variable data. The collected data shall be recorded and maintained by the customer and implementer. The persons responsible for collecting and maintaining the collected data shall be identified in the Energy Data Collection Plan. The implementer shall check with the customer on a regular basis (suggested bimonthly) to ensure that data is being accurately collected and recorded. These reviews shall be documented.

At a minimum, the implementer and customer shall review the collected data when all baseline period data are collected, when the first six months' worth of reporting period one data are collected, and when all data for each of the two reporting periods have been collected. At these points in time the utility will confer with the implementer that the data collection and quality are acceptable. Reviews of data between any combination of customer, implementer, and utility shall be documented as part of the Energy Data Report.

5.3.2. Reviewing for Data Outliers and Missing Data Points

Data outliers and missing data points can negatively impact the accuracy of energy consumption adjustment models.

Energy consumption and relevant variable data shall be screened for anomalous values that are not representative of typical operating conditions. If high variability is characteristic of the operation, outliers do not necessarily need to be removed. Data outliers can be an indicator of poor operational control and offer the potential for identification of an energy performance improvement action. The effect of outliers on the reliability of the adjustment model estimates and the reason for removing them shall be maintained as a record in the Energy Data Report and discussed with the IOU at the appropriate review.

If an anomalous value is found, reasons for the anomaly shall be identified if possible. If the anomaly is determined to be a data error, the error shall be corrected if possible. Otherwise, if the anomaly is determined to be a data error that cannot be corrected, the anomalous value shall be deleted from the adjustment model(s) data set. The effects of data errors on the reliability of the adjustments model estimates and the reason for making any changes to the data set shall be maintained as a record in the Energy Data Report and discussed with the IOU at the appropriate review. If the anomalous value is determined not to be a data error it shall be left in the data set.

An initial review for outliers and missing data shall be conducted by creating time series plots of data for energy consumption and relevant variable independently in a time series format. Outliers and missing or erroneous entries shall be flagged for review, investigation, and correction (if possible) by applying a common rule of thumb for identifying data that lie outside the range of plus or minus three standard deviations from the mean.

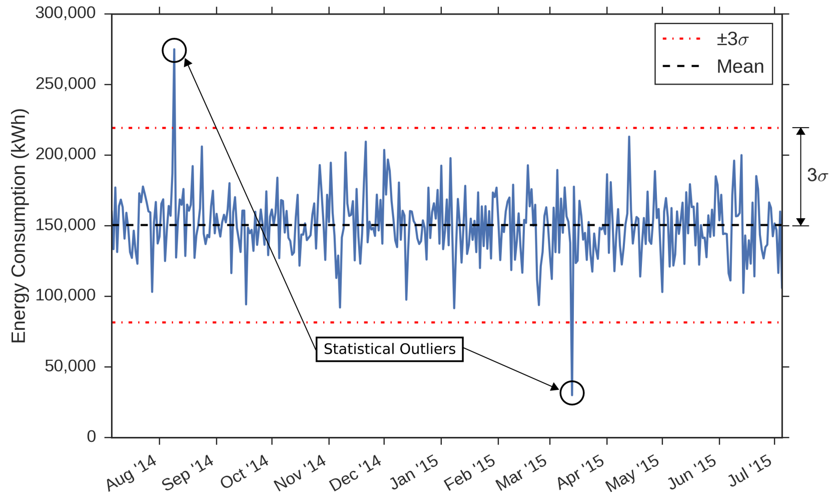


Figure 3. Example of graphical methods to identify outliers.

Omitted data shall be corrected for by closing the gap in the data set, and not by replacement with a calculated interpolation. Filling in missing data can skew model validity tests. In all cases, omitted data cannot be replaced.

The removal of outliers and the efforts taken to replace the omitted data shall be documented as part of the Energy Data Report.

If outliers related to specific operating conditions are excluded from the baseline period, the intervals in the achievement period corresponding to the same conditions must also be excluded from the reporting period.

The customer and implementer shall identify outliers and propose a resolution strategy which will be reviewed with the implementer. Collectively the customer and implementer will decide, using their best judgment, how to account for the outliers. These discussions shall be documented in the Energy Data Report.

> NOTE: A particular type of outlier results from shut-down periods where production is zero. In some facilities, this may only occur for a handful of days per year. If a single adjustment model can be created that reflects both the production and non-production days, the shut-down outliers do not need to be excluded. Alternatively, a relevant variable can be created to account for the effect of reoccurring shutdown days. If an otherwise valid adjustment model cannot be created to accommodate the shut-down periods, these periods may be excluded from the model or treated as a separate mode of operation and modeled independently. When determining a strategy, consider whether energy savings are expected to be achieved during shutdown periods.

> NOTE: Outliers should not be excluded from the model unless there is a reason to do so. For example, a facility may have outliers on major holidays. Consider adding a relevant variable to represent those holidays, or simply exclude these holidays from the model. Note that any reoccurring periods that are excluded from the baseline model must also be excluded from the achievement period.

NOTE: Be careful to distinguish between a zero-data point and a missing data. Missing data should be excluded and not treated as a zero.

NOTE: The removal of outliers, especially in the cases when data is collected on a monthly basis, can significantly affect an energy consumption model's predictive power. Careful consideration should be made regarding the removal of outliers when data is collected on a less frequent basis.

Outliers shall be reviewed by the customer and implementer so that both parties understand the cause of the anomaly. The customer shall take corrective action to reduce the potential for data outliers if possible as outliers can be an indicator of poor operational control or data collection systems. The omission of data points shall be documented in the Energy Data Report.

5.3.3. Adjusting Data for Time-Series Offsets

Data for energy consumption and relevant variables will frequently not be available for exact calendar months, or aligned with time intervals. For example, monthly production data may be reported on the first of the month, while utility data may be provided mid-month. Alignment of time intervals is preferred and may facilitate development of more representative adjustment models, but it is not required.

A time-series offset may exist between energy consumption and relevant variable data. Energy consumption and relevant variable data shall be reviewed to identify time-series offsets. This most commonly occurs when data are collected at high frequency levels (typically weekly or higher). Time-series offsets that negatively affect adjustment model development shall not be used.

Time-series plots shall be used to identify consistent offsets between energy consumption data and each relevant variable (Figure 4). For example, if an energy-intensive process has a two-day lead time from the point at which production levels are measured, a two-day time series adjustment may need to be applied to the production variable.

If such an offset is identified, the customer and implementer shall discuss if the application of a time-series adjustment, or if aggregating data such that the data frequency interval is slower (e.g. aggregate so that all data are represented on a weekly rather than daily time interval), would improve the adjustment model. The decision to use a time-series adjustment shall be documented as part of the Energy Data Report.

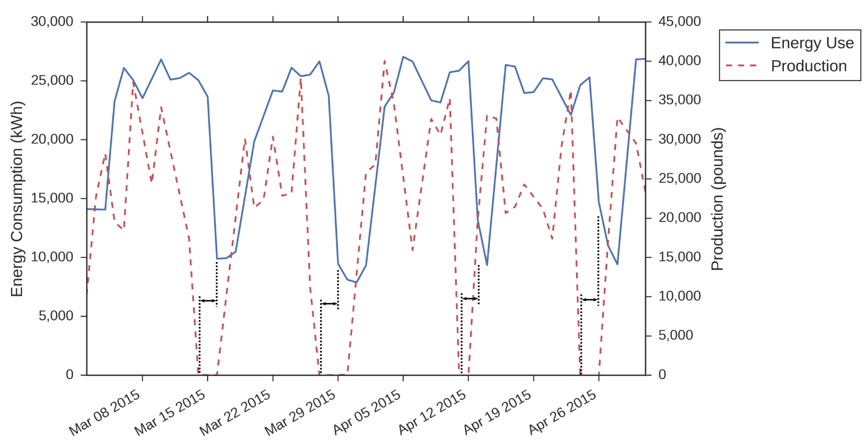


Figure 4. Example of a time-series plot (energy and production vs. Time). Arrows indicate the time-series offset which may be adjusted for.

5.4. Expressing Energy Consumption in Common Units

A common energy unit of kWh for electricity and MMBTUs for natural gas shall be used as part of the energy accounting. Additionally, a MMBTU value of electricity shall be maintained for use in reporting total energy savings (natural gas, electricity, and other). A common energy unit allows for comparison and aggregation of the absolute and relative consumption of multiple energy types. All conversion factors used to convert various units to the chosen common energy unit shall be used consistently for the baseline and reporting periods and recorded as part of the Energy Data Report.

5.5. Establishing Energy Consumption for Time Periods

5.5.1. Baseline Period Energy Consumption

The outputs of the energy accounting are used to determine the energy baseline. An energy baseline is the singular quantifiable value of energy consumption for the baseline period. An energy baseline is established by summing the multiple data points of energy consumption collected as part of the energy accounting during the baseline period (e.g. 12 monthly data points summed).

An energy baseline shall be established for each type of energy for which energy savings are being determined as well as an aggregated energy baseline for all types of energy (e.g., an individual energy baseline for electricity, natural gas, and others and for all energy types together) using common units (MMBTU).

5.5.2. Reporting Period Energy Consumption

Similarly, a value of energy consumption for each energy type and all energy types in aggregate is to be established for each reporting period.

6. Energy Consumption Normalization Through Adjustment Modeling

6.1. General Principles of Normalization

Normalization of energy consumption through the use of adjustment models shall be made so that baseline and each reporting period can be compared as if all relevant variables were the same in the two periods. Normalized baseline period and/or reporting period energy consumption are calculated using one or more adjustment models.

