50001 Ready Measurement & Verification Protocol

Revision Date: 19 April 2017

U.S. DEPARTMENT OF ENERGY

TABLE OF CONTENTS

1. Introduction

Energy savings associated with the U.S. Department of Energy (U.S. DOE) 50001 Ready program are determined at the facility level.

1.1 The 50001 Ready Measurement & Verification Protocol

The *50001 Ready M&V Protocol* (50001 Ready M&V Protocol) is derived from the 2017 version of the *Superior Energy Performance M&V Protocol* (SEP M&V Protocol). The SEP M&V Protocol sets forth the verifiable methodology for determining and demonstrating achievement of the energy performance improvement level claimed by an organization for a defined facility as part of the Superior Energy Performance (SEP) program. The 50001 Ready M&V Protocol is not suitable for use as part of the performance verification required of the SEP program.

Excluding section 1, the structure and headings of the 50001 Ready M&V Protocol are identical to that of the SEP M&V Protocol. Differences between the SEP M&V Protocol and the 50001 Ready M&V Protocol, or the lack thereof, are identified at the start of each section.

1.2 50001 Ready M&V Protocol Approach to Determining Energy Performance Improvement

Determination of energy performance improvement includes accounting for energy consumption, normalization for relevant variables through adjustment modeling, and calculation of energy performance improvement. The determination and demonstration of energy performance improvement per the 50001 Ready M&V Protocol follows the top-down approach of determining facility-wide (facility boundaries based) energy performance improvement.

Top-down energy performance improvement is based upon facility-wide energy consumption by accounting of all energy types that are delivered into or away from the facility boundaries. Top-down energy performance improvement is calculated in the 50001 Ready M&V Protocol as both energy savings and the ratio of baseline period to reporting period facility-wide consumption, with adjustments to make the two periods comparable.

The bottom-up approach of determining energy savings, which is used in the SEP M&V Protocol as a comparison, is not used in the 50001 Ready Protocol.

1.3 The Energy Performance Indicator Tool Lite

The U.S. DOE has developed the Energy Performance Indicator Tool Lite (EnPI Lite) for use in determining facility-wide energy performance improvement. EnPI Lite follows the requirements of this 50001 Ready M&V Protocol. EnPI Lite determines energy performance improvement for one, multiple, or all energy types (source) for the established facility boundaries.

1.4 The 50001 Ready Program

The 50001 Ready program is offered by the U.S. DOE to recognize industrial, commercial, governmental, and institutional facilities for efforts to implement an energy management system (EnMS) that is based upon the requirements of ISO 50001 and demonstrate a level of energy performance improvement. This 50001 Ready M&V Protocol should not be assumed to constitute the energy performance reporting requirements of the 50001 Ready program. 50001 Ready program participants should refer to the program website for complete energy performance reporting requirements.

1.5 About this Version

The 50001 Ready M&V Protocol is derived from the 2017 version of the SEP M&V Protocol. In addition to following the structure and key principles of the SEP M&V Protocol, this 50001 Ready M&V Protocol is consistent with the principles of *ISO 50015:2014 – Measurement and verification of energy performance of organizations* and compatible with *ISO 50047:2016 – Determination of energy savings in organizations*.

2. Normative References

No referenced documents are indispensable for the application of the 50001 Ready M&V Protocol.

3. Terminology and Reference Notation

3.1 Terminology

- This section has been changed from the 2017 version of the SEP M&V Protocol:

The following terms apply. Definitions for these terms can be found in Annex E.

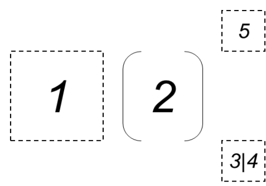
- achievement period
- baseline period
- boundaries
- coefficient of determination (R^2)
- delivered energy
- energy
- energy accounting
- energy consumption
- energy performance
- F-test
- facility
- feedstock
- non-routine adjustment
- normalization
- organization
- p-value
- primary energy
- regression
- relevant variable
- reporting period

- static factor

3.2 Reference Notation

- This section has been changed from the 2017 version of the SEP M&V Protocol:
  - Select notation that is specific to the SEP program has been removed:
    - Base notation – SEnPI, and
    - Modeled period – standard conditions.
  - Added notation for ESP_{TD}.