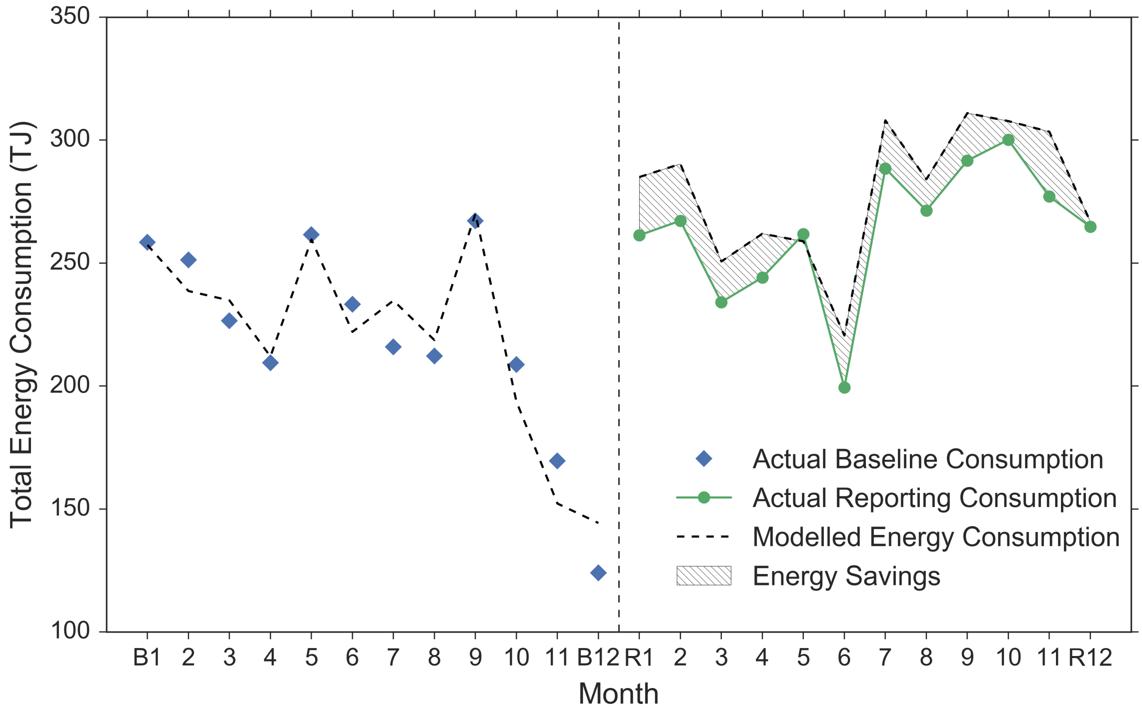


Figure 5. Left: Illustration of baseline period data and the application of a forecast adjustment model to that data. Right: Illustration of actual reporting period energy consumption, the application of the adjustment model to reporting period relevant variables, and the resulting energy savings.

6.2. Primary Methods of Normalization

Three primary methods are allowed to create adjustment models.

6.2.1. Forecast Normalization

Forecast normalization results in a model of baseline period energy consumption that is applied to the reporting period relevant variable values to calculate adjusted baseline period energy consumption ($\mathrm{ECD}(*)_{\mathrm{b|r}}^{\mathrm{a}}$ and $\mathrm{ECD}(\Sigma)_{\mathrm{b|r}}^{\mathrm{a}}$) for comparison with observed (actual) reporting period energy consumption ($\mathrm{ECD}(*)_{\mathrm{r}}^{\mathrm{o}}$ and $\mathrm{ECD}(\Sigma)_{\mathrm{r}}^{\mathrm{o}}$). The adjusted baseline period energy consumption is an estimate of the energy consumption that would have been expected at reporting period-relevant variable values, if the baseline operating systems and practices were still in place during the reporting period.

The forecast normalization method shall be attempted first to create adjustment models.

6.2.2. Backcast Normalization

Backcast normalization results in a model of the second reporting period energy consumption that is applied to the baseline period and first reporting period-relevant variable values to calculate adjusted second reporting period energy consumption ($\mathrm{ECD}(*)_{\mathrm{r|b}}^{\mathrm{a}}$ and $\mathrm{ECD}(\Sigma)_{\mathrm{r|b}}^{\mathrm{a}}$) for comparison with observed (actual) baseline period and first reporting period energy consumption ($\mathrm{ECD}(*)_{\mathrm{b}}^{\mathrm{o}}$ and $\mathrm{ECD}(\Sigma)_{\mathrm{b}}^{\mathrm{o}}$). The adjusted second reporting period energy consumption is an estimate of the energy consumption that would have been expected at baseline period or first reporting period relevant variable values, if the second reporting period operating systems and practices were in place during the baseline period.

The backcast normalization method is applicable in instances where:

- One or more relevant variables has significantly increased or decreased from the baseline period through the reporting period.
- The resolution of the energy signature for the baseline period was relatively poor and the resolution of the energy signature during the reporting period has significantly improved.
- No major operational or structural changes have occurred during the achievement period.

The backcast normalization method shall be attempted to create adjustment models if no valid adjustment model can be created using the forecast normalization method.

6.2.3. Standard Conditions Normalization

Standard condition normalization results in two adjustment models: one of baseline period energy consumption and one for reporting period energy consumption. Standard conditions are applied to each of the models to calculate adjusted energy consumption values ($\mathrm{ECD}(*)_{\mathrm{r|s}}^{\mathrm{a}}$ and $\mathrm{ECD}(\Sigma)_{\mathrm{r|s}}^{\mathrm{a}}$) and ($\mathrm{ECD}(*)_{\mathrm{b|s}}^{\mathrm{a}}$ and $\mathrm{ECD}(\Sigma)_{\mathrm{b|s}}^{\mathrm{a}}$). The adjusted energy consumption for each period is the estimated energy consumption that would have been expected at a standard set of conditions (relevant variable values) in both the baseline and reporting periods.

The standard conditions method has proven valuable when creating adjustment models for facilities with processes which do not change over time and for which energy consumption is affected largely by a single relevant variable (e.g., clean rooms and data centers).

The standard conditions method shall only be used if valid adjustment models cannot be created using the forecast and backcast normalization methods.

6.3. Summary of Primary Normalization Methods

Table 1: summary of normalization methods

	Forecast	Backcast	Standard Conditions
Reporting period energy consumption	Actual reporting period energy consumption	Reporting period model using baseline period conditions	Reporting period model using standard conditions
Baseline period energy consumption	Baseline period model using reporting period conditions	Actual baseline period energy consumption	Baseline period model using standard conditions
Operating characteristics the model is representing	Baseline period operating systems and practices	Reporting period operating systems and practices	Operating systems and practices using standard conditions

6.4. Mean Model

If an adjustment model cannot be developed using one of the three primary normalization methods, a mean model may be used if approval from the utility is obtained. Use of the mean model is not recommended and rational for use shall be documented as part of the Energy

Savings Calculation Report. This modeling method is useful in cases where there is insufficient variation in relevant variables and insufficient correlation between relevant variables and energy consumption. This model is appropriate when the R^2 is very low (e.g. less than 50%).

For a mean model, the baseline energy consumption is the average energy consumption across the baseline period.

This method requires that baseline-operating conditions be thoroughly documented. If plant conditions change significantly between the baseline period and reporting period, the mean model may lose validity.

The mean model method shall not be used if any of the relevant variable values in the reporting period fall more than 10% outside the range of values recorded in the baseline period.

7. Creating and Validating Energy Consumption Adjustment Models

An adjustment model shall be created for each type of energy being considered in the determination of energy savings. The same adjustment model method (forecast, backcast, standard conditions, or mean model) shall be used for all energy types consumed within the facility boundaries for which energy savings are being determined.

7.1. Process for Developing and Validating Energy Consumption Adjustment Models

The following process for developing a valid (Section 7.4) energy consumption adjustment model shall be followed:

1. Create and validate a forecast energy consumption hypothesis model: Once 12 months of baseline period energy consumption and relevant variable data has been collected, the implementer shall create and validate a forecast energy consumption model for each energy type under consideration per this Guide. These models are referred to as the hypothesis models. By developing forecast hypothesis energy consumption models at this point (prior to or during achievement period energy accounting), confidence is established that valid energy savings values can be calculated even prior to conducting the energy accounting for the achievement period. In some instances, more than one statistically valid adjustment model can be formed for a given type of energy. In these instances, the implementer and customer shall use engineering judgment to identify the hypothesis model that best represents the operations of the facility. All statistically valid adjustment models shall be retained and tested as part of the selection of a final model.
    a. If valid hypothesis models are created, the implementer shall review the models with the customer and explain the relationships between energy consumption and relevant variables that are expressed in the hypothesis models.
    b. If valid hypothesis models cannot be created using 12 months of baseline period energy consumption and relevant variable data, additional energy consumption and relevant variable data collected for the 12 months prior to the original 12-month long baseline period shall be collected and used as part of a 24-month long baseline period.
    c. If valid hypothesis models cannot be created using 24 months of baseline period energy consumption and relevant variable data, the Energy Data Collection Plan shall be examined by the implementer and customer for modification that would allow for creating of valid hypothesis models based upon what has been learned through earlier attempts to create hypothesis models.
    d. If all prior attempts to create valid hypothesis models fail, the Energy Data Collection Plan shall be left in its original form and used with the goal of creating a valid backcast or other type of energy consumption adjustment model when all reporting period data have been collected. The implementer shall meet with the customer and explain that no valid forecast hypothesis model was able to be created.

    NOTE: Before creating hypothesis models, the rest of this Guide shall be read and understood.

2. Document hypothesis model: Regardless of whether valid hypothesis models were created or not, the implementer shall review efforts to create hypothesis models with the customer and explain the relationships between energy consumption and relevant variables that are expressed in all hypothesis models created. The results of step 1, including information detailing any valid hypothesis models, extensions to the baseline

period, alterations to the Energy Data Collection Plan, and conversations with the customer regarding the M&V process, shall be documented as part of the Energy Savings Calculation Report and shall be reviewed with the utility. If no valid adjustment models can be created, efforts to create models and suspected reasons for no valid model formation shall be documented in the Energy Savings Calculation Report.