This section describes the notation used in this Protocol. The energy consumption and savings notation is designed to distinguish quantities in the format shown below. Annex A provides a table of all notation used in this Protocol.



1. **Base Notation:** Describes if the energy consumption or savings is for delivered or primary 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.

6. Base Notation

ECP(*)	Primary energy consumption of an unspecified energy type
ECD(*)	Delivered (site) energy consumption of an unspecified energy type
E(*)	Quantity of energy of an unspecified type
ESP(*)	Primary energy savings of an unspecified energy 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
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. $\mathrm{ECP}(\Sigma) = \sum_{*} \mathrm{ECP}(*)$ Example: if observed baseline primary energy types are “e” and “ng”, then $\mathrm{ECP}(\Sigma) = \mathrm{ECP}(\mathrm{e}) + \mathrm{ECP}(\mathrm{ng})$

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

b	Baseline period
r	Reporting period

8. 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

ESP_{TD}	Primary energy savings as determined by the top-down approach
ESD_{TD}	Delivered energy savings as determined by the top-down approach

4. Facility Boundaries and Time Periods

4.1 Facility Boundaries

- This section has been changed from the 2017 version of the SEP M&V Protocol:
  - Minor text changes to reflect the differences in 50001 Ready and SEP requirements, and
  - Reference to the SEP program has been removed.

The organization shall establish facility boundaries for which an energy performance improvement value will be determined. The facility boundaries may be the same or a subset of the boundaries of the organization and its energy management system if one is in place.

Facility boundaries are considered three-dimensional, thus energy accounting shall include energy that enters the facility boundaries from the sky and ground if consumed at the facility (such as water heated by the sun and oil from an on-site well).

The facility boundaries shall not change between the baseline and reporting periods.

4.2 Selection of Time Periods

- This section has been changed from the 2017 version of the SEP M&V Protocol:
  - Minor text changes to reflect the differences in 50001 Ready and SEP requirements, and
  - Baseline and reporting periods must be 12 months, no longer or shorter.

The determination of energy performance improvement is based upon the energy consumption of the baseline and reporting periods. The baseline and reporting periods are each 12 consecutive months (1 year) long to account for variations in operations and seasonality.

The achievement period begins immediately following the conclusion of the baseline period and can be of any duration. The length of the achievement period does not need to be a multiple of 12 months (i.e., 12 or 36 months long). The end of the reporting period and achievement period shall align.

Figure 1 provides an illustrative example of the relationship between time periods.

FIGURE 1: RELATIONSHIP BETWEEN BASELINE, REPORTING, AND ACHIEVEMENT PERIOD

5. Energy Accounting

5.1 Energy Consumption Data

- This section has been changed from the 2017 version of the SEP M&V Protocol:
  - Clarified that energy consumption adjustment models and energy savings are calculated in primary energy while energy accounting can be conducted with both primary and delivered energy then converted to primary energy, and
  - Minor text changes to reflect the differences in 50001 Ready and SEP requirements.

The determination of energy performance improvement shall extend to all types of energy consumed within the facility boundaries. Subsequently, energy accounting includes the quantities of all energy types delivered into and away from the facility boundaries, using metered data as well as selected relevant variables that affect energy consumption. Use of existing utility meters may be sufficient to conduct energy accounting at many facilities. Requirements of energy accounting are presented in this section. Special cases of energy accounting are presented in Annex C.

Data sufficient to determine the facility energy consumption during the baseline and reporting period shall be collected. This includes the quantity and energy content of each energy type and relevant variables included in the energy accounting.

Facility energy consumption is accounted for in terms of primary and delivered energy. Energy consumption adjustment models and energy savings are based upon primary energy. The collection of delivered energy data will be of use in determining primary energy quantities.

Annex B provides details on how to convert various types of energy from typically available units to common units and from a delivered to primary energy basis.

Data quantifying relevant variables that affect energy consumption shall be collected as part of the energy accounting.

The outputs of the energy accounting are used to determine energy consumption for the baseline and reporting periods. Data shall be collected at least monthly, though it may be necessary or desirable to collect data more frequently.

5.1.1 Primary and Delivered Energy

- This section has been changed from the 2017 version of the SEP M&V Protocol:
  - References to the requirements of the SEP program have been removed.

All energy types delivered into and away from the facility boundaries shall be accounted for on a delivered energy basis and converted to a primary basis. Energy consumption values from a bill (e.g., electricity from the utility) are typically reported as delivered energy. Conversion from delivered to primary energy accounts for the losses in generation, transmission, and distribution of various energy types. Conversion of delivered energy of an unspecified type to primary energy is expressed by Equation 1:

Eq (1) $$\mathrm{ECP}(*) = \mathrm{m}(*) \times \mathrm{ECD}(*)$$

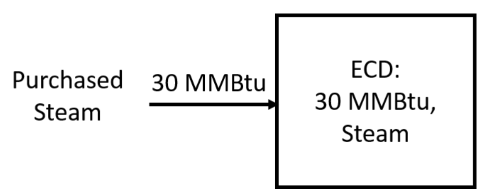
Where $\mathrm{m}(*)$ is the primary energy conversion factor for the unspecified type of energy. The primary energy conversion factor is comprised of two separate terms, the energy conversion multiplier ($\mathrm{ecm}(*)$) and the electricity generation multiplier ($\mathrm{egm}(*)$). Equation 2 expresses this relationship:

Eq (2) $$\mathrm{m}(*) = \mathrm{ecm}(*) \times \mathrm{egm}(*)$$

Annex B provides a list of common energy conversion and electricity generation multipliers for energy types from various sources. Alternative energy conversion and electricity generation multipliers to those listed in Annex B may be used. The choice of $\mathrm{m}(*)$, $\mathrm{ecm}(*)$, and $\mathrm{egm}(*)$ for each energy type shall be maintained and used consistently both in the baseline and reporting periods.

> NOTE: For a given type of energy multiple values of $\mathrm{m}(*)$ may be required. For example this may be the case when electricity is delivered to a facility via the grid as well as produced on-site from a photovoltaic panel. These multiple values of $\mathrm{m}(*)$ should be appropriately used in Equation 3.

EXAMPLE: A facility purchases and consumes 30 MMBTU of steam generated in a natural gas fired boiler at a neighboring facility. Annex B lists an $\mathrm{ecm}(*)$ of 1.33 and an $\mathrm{egm}(*)$ of 1.00 for “steam: fired boiler”, $\mathrm{m}(*)$ is thus 1.33 (1.33 x 1.00).



$$\mathrm{ECD(st)} = 30\ \mathrm{MMBTU}$$

$$\mathrm{ECP(st)} = (1.33\ \mathrm{x}\ 1.00)\ \mathrm{x}\ 30\ \mathrm{MMBTU} = 39.9\ \mathrm{MMBTU}$$

5.1.2 Measurement of Energy Consumption

- This section is unchanged from the 2017 version of the SEP M&V Protocol

The energy consumption of each 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, primary 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 should be taken to ensure energy export and energy product are correctly accounted for.

Equation 3 describes how to calculate energy consumption on a primary energy basis for each type of energy. Conversion of delivered energy to primary energy shall be conducted with primary energy factors prior to determining the energy performance improvement. Figure 2 graphically illustrates this relationship.

Eq (3)
$$\begin{aligned} \mathrm{ECP}(*) = {} & \mathrm{m}(*) \text{ x } [\mathrm{E}(*) \text{ delivered to the facility } - \mathrm{E}(*) \text{ delivered away as export}] + \\ & \mathrm{m}(*) \text{ x } [\mathrm{E}(*) \text{ onsite generation/extraction } - \mathrm{E}(*) \text{ delivered away as product}] + \\ & \mathrm{E}(*) \text{ drawn out of storage } - \mathrm{E}(*) \text{ added to storage } - \mathrm{E}(*) \text{ used as feedstock} \end{aligned}$$