3. <u>Test the hypothesis models during the first reporting period</u>: Once 6 months of reporting period one energy consumption and relevant variable data have been collected per the Energy Data Collection Plan, the implementer shall apply these data to the hypothesis models to test if the models are able to generate valid results. Results of this testing shall be shared by the implementer with the customer.
    a. If the hypothesis model testing produces valid results and no issues are identified by the implementer, the hypothesis model can be used by the implementer and customer together, or by the implementer alone if so desired by the customer, to continuously track energy performance improvement as additional data are collected per the Energy Data Collection Plan.
    b. If the hypothesis model testing does not produce valid results,
        i. The implementer shall review the hypothesis models and attempt to create hypothesis models that are valid with the data collected.
        ii. If no such hypothesis models can be created, the implementer shall review the Energy Data Collection Plan to ensure the selected relevant variables and sources of energy consumption and relevant variable data are reflective of the operations of the facility. If discrepancies between the Energy Data Collection Plan and the realities of the facility are found, the implementer shall adjust the Energy Data Collection Plan and review the changes with the customer.
        iii. If no adjustments can be made to the Energy Data Collection Plan which result in valid hypothesis models, the Energy Data Collection Plan shall be left in its original form and used with the goal of creating a valid backcast or other type of energy consumption adjustment model when all reporting period data have been collected. The implementer shall meet with the customer and explain that no valid forecast hypothesis model was able to be created and shall meet with the utility to discuss modeling options.
4. <u>Transition from hypothesis to final models</u>: When all data for the first reporting period have been collected, the implementer shall use the data with the hypothesis models and test for statistical and qualitative validity. If the hypothesis models are valid, they are considered final and are now referred to as the final models. In cases where there are multiple statistically valid hypothesis models for a given type of energy, the implementer and customer shall work together to use engineering judgment to selected the model that best represents the operations of the facility. In some cases, a model that meets the majority but not all of the statistical requirements best represents the operations of the facility. In these cases, the implementer shall obtain permission from the utility to use the less statistically valid model as the final model. If this is done, the final model, the other models not selected, and the rational for selecting the less statistically valid model shall be documented. The final models can be used with data from the first and second reporting periods to calculate energy savings for the two periods per the instructions in this Guide. The implementer is responsible for using the final models as part of the SEM engagement but shall review the final models with the customer and show the customer how the models can be used to understand changes in energy performance as well as be used to gain better operational control of the facility. The final models shall be documented in an Energy Savings Calculation Report.

7.2. Connecting Relevant Variables to Energy Consumption

Adjustment models shall be created based upon an informed understanding of the physical characteristics of the equipment, operations, and processes present within the facility boundaries.

There are no requirements at any point to use any software to create adjustment models. Regardless of any tools used to create adjustment models (using any method), the validity requirements of Section 7.4 must be met.

7.2.1. Establishing Relationships Between Energy Consumption and Relevant Variables

Use scatter diagrams to confirm whether a linear relationship exists between the data for energy consumption of each type of energy for which energy savings are being determined and each relevant variable. These graphs shall be included as part of the Energy Savings Calculation Report.

Though not statistically tested at this point, a lack of relationship between energy consumption and a relevant variable for which a relationship was expected shall prompt a discussion between the customer and implementer. This result may be due to poor operational control or a mischaracterization of the facility. These discussions shall be documented as part of the Energy Savings Calculation Report.

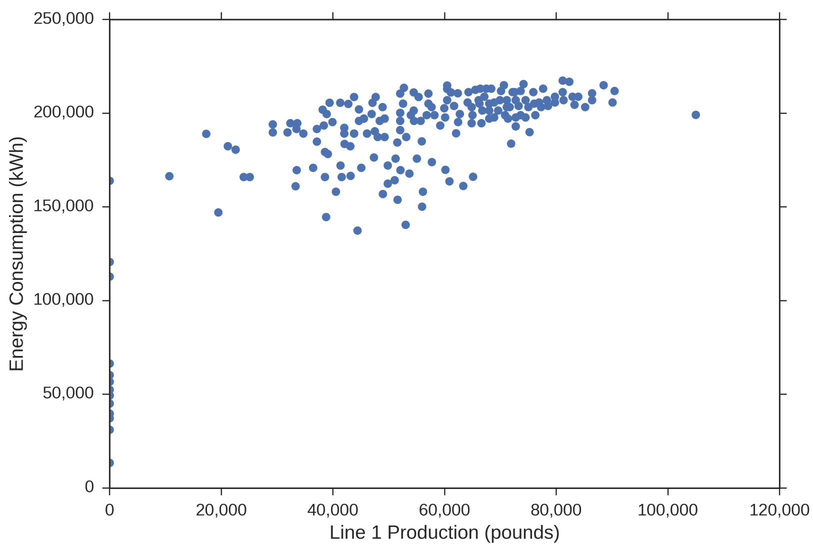


Figure 6. Example of a scatter plot (energy vs. production).

NOTE: Facilities that have an ambient-dependent energy profile will often exhibit a "change-point" characteristic. The presence of a "change-point" can be determined by plotting a relevant variable versus energy consumption. Modeling a facility that exhibits a change-point with a single linear model introduces unnecessary error. Consider alternative relevant variables or a Multi-Mode Model if a change-point is observed (Section 7.3.1).

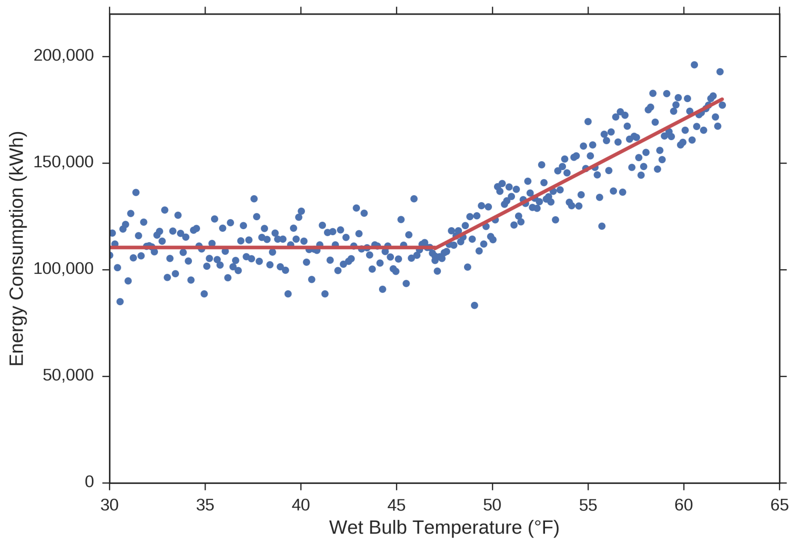


Figure 7. Example of a 3-parameter cooling change-point model.

NOTE: When two or more relevant variables exhibit correlation for a singular energy type, multicollinearity is present. Adding and removing variables from the adjustment model will affect the significance of other variables. The presence of collinear variables can understate the statistical significance of individual relevant variables. Although in many cases multicollinearity is unavoidable, it removes the value of t-stat and standard error metrics. While multicollinearity does not affect the model's predictive capacity, it has the potential to add unnecessary complexity. See Annex C for a discussion on the effect of multicollinearity on an adjustment model.

7.3. Creating Energy Consumption Adjustment Models

Adjustment models shall be created for each type of energy such that the combined models describe energy consumption as a function of relevant variables for each energy type included in the energy accounting plan (i.e. electricity, natural gas). The starting date and duration of the period for which adjustment models for all energy types are created shall be the same.

A minimum of 12 months of data are required when creating an adjustment model. More frequent data may be used per the Energy Data Collection Plan. The data used to create an adjustment model may be at any regular frequency of observation from metering data for each energy type and relevant variable as was collected as part of the energy accounting provided the model significance testing criteria of Section 7.4 are met. The frequency of data used in adjustment models for different types of energy does not have to be the same (e.g., weekly for electricity, monthly for natural gas).

Linear regression is used to create the adjustment models. Linear regression adjustment models allow for multiple relevant variables that affect energy consumption to be taken into account. The model takes the form:

Eq (5) $$ECD(*) = b_0 + b_1x_1 + b_2x_2 + \ldots + b_kx_k$$

where x_i is the relevant variable quantity, b_0 is the base load delivered energy consumption not related to relevant variables, and $b_{i>0}$ is the incremental energy consumption per unit of that relevant variable (coefficient).

All energy consumption adjustment model parameters (including the relevant variables, units, and associated coefficients used to make the model) shall be included in the Energy Savings Calculation Report.

> NOTE: The linear adjustment model form allowed for in this Guide is not the only form of adjustment model used in various SEM programs around the country. Other adjustment model forms may be included in the Guide in future revisions.

7.3.1. Multi-Mode Models

Many industrial facilities experience seasonal swings in operation. Swings can occur as a result of seasonal changes in product type, product quantity or correlations between ambient temperature and process loads. When operational swings cause a fundamental change in the energy signature of a facility, consider building multiple models with distinct baseline periods.

If seasonal changes are abrupt and extreme, contemplate creating an adjustment model based upon production and another adjustment model based upon other relevant variables. For example, if a frozen vegetable processor only runs processing lines for a few months during harvest season, and acts as a frozen storage warehouse for the remainder of the year, the energy signature of these two operating modes is very different.

If seasonal changes are moderate and gradual, a single model will generally be sufficient to characterize the entire baseline period. For example, production increases at an ice cream manufacturer in the summer, but the mixture of product stays the same. In most cases, the single model will be valid for production and non-production days.

If a facility has a short period of abnormally high or low production with a different energy signature, or a negligible number of shutdown days throughout the year, consider ignoring these periods in the baseline and performance period.

Facilities experiencing swings due to weekend shutdowns are best modeled as one model with Saturday/Sunday/weekend relevant variables for simplicity.

Table 2 outlines the pros and cons for building one model versus two models.