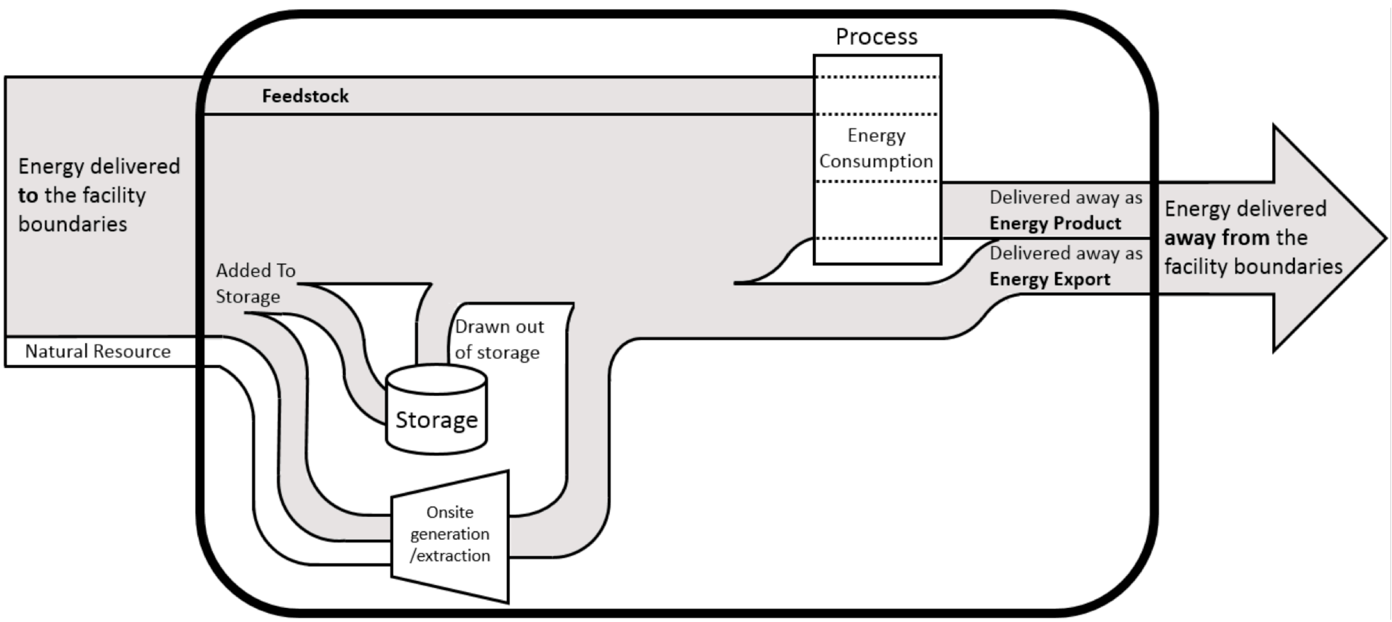


FIGURE 2: GENERIC ENERGY CONSUMPTION ACCOUNTING FLOW DIAGRAM

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 or taken from a supplier invoice. Meters 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.

The energy content of various energy types (the amount of energy potentially available within each unit of energy) may vary with factors such as density or heating value. Conversion factors from units as sold (e.g. cubic feet, gallons, or tons) to energy units may be available from the supplier. For most fuel types, information regarding the energy content per unit volume is typically available from the fuel supplier. The energy units for fuels shall be converted to the common energy unit being used for the energy accounting. The higher heating value (HHV) of energy types shall be used to calculate delivered energy units.

Data for energy consumption and relevant variables will frequently not be available for exact calendar months or for exactly aligned time intervals. For example, monthly production data may be reported on the first of the month, while utility data may be provided mid-month. Energy data may be collected at irregular intervals; for example, with bulk fuels if deliveries are unequally spaced in time but shall still be metered on an at least monthly basis as it is consumed. Alignment of time intervals is preferred and may facilitate development of more representative adjustment models, but it is not required.

5.1.3 Types of Energy with Relatively Insignificant Consumption

- This section is unchanged from the 2017 version of the SEP M&V Protocol

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 primary 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 primary energy basis. The determination to omit energy types may be based on measured or calculated data.

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.

5.1.4 Special Cases in Energy Accounting

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - The sub-sections contained in section 5.1.4 have been moved to Annex C.

5.2 Expressing Energy Consumption in Common Units

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - Removed reference to the SEP required bottom-up calculation

A common energy unit (e.g., kWh, BTU, Mtoe, Joules) shall be selected and used consistently as part of the energy accounting. A common energy unit allows for comparison and aggregation of the absolute and consumption of multiple energy types. All conversation factors used to convert various units to the chosen common energy unit shall be used consistently for the baseline and reporting periods and maintained. Annex B lists conversion factors useful for converting from commonly measured energy units to MMBTU.

5.3 Energy Consumption and Non-Routine Adjustments for the Time Periods of Interest

- This section is unchanged from the 2017 version of the SEP M&V Protocol

5.3.1 Establishing the Baseline and Reporting Period Energy Consumption

- This section is unchanged from the 2017 version of the SEP M&V Protocol

For each type of energy included in the energy accounting, an unadjusted energy baseline is established for the baseline period. Additionally, an unadjusted total energy baseline for the facility is established by summing the energy consumption of all energy types during the baseline period.

Similarly, unadjusted energy consumption for each type of energy consumed within the facility boundaries shall be established for the reporting period. The total of unadjusted energy consumption during the reporting period for the facility is then established by summing the energy consumption across all energy types in the reporting period.

5.3.2 Non-Routine Adjustments

- This section has been changed from the 2017 version of the SEP M&V Protocol:
  - The third bullet of examples of events that might require a non-routine adjustment has been modified as it references the encouragement of the SEP program to increase biomass utilization has been removed and
  - Reference to obtaining SEP Administrator approval prior to using a non-routine adjustment has been removed.

Energy consumption may be affected by relevant variables and static factors during the baseline and reporting periods. Normalization through adjustment modeling is used to account for regular changes in relevant variables. 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 reporting 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.
- A facility increases the amount of biomass consumed as energy. The efficiency of a biomass combustion system is typically less than that of systems that utilize conventional fossil fuels. If a participating facility shifts to using a greater amount of biomass, a non-routine adjustment may be used to compare reporting period to baseline period energy consumption as if the extent of biomass consumption were the same in both periods.
- 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.

5.4 Relevant Variables

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - The requirement that activity level and weather *shall* be considered as relevant variables has been changed to that they *should* be considered.

Relevant variables are variables that directly affect the amount of energy consumed within the facility boundaries and are used to normalize energy consumption as part of an adjustment model. When developing an adjustment model, care shall be taken to avoid both (1) omitting relevant variables that affect energy consumption and (2) including variables that are not relevant to energy consumption. Variables are excluded from the model if there is no logical mechanism by which the variable would affect the consumption of the energy types being modeled.

Data quantifying relevant variables is collected as part of the energy accounting process. 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 because they lack a physical relationship to energy consumption.

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

For any type of facility (industrial and commercial) the following should be considered:

- Activity level (e.g., occupancy, operating hours, production level, and equivalent products)
- Weather (e.g., heating degree-day, cooling degree-day, and humidity)

5.5 Data Sources and Quality

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - The requirement that all data sources be of sufficient quality to be verifiable by a SEP Performance Verifier has been removed,
    - The requirement that calibration records and records of repairs to calibrated meters shall be maintained, the exemption of utility meters from calibration records keeping, calibration

requirements for scales, acceptability of previously submitted reports, and requirements on weather data sources has been removed,
  - The requirements on weather data sources have been converted to guidance as a note,
  - The requirement that energy consumption and relevant variable data shall be screened for anomalous values has been changed to should be screened,
  - The requirement to retain records of the removal of data outliers has been removed, and
  - The requirement that if anomalies in data are determined to be a data error that they shall be corrected if possible has been change to should be corrected if possible.

All data sources used as part of the energy accounting, including those for energy consumption and relevant variables, should be of sufficient quality to ensure reasonable results. Data should be taken from precise control and/or measurement systems, such as revenue 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.

Calibration of meters should follow manufacturer's recommendations.

> NOTE: Weather data should be actual weather data from the baseline and reporting periods, from published government sources, such as primary National Oceanic and Atmospheric Administration (NOAA) weather stations, or from a calibrated weather meter within close enough proximity to the facility to reflect the weather conditions at the facility.

Energy consumption and relevant variable data should 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.

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 should be corrected if possible; otherwise deleted from the model.

6. Normalization for Relevant Variables – Adjustment Modeling

6.1 General Principles of Normalization

- This section is unchanged from the 2017 version of the SEP M&V Protocol

Normalization of energy consumption through the use of adjustment models shall be made so that baseline and reporting periods 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.

6.2 Methods of Normalization

- This section has been changed from the 2017 version of the SEP M&V Protocol:
  - Two methods are allowed to create adjustment models as part of the 50001 Ready M&V Protocol, four methods are allowed as part of the SEP M&V Protocol. The standard conditions and chaining methods are not allowed.