Table 2: Options for modeling for facilities with production swings

Strategy	Pros	Cons
Single model with year-round savings	Captures savings at all intervals Easier to maintain one model than two. Most straightforward method, if energy signature stays consistent.	Periods with abnormally high or low production can skew the model. Seasonal production indicators can lead to complex models with many variables.
Single model with abnormally high or low production periods removed	Improves model accuracy during normal production periods. Works well if energy efficiency opportunities are minimal during excluded periods.	Cannot claim energy savings from excluded periods. Reduces number of baseline data points.
Dual production/non-production model	Each model has fewer variables and is easier to understand. Can improve model fitness compared to single model.	Modeler must maintain two models. Reduces number of baseline data points for each model.

7.4. Validating Energy Consumption Adjustment Models

The validity of applying adjustment models to relevant variables shall be tested through quantitative and qualitative tests. Adjustment models used to calculate adjusted energy consumption shall satisfy the validity requirements described in this section.

The implementer is responsible for establishing the validity of the adjustment model, reviewing the validity with the customer, and preparing documentation supporting adjustment model validity to be included in the Energy Savings Calculation Report.

7.4.1. Valid Quantitative Range of Model Relevant Variables

For an adjustment model to be valid for use to calculate adjusted energy consumption, the mean of the adjustment model's relevant variables used to calculate the adjusted energy consumption shall fall within both:

- The range of observed relevant variable data that went into the model, and
- Three standard deviations from the mean of the relevant variable data that went into the model.

Any outliers excluded when creating the adjustment model shall also be excluded when calculating the valid quantitative range of model-relevant variables.

7.4.2. Model Validity Testing

To establish quantitative validity, all adjustment models shall meet all of the following statistical tests:

Statistical Tests	Statistical Test Threshold Values
Model R^2	> 0.75
F-test overall model p-value	< 0.10
At least one relevant variable p-value	< 0.10
All relevant variables p-value	< 0.20
Net Determination Bias	< 0.005%
Coefficient of Variation	< 20% for daily models
	< 10% for weekly models
	< 5% for monthly models

In cases where all of the tests cannot be met but a model passes a majority of the statistical tests and meets the qualitative requirements of section 7.4.3, the implementer shall document why the model should be accepted as valid and shall review the model and justification with the utility. Upon acceptance by the utility, the model will be considered valid.

As a visual check of adjustment model validity, for each adjustment model plot on a scatter diagram observed (actual) energy consumption versus the energy consumption calculated using the adjustment model. Check to see that the point pattern is narrowly clustered and uniformly distributed along the diagonal as illustrated in Figure 8. This graph shall be included in the Energy Savings Calculation Report.

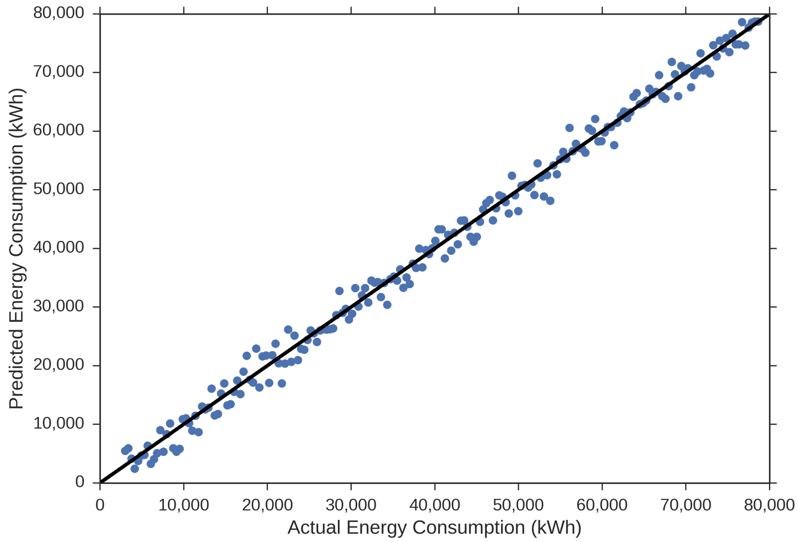


Figure 8. Example of actual vs. predicted scatter plot.

7.4.3. Valid Qualitative Factors

For the adjustment model to be valid for use to calculate adjusted energy consumption, the following qualitative factors shall also be true of the adjustment model period and the application conditions.

- The selection of relevant variables in the adjustment model and the subsequently determined relevant variable coefficients are consistent with a logical understanding of the energy use and energy consumption of the facility.
- No substantial difference between the two periods in product types.
- Meters used were functioning, calibrated and maintained as appropriate.

7.4.4. Documenting Hypothesis Model Validity

Each adjustment model must be supported by documentation including validity statistics and graphics as part of the Energy Savings Calculation Report. The implementer will assemble the adjustment model documentation and review with the customer. Through discussions between the customer and implementer, the customer shall be left in a position to be able to explain the model(s) in its entirety. The documentation shall include for each adjustment model:

- Coefficient values
- R^2 value
- Coefficient of Variation
- Net Determination Bias
- Overall F-Test p-value
- P-value of each relevant variable
- XY scatterplots for each relevant variable
- Time-series graphs for each relevant variable
- Scatterplot of actual versus predicted energy consumption
- Time series graph of actual versus predicted energy consumption
- Time-series graph of residuals and/or cumulative residuals, with bands at +/- 3 standard deviations and +/-2.5% annual energy consumption as the axis scale.

7.5. Options when a Valid Adjustment Model Cannot Be Created

If a valid adjustment model cannot be created using the forecast normalization method, the customer and implementer shall review why the model cannot be created and document their findings in the Energy Savings Calculation Report. The Energy Data Collection Plan shall be altered if deemed necessary. If the Energy Data Collection Plan is altered to include new relevant variables or data sources, the plan shall be used to collect new baseline period data. An adjustment model based upon the forecast method shall be created using this new data.

7.5.1. Non-Routine Adjustments to the Baseline Energy Consumption

Normalization through adjustment modeling is used to account for regular changes in relevant variables. If non-regular changes have occurred this will negatively impact the ability to create a valid adjustment model. Non-routine adjustments are made to the observed (actual) energy consumption in the baseline and/or reporting periods if one or both of the following have occurred:

1. If static factors have changed during the achievement period.
2. If relevant variables have been subject to unusual changes in at least one of the two periods.

Examples of events that might require a non-routine adjustment include the following:

- A supplier goes out of business, and an equivalent raw material is not available. A process modification is needed to use a different type of raw material. No data exist for baseline-period operating conditions with the new type of raw material.
- Processes are outsourced, enhancing profitability and decreasing energy consumption.
- Business acquisition occurs which results in data not being available or limits on the data availability for the period prior to the acquisition.

Any numeric inputs to non-routine adjustment calculations shall be based on observed, measured, or metered data.

Non-routine adjustments are typically based on an engineering analysis to calculate energy consumption in the baseline and reporting periods as if static factors were at the same condition in both periods. In this case, the adjustment will be to calculate baseline period energy consumption as if the reporting period condition of the static factors had been the same as in the baseline period.

The method for making the non-routine adjustment and the rationale for that method shall be maintained, including the general reasonableness of the methodology and calculations, the adequacy of the metering and monitoring methodologies, and conformance of the calculations applied. Non-routine adjustments may be used, but only after review and approval from the implementer and a review of the decision with the utility. The method for making the non-routine adjustment and the rationale for that method must be recorded and documented in the Energy Savings Calculation Report.

7.5.2. Modifying an Adjustment Model

Any adjustment model that does not pass the validity requirements of Section 7.4 cannot be used in the calculation of energy savings.

If such a case occurs, the implementer shall first attempt to modify the forecast adjustment model. This process might include modifications to the assumed relevant variables and frequency of data collection.

If the measurement boundary is supplied by multiple meters, disaggregating the meters may result in better model resolution.

In forming an alternative adjustment model, the implementer shall confirm that the characteristic of the equation remains aligned with the operations, equipment, and processes of the facility, and that the baseline data set meets the standards of this Guide.

7.5.3. Use an Alternative Modeling Method

If after attempts to create a forecast adjustment model an adjustment model that meets the validity requirements cannot be created, an alternative modeling method shall be considered. Attempts shall be made to create a valid backcast adjustment model prior to attempting to use the standard conditions method. If all primary adjustment model methods fail, a mean model can be considered with prior approval by the utility.

If all modeling attempts are unsuccessful, a non-modeling approach that relies upon the aggregation of energy savings from individual energy performance improvement actions (EPIAs) can be used. This is performed by aggregating all implemented non-incentivized custom capital energy performance improvement actions documented in the Opportunities Register (see Section 8.2.2). This option shall only be used with prior approval from the utility.

8. Calculating Energy Savings

For each type of energy being considered and all energy types in aggregate, two energy savings values will be calculated:

1. Facility-wide energy savings, and
2. SEM Program energy savings

The facility-wide energy savings represent the overall energy performance improvement achieved within the facility boundaries. The SEM Program energy savings are those energy savings that the utility can claim as part of the SEM program.

An aggregated Facility-wide energy savings value will be calculated by summing the Facility-wide energy savings for each type of energy. Similarly, an aggregated SEM Program energy savings value will be calculated by summing the SEM Program energy savings for each type of energy.

8.1. Calculating Facility-Wide Energy Savings

For each type of energy, facility-wide energy savings shall be calculated by the implementer by applying the following equation using observed (actual) and estimated (predicted), from the final models, energy consumption values as appropriate.

Modeling Method	Energy Savings Equation
Forecast	Energy savings = baseline period adjustment model calculated reporting period energy consumption - actual reporting period energy consumption
Backcast (Reporting Period 2)	RP2 energy savings = actual baseline period energy consumption – RP2 adjustment model calculated baseline energy consumption
Backcast (Reporting Period 1)	RP1 energy savings = RP2 energy savings – (actual RP1 energy consumption – RP2 adjustment model calculated RP1 energy consumption)
Standard Conditions	Energy savings = baseline adjustment model calculated energy consumption – reporting period adjustment model calculated energy consumption
Mean Model	Energy savings = mean value from the baseline period – actual reporting period energy consumption

8.2. Calculating SEM Program Savings

8.2.1. Adjusting Facility-Wide Energy Savings for Incentivized Projects

The energy savings calculated in Section 8.1 are the Facility-wide energy savings values. These values reflect the overall accomplishments of the customer within the facility boundaries.

For SEM program reporting, energy savings resulting from the implementation of incentivized custom capital projects during the reporting period must be netted out of the Facility-wide SEM energy savings values for each energy type and reported separately. The resulting energy savings value is known as the SEM Program energy savings values.

8.2.2. Opportunity Register

All energy performance improvement actions, regardless of whether the customer did or did not receive an incentive from a utility program outside of the SEM program, shall be documented in the Opportunity Register and reviewed by the implementer. The Opportunity Register documents all the energy performance improvement efforts, both identified and implemented, within the facility boundaries during the reporting period. In addition to being used to net out energy savings attributable to incentivized custom projects, this documentation provides the customer, implementer, and utility information regarding the types and levels of savings achieved through various individual actions.

The customer shall regularly update and maintain the Opportunity Register for the facility boundaries. The implementer shall verify, at least quarterly, that the Opportunity Register is updated and maintained. Any energy performance improvement actions that identified during the SEM engagement and receive incentives outside of SEM shall be included in the Opportunity Register.

Energy performance improvement opportunities entered into the Opportunity Register must include at least:

- The opportunity name
- A description of the opportunity (including location, system or process, equipment type, size, capacity, load, and operating conditions)
- Type of action (behavioral, operational, capital, or process)
- Date initiated
- Date completed (and if not completed a brief rational)
- Energy type impacted
- Final energy savings for each type of energy impacted, and the method used to calculate the savings.

NOTE: See the California Industrial SEM Design Guide for further reporting requirements for the Opportunity Register

8.2.3. Adjusting Energy Savings for Concurrent Incentivized Projects

SEM Program energy savings are calculated by taking the Facility-wide energy savings values for each type of energy and subtracting energy savings from all incentivized custom energy performance improvement actions included in the Opportunity Register. Utility-approved energy savings value associated with the incentivized EPIAs are used, prorated from the in-service date to the end of the achievement period. The SEM Program energy savings shall be documented as part of the Energy Savings Calculation Report, for each type of energy individually and in aggregate.

8.3. Visualizing Energy Savings

The CUSUM calculation is an effective means of quantifying and visualizing energy savings for each type of energy as well as all energy types in aggregate. In graphical form, the CUSUM provides a powerful illustration of the total savings achieved.

A CUSUM graph is best accompanied by a time-series plot of actual and predicted energy. An example of a hybrid CUSUM graph is shown in Figure 9. A standardization on whether to display savings as a positive or negative CUSUM does not exist, however California SEM programs shall indicate energy savings using a downward trend.

A CUSUM graph using facility-wide SEM energy savings shall be made for each type of energy and for all energy types in aggregate. Using the Opportunity Register, the customer and implementer shall work together to correlate inflections in the cumulative sum of differences (CUSUM) graph to these actions.

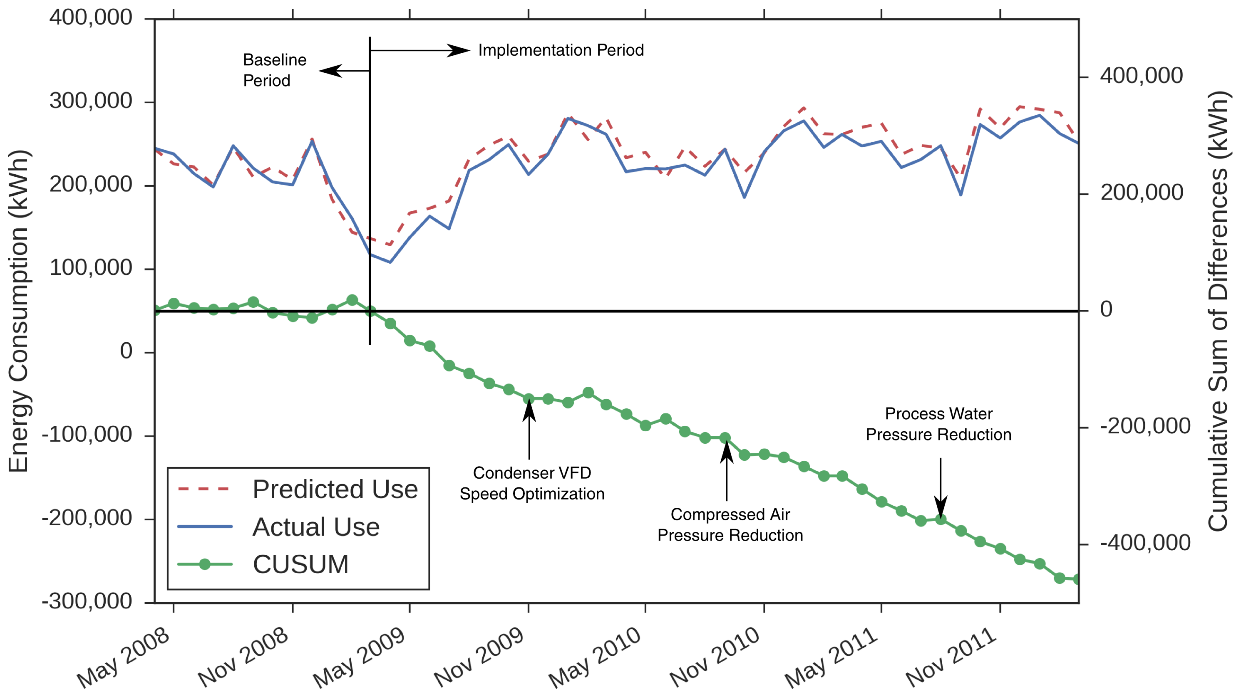


Figure 9. CUSUM graph example.

8.4. Representing Energy Savings as Improvement Percentage

Additionally, energy savings can be represented as an energy performance improvement percentage value. To calculate energy savings as a percentage:

1. Calculate energy performance improvement as a ratio using
2.
3.
4.
5.

6. Table 3. These ratios shall be calculated using facility-wide reporting period energy consumption and baseline period energy consumption, where the energy consumption of one or both periods is adjusted so that they correspond to consistent conditions of relevant variables. A ratio value less than 1.0 indicates that energy performance has improved. The ratio shall be calculated for each energy type for which energy savings are being determined independently as well as for all energy types being considered in aggregate.
7. Convert the ratio to energy performance improvement percentage: Energy performance improvement (%) = (1-ratio) x 100 lists the notation used to refer to the actual and

adjusted energy consumption for each normalization method, as well as the data used to create the adjustment model and the data used to apply the adjustment model.

Table 3: Use of observed and adjusted energy consumption for the various normalization methods

	Forecast Method	Backcast Method	Standard Conditions Method	Mean Model Method
Energy performance improvement ratio for the First Reporting Period	$\frac{ECD(\Sigma)^{o}_{r1}}{ECD(\Sigma)^{a}_{b\mid r1}}$	$\frac{\left(\frac{ECD(\Sigma)^{a}_{r2\mid b}}{ECD(\Sigma)^{o}_{b}}\right)}{\left(\frac{ECD(\Sigma)^{a}_{r2\mid r1}}{ECD(\Sigma)^{o}_{r1}}\right)}$	$\frac{ECD(\Sigma)^{a}_{r\mid s}}{ECD(\Sigma)^{a}_{b\mid s}}$	$\frac{ECD(\Sigma)^{o}_{r2}}{ECD(\Sigma)^{a}_{b\mid m}}$
Energy performance improvement ratio for the Second Reporting Period	$\frac{ECD(\Sigma)^{o}_{r2}}{ECD(\Sigma)^{a}_{b\mid r2}}$	$\frac{ECD(\Sigma)^{a}_{r2\mid b}}{ECD(\Sigma)^{o}_{b}}$	$\frac{ECD(\Sigma)^{a}_{r2\mid s}}{ECD(\Sigma)^{a}_{b\mid s}}$	$\frac{ECD(\Sigma)^{o}_{r2}}{ECD(\Sigma)^{a}_{b\mid m}}$

Forecast Method	
$\mathbf{ECD(\Sigma)^{o}_{r1}}$	Observed (actual) first reporting period energy consumption
$\mathbf{ECD(\Sigma)^{a}_{b\mid r1}}$	Modeled baseline period delivered energy consumption adjusted to first reporting period conditions
$\mathbf{ECD(\Sigma)^{o}_{r2}}$	Observed (actual) second reporting period energy consumption
$\mathbf{ECD(\Sigma)^{a}_{b\mid r2}}$	Modeled baseline period delivered energy consumption adjusted to second reporting period conditions
Backcast Method	
$\mathbf{ECD(\Sigma)^{a}_{r2\mid b}}$	Modeled second reporting period delivered energy consumption adjusted to baseline period conditions
$\mathbf{ECD(\Sigma)^{o}_{b}}$	Observed (actual) baseline period energy consumption
$\mathbf{ECD(\Sigma)^{a}_{r2\mid r1}}$	Modeled second reporting period delivered energy consumption adjusted to first reporting period conditions
$\mathbf{ECD(\Sigma)^{o}_{r1}}$	Observed (actual) first reporting period energy consumption
Standard Conditions Method	
$\mathbf{ECD(\Sigma)^{a}_{r2\mid s}}$	Modeled second reporting period delivered energy consumption adjusted to standard conditions
$\mathbf{ECD(\Sigma)^{a}_{b\mid s}}$	Modeled baseline period delivered energy consumption adjusted to standard conditions

Mean Model Method	
$\mathbf{ECD(\Sigma)^{o}_{r2}}$	Observed (actual) second reporting period energy consumption
$\mathbf{ECD(\Sigma)^{a}_{b\|m}}$	Modeled baseline period delivered energy consumption adjusted to mean conditions

9. M&V Report

The M&V Report is comprised of the:

1. Energy Data Collection Plan,
2. Energy Data Report, and
3. Energy Savings Calculation Report.

The M&V Report is to be finalized by the implementer and reviewed with the customer prior to submission to the utility.