Two methods are allowed to create adjustment models. The same adjustment model method shall be used for each energy type consumed within the facility boundaries.

6.2.1 Forecast Normalization

- This section is unchanged from the 2017 version of the SEP M&V Protocol.

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 ($\mathrm{ECP}(\Sigma)^{\mathrm{a}}_{\mathrm{b|r}}$) for comparison with observed (actual) reporting period energy consumption ($\mathrm{ECP}(\Sigma)^{\mathrm{o}}_{\mathrm{r}}$). 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.

6.2.2 Backcast Normalization

- This section is unchanged from the 2017 version of the SEP M&V Protocol.

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

6.2.3 Standard Condition Normalization

- This section has been changed from the 2017 version of the SEP M&V Protocol:
  - The use of standard conditions normalization is not included in the 50001 Ready M&V Protocol and has been removed.

6.2.4 Chaining Normalization

- This section has been changed from the 2017 version of the SEP M&V Protocol:
  - The use of chaining normalization is not included in the 50001 Ready M&V Protocol and has been removed.

6.2.5 Summary of Normalization Methods

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - The use of chaining and standard conditions normalization is not included in the 50001 Ready M&V Protocol and has been removed.

TABLE 1: SUMMARY OF NORMALIZATION METHODS

	Forecast	Backcast
Reporting period energy consumption	Actual reporting period energy consumption	Reporting period model using baseline period conditions
Baseline period energy consumption	Baseline period model using reporting period conditions	Actual baseline period energy consumption
Intermediate period energy consumption	Not applicable	Not applicable
Operating characteristics the model is representing	Baseline period operating systems and practices	Reporting period operating systems and practices

6.3 Determination of Normalized Energy Consumption

- This section is unchanged from the 2017 version of the SEP M&V Protocol.

6.3.1 General

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - Reference to the chaining and standard conditions method was removed.

Use of the forecast and backcast normalization methods requires computation of adjusted energy consumption with an adjustment model. An adjustment model is created using observed (actual) energy consumption and relevant variable data (as determined using the energy accounting requirements described in Section 5) from either the baseline or reporting periods. The period whose data is used to create the model is the adjustment model period. The adjustment model is then applied to conditions (relevant variable values) from a different period. The result is adjusted energy consumption representing the systems and operations of the adjustment model period, at the conditions (relevant variable values) of the application conditions.

6.3.2 Creating an Adjustment Model

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - Indicated that one model shall be created for each type of energy regardless of the number of sources of that type of energy, and
    - Removed reference to model from 1 (ratio of energy consumption to a single relevant variable) and model from 3 (complex regression).

An adjustment model shall be created that describes primary energy consumption as a function of relevant variables for each energy type included in the energy accounting. Energy types for which there are multiple sources (e.g., grid delivered electricity and on-site PV generated electricity should be converted to primary energy with common units and then aggregated for use in creating a single electricity model). The starting date and duration of the period for which adjustment models for all energy types are created shall be the same. The resulting adjusted energy consumption values for each energy type are then summed to determine an adjusted total energy consumption value.

However, in some instances it is advantageous to aggregate the consumption of multiple energy types prior to modeling (e.g. electricity consumption includes multiple sources such as the grid and on-site PV panels). If the following three conditions are met then the energy consumption of one more energy types may be summed together prior to being modeled in aggregate:

1. All energy consumption units are converted to a common energy unit (e.g., BTU, Joules, kWh) using document multipliers and are converted to primary energy.
2. The period during which the data to be summed was collected is the same for all energy types.
3. The model for the combined energy types satisfies validity requirements (Section 6.4).

A minimum of 12 months of data are required when creating an adjustment model. 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 6.4 are met. Data reported at intervals of one hour or less may be summed or averaged to weekly or monthly totals.

The sole adjustment model form that may be used is described below.

Model Form: Linear Regression

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

Eq (4) $$ECP(*) = b_0 + b_1x_1 + b_2x_2 + \ldots + b_kx_k$$

where x_i is the relevant variable quantity, b_0 is ideally the base load primary energy consumption not related to relevant variables, and b_i is the incremental energy consumption per unit of that relevant variable (coefficient) where b_i should be greater than 0.

6.4 Validity Requirements

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - Removed reference to multiple model forms.