This section outlines major requirements of the three sections that comprise the M&V Report. Relevant section numbers from the M&V Guide are in parenthesis as a reference.

Additional requirements for these three documents may be made by the utility and additional information may be included at the discretion of the implementer and customer. This section shall not be considered as a complete list of requirements for these reports but as a reference. If provided, a sample or template guide shall be followed.

9.1. Energy Data Collection Plan

The Energy Data Collection Plan is included as part of the M&V Report.

Section 5.2 includes required details for the contents for the Energy Data Collection Plan. Those requirements are consolidated here with additional information from other sections of the Guide.

- <u>Time Periods</u>
    - Baseline period dates
    - Achievement period dates
    - Reporting period dates
- <u>Facility Boundaries</u>
    - Finalization of the facility boundaries described and detailed with line drawing(s)
        - Showing the facility boundaries, buildings, major equipment and processes, energy flows, and utility and relevant variable data meters and submeters
- <u>Energy Consumption Data</u>
    - The types of energy that cross the facility boundaries and are to be included in the energy accounting:
        - Electricity, natural gas, and/or others
    - The types of energy that cross the facility boundaries and are to be omitted from the energy accounting along with the rational for their omission.
    - The energy flows
        - Identification if energy enters or leaves an energy storage system, is delivered away from the facility boundaries, is delivered to the facility boundaries as a feedstock, or is generated or extracted within the facility boundaries
    - The sources of data (meters) from which data for the energy consumption data will be collected, including:
        - Serial number or another unique identifier for each meter, (3.1.2) and
        - The owner of the meter (utility, the facility, or other organization)
    - Equation and conversion factors used to calculate energy consumption values from physical properties such as pressure, temperature, mass, volumetric flow, and heating value (3.1.2)

- The units for which energy consumption data are available and for which they will be recorded.
  - kWh for electricity energy consumption data is recommended
  - MMBTU for natural gas data is recommended
    - NOTE: If natural gas consumption data is only available in units of volume, the heating value of the natural gas must also be recorded as part of the Energy Data Collection Plan. The higher heating value of the natural gas shall be used if this is the case.
- The frequency at which energy consumption data will be recorded from the identified meters.
- The method and location for which energy consumption data will be documented.

- Relevant Variable Data
  - Initial list of potential relevant variables and the energy types they are assumed to affect.
  - The relevant variables for which data are to be collected.
  - The sources of data from which relevant variable data will be collected.
  - The units for which relevant variable data are available and for which they will be recorded.
  - The frequency at which relevant variable data will be recorded.
  - The method and location for which relevant variable data will be recorded.

9.2. Energy Data Report

The Energy Data Report the second part of the M&V Report and details alterations to the data collected as part of implementing the Energy Data Collection Plan. Data collected as part of implementing the Energy Data Collection Plan are not included in the M&V Report and are only made available to the utility upon request. Raw data can be recorded in a number of ways including computer based spreadsheets and report style documentation. A combination or recording methods may best serve the customer and implementer.

The Energy Data Report must include, but is not limited to:

- Data collected as a result of implementing the Energy Data Collection Plan. (5.3.1)
- The effect of outliers on the reliability of the adjustment model estimates and the reason for removing them (5.3.2)
- Removal of outliers and the efforts taken to replace the omitted data (5.3.2)
- Discussions related to the effect of outliers on the adjustment model and proposed resolution strategies. (5.3.2)
- Omission of data points (5.3.2)
- Decision to use a time-series adjustment to improve adjust model. (5.3.3)
- All conversion factors used to convert various units to the choses common energy unit (5.4)

9.3. Energy Savings Calculation Report

The Energy Savings Calculation Report is the third part of the M&V Report.

The Energy Savings Calculation Report details the adjustment models created and the resulting energy savings calculated. For each type of energy included in the energy accounting plan, the Energy Savings Calculation Report must include, but is not limited to:

- Information detailing all hypothesis models for the model form that is ultimately used that meet the statistical requirements, why the final models for each energy type were selected over other statistically valid models, any proposed extension to the baseline period, any proposed alterations to the Energy Data Collection Plan, and key conversations with the customer (7.1)
- The final models (coefficients and relevant variables and associated units) (7.1)
- Scatter diagram graphs used to confirm a linear relationship between data for energy consumption of each type of energy for which energy savings are being determined and each relevant variable (7.2.1).
- Discussions related to the visual relationship between relevant variables and energy types (7.2.1)
- Energy consumption adjustment model parameters (including the relevant variables, units, and associated coefficients used to make the models) (7.3)
- Documentation of validity tests and values for each adjustment model (7.4.2)
- For each adjustment model, a scatter diagram of observed (actual) energy consumption versus the energy consumption calculated using the adjustment model. (7.4.2)
- Each adjustment model must be supported by documentation including validity statistics, and graphics (7.4.4)
    - Coefficient values reported to six significant figures
    - R^2 value
    - Coefficient of Variation
    - Net Determination Bias
    - Overall F-Test p-value
    - P-value of each relevant variable
    - XY scatterplots for each relevant variable
    - Time-series graphs for each relevant variable
    - Scatterplot of actual versus predicted energy consumption
    - Time series graph of actual versus predicted energy consumption
    - Time-series graph of residuals and/or cumulative residuals, with bands at +/- 3 standard deviations and +/-2.5% annual energy consumption as the axis scale.

- If applicable, reasons why a forecast adjustment model cannot be created (7.5)
- Method for making non-routine adjustments and the rationale for that method (7.5.1)
- Energy savings for each type of energy individually and in aggregate (8.3) for each type of savings as outlined in Annex E.

10. References

- ASHRAE Guideline 14:2014 – Measurement of Energy, Demand and Water Savings
- Bonneville Power Administration Monitoring Tracking and Reporting Reference Guide, Revision 5.0, February 20, 2015
- Energy Trust of Oregon Energy Intensity Modeling Guideline, Version 1.1, January 27, 2016
- International Performance Measurement and Verification Protocol – Option C, January 2012.
- ISO 50015:2014 – Measurement and verification of energy performance of organizations – General principles and guidance
- ISO 50047:2016 – Determination of energy savings in organizations
- U.S. Department of Energy Superior Energy Performance Measurement and Verification Protocol, July 2016

Annex A - Special Cases in Energy Accounting

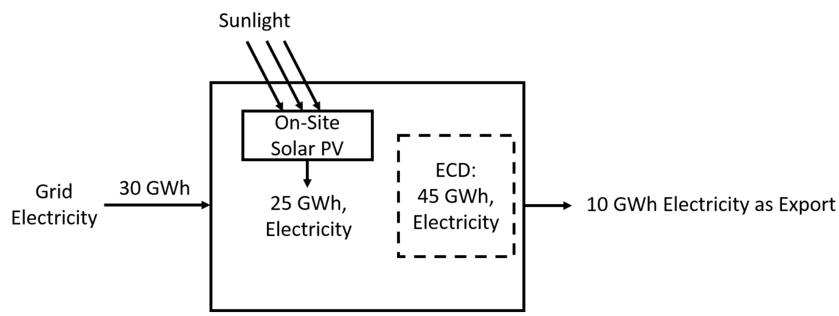
Energy Accounting of Energy Export and Energy Product

Energy delivered away from the facility boundaries shall be accounted for as either an energy export or energy product.

Energy Export

The maximum allowable amount of energy export is equal to the quantity of energy delivered into the facility boundary of the same energy type such that a net zero level is reached on a delivered energy basis. A facility may not be counted as a net negative consumer of any energy type.

EXAMPLE: A facility purchases 30 GWh of grid electricity and produces 25 GWh of electricity with on-site photovoltaic (PV) panels. The facility consumes 45 GWh and delivers 10 GWh away from the facility boundaries. The 10 GWh delivered away from the facility boundaries is treated as energy export. See figure below.

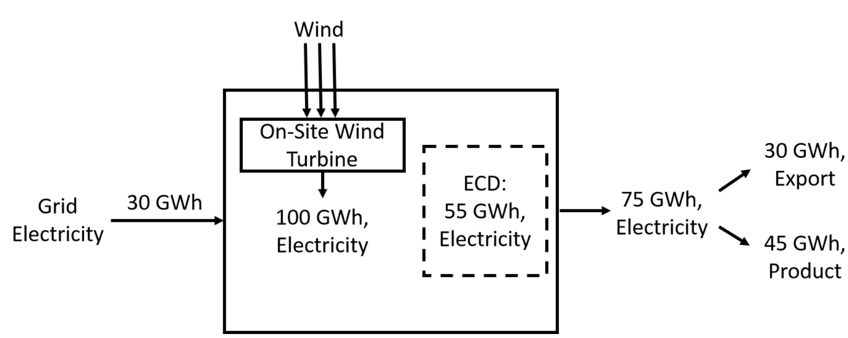


$$\mathrm{ECD(e)} = 30\ \mathrm{GWh} + 25\ \mathrm{GWh}\ -\ 10\ \mathrm{GWh} = 45\ \mathrm{GWh}$$

Energy Product

For each energy type, if a net zero level is reached on a delivered energy basis, any excess energy delivered away from the facility boundaries is accounted for as an energy product. This may result from a facility producing large quantities of on-site energy. Energy product shall be considered as a relevant variable for adjustment models.

EXAMPLE: A facility purchases 30 GWh of grid electricity and generates 100 GWh of electricity with on-site wind turbines. The facility consumes 55 GWh and delivers 75 GWh away from the facility boundaries. A maximum quantity of 30 GWh is treated as energy export. The remaining 45 GWh is treated as energy product. See figure below.