Adjustment models used to calculate adjusted energy consumption shall satisfy the validity requirements described in this section.

6.4.1 Model Validity Testing

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - Added language clarifying the purpose and use of the F-test.

For the adjustment model to be considered valid, all the following shall be demonstrated:

- An F-test for the overall model fit shall have a p-value less than 0.10 (i.e., the overall fit of the adjustment model is statistically significant greater than the 10% significance level).
    - An F-test is used to test the overall statistical significance of a regression model, regardless of the number of variables used in the regression model. The F-test compares a particular regression model against an intercept-only model. If the p-value calculated from the F-statistic and model degrees of freedom is less than 0.10, then one can reject the intercept-only model in favor of the regression model. The regression model is considered statistically significant (i.e. at least one of the regression variables used in the model has a “significant” effect on energy consumption)
- All included relevant variables in the model shall have a p-value less than 0.20.
- At least one of the relevant variables in the model shall have a p-value less than 0.10.
- The coefficient of determination (R^2) for the regression shall be 0.50 or greater.
- 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.

  NOTE: EnPI Lite applies all quantitative statistical validity tests. Review of the qualitative validity test must be condusted by the EnPI Lite user.

6.4.2 Validity of Applying Adjustment Models to Relevant Variables

- This section is unchanged from the 2017 version of the SEP M&V Protocol.

The validity of applying adjustment models to relevant variables shall be tested through quantitative and qualitative tests.

6.4.2.1 Valid Quantitative Range of Model Relevant Variables

- This section is unchanged from the 2017 version of the SEP M&V Protocol.

For the adjustment model to be valid for calculating adjusted energy consumption, the mean of the adjustment model’s relevant variables used to calculate the adjusted energy consumption shall fall within either:

- The range of observed relevant variable data that went into the model, or
- 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.

6.4.2.2 Valid Qualitative Factors

- This section is unchanged from the 2017 version of the SEP M&V Protocol.

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

- No substantial difference between the two periods in product types.
- Meters used were functioning, calibrated and maintained as appropriate.

6.5 Creating Adjustment Models for Different Operating Modes

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - The use of multi-mode models is not supported by EnPI Lite and is thus not included in the 50001 Ready program and as such multi-mode models have been removed from the 50001 Ready M&V Protocol. For details on how to conduct multi-mode modeling please see the SEP M&V Protocol.

6.6 Facility Subsets

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - The use of facility subsets is not supported by EnPI Lite and is thus not included in the 50001 Ready program and as such facility subsets have been removed from the 50001 Ready M&V Protocol. For details on how to modeling using facility subsets please see the SEP M&V Protocol.

7. Calculation of Energy Performance Improvement

- The title of this section has been changed from the 2017 version of the SEP M&V Protocol:
    - Reference to the SEP program has been removed

7.1 Calculating the Energy Performance Indicator Ratio

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - Reference to SEnPI, the SEP specific EnPI metric, has been removed, and
    - Details about how to calculate an EnPI Ratio using the chaining normalization approach has been removed.

An Energy Performance Indicator (EnPI) Ratio is calculated as a prerequisite to determining the facility-wide energy performance improvement percentage. The EnPI Ratio is a ratio of the facility-wide, reporting period total energy consumption and baseline period total energy consumption, where the energy consumption of one or both periods is adjusted so that they correspond to consistent conditions of relevant variables (Equation 5). The EnPI Ratio is calculated on a primary energy basis. An EnPI Ratio value less than 1.0 indicates that energy performance has improved.

Eq (5) $$\text{EnPI Ratio} = \frac{\text{ECP}(\Sigma)_r}{\text{ECP}(\Sigma)_b}$$

Where $\text{ECP}(\Sigma)_r$ and/or $\text{ECP}(\Sigma)_b$ have been adjusted depending upon the normalization method utilized.

Table 2 lists the notation used to refer to the actual and adjusted energy consumption for each method, as well as the data used to create the model and the data used to apply the model.