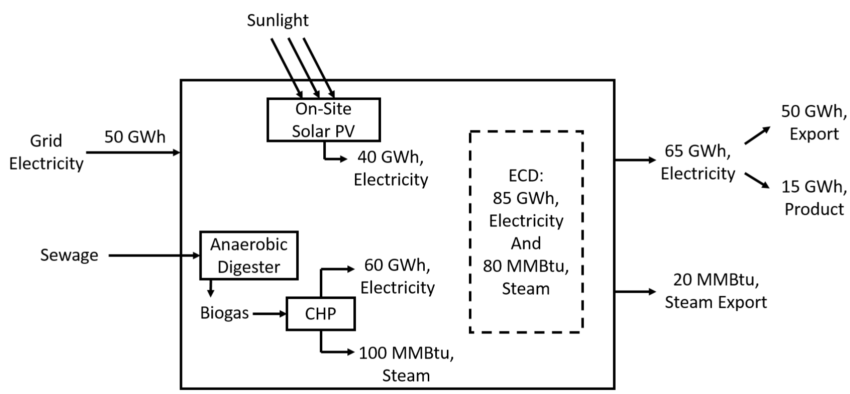
$$\mathrm{ECD(e)} = 30\ \mathrm{GWh} + 100\ \mathrm{GWh} - 30\ \mathrm{GWh} - 45\ \mathrm{GWh} = 55\ \mathrm{GWh}$$

On-site Extraction or Generation of Energy from Natural Resources

Energy from natural resources that are delivered into and consumed within or delivered away from the facility boundaries shall be included in the energy accounting. The point at which on-site extracted or generated energy is metered and accounted for may be selected by the organization so long as it is at a reasonable point along the extraction or generation process flow (e.g., a facility may choose to meter biogas flow and energy content or the resulting electricity and hot water generated from the utilization of the same biogas). This measurement point shall be consistent between the baseline and reporting periods. This allowance is made recognizing that the quantity of energy of some natural resources (e.g., photons or wind) or the energy derived thereof (e.g., biogas) may be difficult to meter. In such cases, the quantity of energy generated within the facility boundaries from the natural resource (e.g., AC electricity from the inverter of a PV panel system) may be metered and included in the energy accounting.

NOTE: While metering energy at a point along the extraction or generation process flow downstream of the facility boundaries may be simpler and more cost effective (e.g. metering hot water produced from a biogas fired boiler, rather than the biogas produced from a sewage fed digester), the effect of energy performance improvement actions implemented upstream of the point of metering may not be reflected in the calculated facility-wide energy performance improvement.

EXAMPLE: A wastewater treatment facility uses sewage to generate biogas, which is used to generate electricity and steam in a CHP system. The facility also purchases grid electricity, and generates on-site electricity with an array of PV panels. As the facility cannot cost-effectively install meters to measure biogas flow and energy content, the facility decides to meter the electricity and steam coming out of the CHP system for energy accounting purposes. In one month, the biogas CHP system produces 60 GWh of electricity and 100 MMBTU of steam. The facility purchases 50 GWh of grid electricity and generates 40 GWh of on-site electricity with the PV panels. The facility consumes 85 GWh of electricity and delivers 65 GWh of electricity away from the facility boundaries. The facility consumes 80 MMBTU of steam and delivers 20 MMBTU away from the facility boundaries. See figure below.



Electricity: $\mathrm{ECD(e)} = 50\ \mathrm{GWh} + 60\ \mathrm{GWh} + 40\ \mathrm{GWh} - 50\ \mathrm{GWh} - 15\ \mathrm{GWh} = 85\ \mathrm{GWh}$

Feedstock and Resulting Energy Types

In some instances, energy delivered to the facility boundaries may be used as a feedstock rather than consumed as energy. The portion of an energy type used as a feedstock shall be subtracted from the delivered energy. The commodity that is being produced from the feedstock shall be considered as a relevant variable in the energy consumption adjustment model.

Any energy types resulting from the processing of feedstock (e.g., process gas produced during the refining process, heat generated by an exothermic reaction, biogas generated from sewage) that are consumed within or delivered away from the facility boundaries shall be included in the energy accounting.

EXAMPLE: A facility purchases 1000 Therms of natural gas and uses 750 Therms to produce hydrogen, which is sold as a commodity, while consuming the other 250 Therms within the facility boundary in a boiler. The energy accounting shall include 250 Therms. The production quantity of hydrogen shall be considered as a relevant variable in the energy consumption adjustment model.

Annex B - Selecting Production Relevant Variables

Raw material, in-line production, and finished product metrics each have pros and cons that shall be considered when selecting production relevant variables. An informed decision will take into account factors such as lead time, the desire to account for yield effects, as well as the prevalence of inventory fluctuations in-process or at the finished-product stage.

Table 4: Options for Production Variable Measurement Points

Measurement Points	Pros	Cons
Raw material input	Provides a mechanism for capturing the effects of different types of raw materials.	Fails to provide a mechanism for understanding energy impact of yield/productivity improvements.
In-line metric	Allows for the selection of a production variable at energy-intensive processes, thereby minimizing a time-series shift.	Fails to provide a mechanism for incentivizing the energy impact of yield/productivity improvements downstream, from point of measurement.
End-of-line metric	Provides a mechanism for incentivizing the energy impact of yield/productivity improvements.	May induce a time-series shift for long lead-time processes.
Finished product shipped	Data can be captured via accounting systems.	May not sync with production depending on dwell time in the warehouse.

Assess where production data is available, relative to the energy-intensive process steps. If a significant time offset exists between the energy-intensive process step and the measurement point, consider adding a time-shift in interval data to align the production data with energy data.

If multiple production variables are available, use process flow diagrams and energy maps to identify potential interactive effects and correlations. Using multiple measurement points in the same process line may not be necessary or beneficial.

Annex C - Multicollinearity

Multicollinearity is present when two or more relevant variables in a regression model are correlated between themselves. When two relevant variables are correlated, including both variables, instead of just one, may not add appreciably to the model's explanatory power.

Keep the following points in mind when validating an adjustment model:

- The presence of correlated variables should serve as a warning that the statistical significance of a variable in a particular regression does not, by itself, indicate how closely that variable is correlated with energy consumption. The modeler should use caution in excluding any variables that may actually be relevant variables, but are masked by correlated variables.
- Multicollinearity has limited influence on the predictive capability of the final model if operating conditions stay relatively consistent. However, if the relationship between the correlated relevant variables changes during the reporting period, the model will lose predictive power.
- Multicollinearity can be identified by using XY scatterplots to view the relationship between two relevant variables. Additionally, the coefficients in a model will swing drastically if a variable with multicollinearity is added or removed.
- Perform a general assessment of multicollinearity by regressing each variable against the other hypothesis variables and examine the R^2 of each relationship. As a rule of thumb, any bivariate correlation with $R^2 > 0.7$ is an indication that multicollinearity needs to be carefully considered in the variable selection process.
- Multicollinearity can also be identified by calculating the variance inflation factor (VIF), which describes the increase in standard error compared to the standard error if the variable were uncorrelated with the other predictor variables.
- The simplest solution to addressing multicollinearity is to drop one of the variables from the regression analysis. However, this approach may negatively affect the model's predictive capability. The modeler should use his/her best engineering judgment along with an understanding of how the customer's facility uses energy to include or exclude variables, while considering factors such as data availability and model complexity.

  EXAMPLE: At a soft drink bottling facility, energy consumption and production increase in the summer, due to higher seasonal sales. Both energy and production show a strong correlation with ambient, dry bulb temperature. The modeler includes the production variable in the adjustment model, but is unsure whether to include the ambient temperature variable. In this example, plot the production variable against the temperature variable to determine the correlation. If the R^2 is greater than 0.7, consider removing the temperature variable from the model. Justify the decision using engineering knowledge about the temperature dependency of equipment and loads at the facility.

Annex D - Autocorrelation

Autocorrelation is present when the error term in a time period is related to the error term in a prior time period. In other words, autocorrelation is characterized by a correlation in the residuals.

Calculate the autocorrelation coefficient and plot model residuals over the baseline period. If autocorrelation is detected, the number of independent baseline points is effectively reduced. The typical remedy involves increasing the sample size, or selecting a different data interval. For annual models with daily baseline intervals, moderate autocorrelation may not be a concern.

Typically, regression-based energy models exhibit positive autocorrelation. Positive auto-correlation occurs when the sign change of the residuals is infrequent. Conversely, too frequent sign changes in the residual pattern results in negative autocorrelation.

There is no defined threshold for the autocorrelation coefficient in the model development phase. Autocorrelation becomes a factor in the fractional savings uncertainty analysis when it has the mathematical effect of reducing performance period energy data samples.

The Durbin-Watson test can also be used to determine if autocorrelation is statistically significant. For uncorrelated errors, the Durbin-Watson number, d, should be approximately 2. The upper and lower bounds for the Durbin-Watson statistic are a function of sample size, the number of predictor variables and desired confidence level.

Annex E – Addressing Incented and Custom Capital Projects in Relation to California Industrial SEM Programs

California Industrial SEM programs take a facility-wide approach to the determination of energy savings. Because of this, in some instances the energy savings that result from the implementation of projects incented through other programs (such as custom capital projects) must be netted out of this facility-wide energy saving value.

This Annex provides details for how to account for energy savings resulting from the implementation of projects incented outside SEM.

Custom capital projects, in this context, are defined as technology based energy efficiency projects that are designed and implemented specifically for a given industrial facility and for which the outlay of required capital is considered large with respect to other energy efficiency projects undertaken by the facility.

In all cases, the SEM Implementer, or Coach shall work with the facility and utility to complete an Opportunity Register. The Opportunity Register includes shall include details about all identified and implemented energy performance improvement actions, whether incented outside of SEM or not. These energy performance improvement actions could be capital, behavioral, operational, or other. Care shall be taken to identify energy performance improvement actions that were identified, or for which implementation was begun but not been completed, prior to the SEM engagement. As part of the Opportunity Register, documentation demonstrating the implementer and utility influence on the identification and decision to implement actions that were identified prior to the SEM engagement shall be included.

At the start of the SEM engagement, the implementer, working with the utility and facility, is responsible for the creation of, and subsequent updates to, a "Scoping Report." This Scoping Report is detailed in the Design Guide and includes a summary of custom capital projects (incentivized and non-incentivized) that are included as part of the Opportunity Register before the start of the SEM engagement. The Scoping Report provides information beyond what is required of the Opportunity Register including inclusion of historical records documenting the identification and subsequent implementation (if applicable) of each project and if the project had been identified prior to the SEM engagement.

The process by which to determine how to address energy savings resulting from custom capital projects can be divided into two cases:

1. In which an incented project (i.e. custom capital project) has been identified prior to the SEM engagement, and
2. In which an incented project (i.e. custom capital project) has been identified during the SEM engagement.

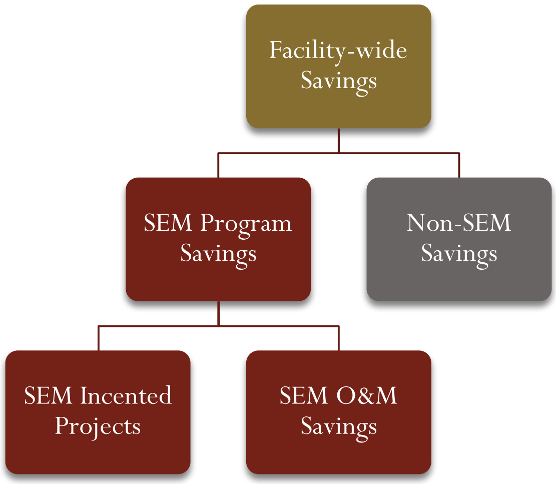
Energy savings terminology for California industrial SEM programs

Savings for California Industrial SEM programs will be reported as follows:

1. ***Facility-wide Energy Savings***: The overall savings the facility achieved during the reporting period. This includes all savings listed below and is used by the facility to estimate their performance improvement versus goal.
2. ***Non-SEM Savings***: Pre-existing projects identified and planned prior to SEM engagement and implemented during the SEM engagement, whether receiving incentives or not.
3. ***SEM Program Savings***: Facility-wide Energy savings minus Non-SEM Savings, used by the program to calculate program effectiveness.

4. ***SEM Incented Project Savings***: Incented projects (i.e. custom projects) identified, planned, and implemented during the SEM engagement receiving incentives at or near the incentive rate for another program (i.e. “capital project” incentive rate).
5. ***SEM O&M Savings***: SEM Program Savings minus SEM Incented Project Savings.

Below is a visual representation of the savings.



Case 1 – In which an incented (i.e. custom capital) project has been identified prior to the SEM engagement

For projects included in the Scoping Report that were identified prior to the SEM engagement, the treatment of resulting energy savings will be determined by whether the utility has or will be providing an incentive.

1. Pre-existing incented or custom capital projects completed during SEM engagement and receiving a utility incentive:
    a. Savings from any incented or custom capital projects receiving an incentive must be netted out of the SEM savings. Project savings will be calculated using the custom project M&V process.
    b. These projects will be reported as “Non-SEM Savings” by the SEM implementer
2. Pre-existing custom capital projects completed during SEM engagement not receiving utility incentives that are not influenced by the SEM program:
    a. These projects will not be M&V’ed by the utility, savings cannot be accurately recorded without some level of program effort.
    b. Savings will be estimated with best available engineering calculations based on data available and collected by the program.
    c. Savings will be backed out of “Facility Savings” as “Non-SEM Savings”.
3. Pre-existing custom capital projects not receiving utility incentives that are influenced by the SEM program.
    a. The program will delineate where project planning was prior to SEM engagement. Similar to any other capital projects in the custom capital track, the program must be able to prove program influence and must calculate NTG according to custom capital project rules and processes. Potential program influence may include:
        i. Project was identified but lacked sufficient information to act on the project (i.e. no calculations of savings, no cost estimates, no identified owner or timeline) and SEM program assisted in defining and

implementing the project. The SEM program must show its influence on the project definition and implementation (i.e. development of calculations, cost estimates, timelines, implementation plans, etc.).

ii. Project was identified and had information to act but SEM program influenced to go to more efficient option. The program must show its influence on the more efficient option selected (i.e. efficient options presented to the customer, calculations created with customer, etc.)

iii. Project was identified and planned for the long-term but the SEM program significantly accelerated implementation. The SEM program must show its influence on implementation timeline.

Case 2 – In which an incented (i.e. custom capital) project is identified during the SEM engagement

The SEM implementer, with assistance from the utility and facility, must document how the incented or custom capital project was identified, establish program influence on the project, planned implementation date, etc., per custom capital project guidelines and processes. If the project was identified during the SEM "Treasure Hunt", the Treasure Hunt Report must document that project and the role the program took in identifying and documenting the project. This project must be included in the Opportunity Register.

For projects included in the Opportunity Register that were identified during the SEM engagement, the treatment of resulting energy savings will be determined by whether the utility has or will be providing an incentive.

1. If the project is completed during SEM engagement and qualifies for a custom program incentive:
    a. The project will receive an incentive near the current custom capital project incentive rate
    b. Project savings will be estimated using custom capital project M&V process
    c. As outlined in the M&V Guide, the project savings will be deducted from the facility-wide savings
    d. The project will follow custom capital projects M&V requirements (ex ante, ex post, etc.) and savings will be estimated using processes outlined in current custom project processes.
    e. Project savings will be reported as "SEM Custom Savings" by the Coach.
2. If the project is completed during SEM engagement but does not qualify for custom project incentives:
    a. Project savings will be kept in the SEM Program Savings and will be incented per the SEM O&M incentive level.
3. If project is identified during SEM engagement, qualifies for a custom program incentive, but is not completed during the SEM engagement (i.e. facility "drops out" of SEM after two years and completes project in year 3)
    a. Project will be treated as a custom project and will follow custom project M&V processes for projects that are not finished during an engagement.

Annex F – Establishing Statistical Confidence

Fractional savings uncertainty (FSU) analysis is a method for judging the validity of energy savings based on regression modeling. FSU is not a requirement of this Guide or reports but should be considered and is highly recommended. This annex is included as an informational piece for consideration when evaluating energy savings and as a basis from which future versions of this Guide may further develop guidance or requirements. A deeper analysis of FSU is provided in ASHRAE Guideline 14-2002 Annex B.

The fractional uncertainty can be estimated as follows:

$$\frac{\Delta E_{save,m}}{E_{save,m}} = t \cdot \frac{1.26 \cdot CV((\frac{n}{n'})(1+\frac{2}{n}) \cdot \frac{1}{m})^{\frac{1}{2}}}{F}$$

Where:

- t= t-statistic for desired confidence level
- CV= coefficient of variation
- n= number of observations in the baseline period
- m = number of observations in the reporting period
- F= observed savings during reporting period
- n'= number of independent baseline period observations
- ρ= auto-correlation coefficient

$$n' = n\frac{(1-\rho)}{(1+\rho)}$$

ASHRAE Guideline 14-2002, Section 5.3.2.2 specifies that the level of uncertainty must be less than 50% of the annual reported savings, at a confidence level of 68%.

While the preceding methodology is generally applied to analyze savings uncertainty in an ex-post analysis, the same analysis can be used to inform model development, for example, FSU can assist with the following decisions:

- Relevant variable selection
- Minimum number of reporting period observations
- Minimum energy savings needed to make the model statistically meaningful

Though not required, FSU and the guidance of ASHRAE Guideline 14-2002 would promote that if the uncertainty in the modeled savings is higher than 50% at a 68% confidence interval, the baseline model should be adjusted.

The below table provides additional information for difference uncertainty scenarios.

Fractional Savings Uncertainty Scenarios

Daily Model

68% confidence, 365 baseline intervals, 90 reporting intervals

	F (% savings)				
CV	**2.5%**	**5.0%**	**10.0%**	**15.0%**	**20.0%**
0.03	23%	12%	6%	4%	3%
0.05	46%	23%	12%	8%	6%
0.10	92%	46%	23%	15%	12%
0.15	139%	69%	35%	23%	17%
0.20	185%	92%	46%	31%	23%
0.30	277%	139%	69%	46%	35%

68%	confidence
1.00	T-stat
365	baseline intervals
90	reporting intervals
0.5	autocorrelation coefficient
121.67	n-prime

Weekly Model

68% confidence, 52 baseline intervals, 13 reporting intervals

	F (% savings)				
CV	**2.5%**	**5.0%**	**10.0%**	**15.0%**	**20.0%**
0.03	47%	23%	12%	8%	6%
0.05	93%	47%	23%	16%	12%
0.10	187%	93%	47%	31%	23%
0.15	280%	140%	70%	47%	35%
0.20	374%	187%	93%	62%	47%
0.30	561%	280%	140%	93%	70%

68%	confidence
1.00	T-stat
52	baseline intervals
13	reporting intervals
0.25	autocorrelation coefficient
31.20	n-prime

Monthly Model

68% confidence, 12 baseline intervals, 3 reporting intervals

	F (% savings)				
CV	**2.5%**	**5.0%**	**10.0%**	**15.0%**	**20.0%**
0.03	82%	41%	20%	14%	10%
0.05	164%	82%	41%	27%	20%
0.10	327%	164%	82%	55%	41%
0.15	491%	246%	123%	82%	61%
0.20	655%	327%	164%	109%	82%
0.30	982%	491%	246%	164%	123%

68%	confidence
1.04	T-stat
12	baseline intervals
3	reporting intervals
0	autocorrelation coefficient
12.00	n-prime

Notes: ASHRAE guidelines specify 50% uncertainty at 68% confidence.
100% uncertainty means that the savings are not negative.
Uncertainty higher than 100% means there is a chance that savings are negative.
Monthly models will generally not show autocorrelation.
Daily and weekly models will generally show autocorrelation. Usually the addition of production data lowers the autocorrelation.