TABLE 2: USE OF OBSERVED AND ADJUSTED ENERGY CONSUMPTION FOR THE VARIOUS NORMALIZATION METHODS

		Normalization Methods	
		Forecast	Backcast
Energy Consumption Quantity	Reporting Period $\text{ECP}(\Sigma)_r$	Observed (actual) $\text{ECP}(\Sigma)_r^o$	Adjusted to baseline conditions $\text{ECP}(\Sigma)_{r\|b}^a$
	Baseline Period $\text{ECP}(\Sigma)_b$	Adjusted to reporting period conditions $\text{ECP}(\Sigma)_{b\|r}^a$	Observed (actual) $\text{ECP}(\Sigma)_b^o$
EnPI Ratio		$\frac{\text{ECP}(\Sigma)_r^o}{\text{ECP}(\Sigma)_{b\|r}^a}$	$\frac{\text{ECP}(\Sigma)_{r\|b}^a}{\text{ECP}(\Sigma)_b^o}$

7.2 Calculating the Energy Performance Improvement Percentage

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - Reference to SEnPI, the SEP specific EnPI metric, has been removed, and
    - Reference to the *SEP Certification Protocol* and *SEP Scorecard* has been removed.

The energy performance improvement percentage is calculated as:

Eq (6) Energy performance improvement percentage = (1-EnPI Ratio) x 100

8. Bottom-Up Comparison

8.1 Purpose of the Bottom-Up Comparison

- This section has been changed from the 2017 version of the SEP M&V Protocol:
    - The use of the bottom-up comparison is not part of the 50001 Ready M&V Protocol and has been removed.

8.2 Register of Implemented Energy Performance Improvement Actions (Register)

- This section has been changed from the 2017 version of the SEP M&V Protocol:

- The use of the bottom-up comparison is not part of the 50001 Ready M&V Protocol and has been removed.

8.3 Conducting the Bottom-Up Comparison

- This section has been changed from the 2017 version of the SEP M&V Protocol:
  - The use of the bottom-up comparison is not part of the 50001 Ready M&V Protocol and has been removed.

9. Accounting for Carbon Dioxide Emissions

- This section is not found in the 2017 version of the SEP M&V Protocol and is new to the 50001 Ready M&V Protocol.

Carbon Dioxide (CO_2) emissions savings determination shall be performed. Carbon Dioxide emissions shall be determined using actual (i.e. unadjusted), delivered energy consumption.

Carbon Dioxide emissions from all energy consumed onsite (except for those identified in section 5.1.3), including purchased energy sources such as grid electricity or district steam, shall be accounted for. Emissions shall be reported in units of Metric Tons. Emissions are calculated by multiplying unadjusted, delivered energy consumption by the corresponding CO_2 emissions factor for each energy type:

Eq (7) $$\text{Metric Tons of CO}_2 = \sum_{i=1}^{n} (EF \ x \ ECD)_i$$

Where:

- EF = Emissions factor
- n = Number of energy types

Emissions factors represent the amount of CO_2 released per unit of energy consumed.

- Electricity generated onsite using solar, wind, or other such renewable type of energy shall be accounted for separately from grid delivered electricity.
- A CO_2 emissions factor of zero shall be used for electricity generated onsite using solar, wind, or other such renewable type of energy.
- Grid purchased electricity shall use an appropriate CO_2 emissions factor from eGrid 2014 or later.
- District steam and heat shall use the emissions factor given in the “Emission Factors for Greenhouse Gas Inventories” published by the U.S. EPA.
- Any energy type that is directly combusted/reacted onsite for energy consumption purposes resulting in the release of CO_2 from the facility shall use an appropriate emissions factor from the Electronic Code of Federal Regulations (e-CFR) Table C-1 to Subpart C of Part 98 of Title 40: “Default CO_2 Emission Factors and High Heat Values for Various Types of Fuel”.

NOTE: In EnPI Lite, CO_2 emissions are calculated for the baseline and reporting periods in order to calculate Metric Tons of CO_2 saved from the baseline to reporting periods.

An example of the application of CO_2 emissions savings for a wastewater facility is provided in Annex D.

10. References

- This section is unchanged from the 2017 version of the SEP M&V Protocol. In the 2017 version of the SEP M&V Protocol this section is section 9.

The following standard references apply to the 50001 Ready M&V Protocol.

- ISO 50001
- ANSI/MSE 50021
- ISO 17747
- ISO 50003
- ANSI/MSE 50028
- *Superior Energy Performance Scorecard*
- *Superior Energy Performance Certification Protocol*

Annex A - Informative: Reference Notation used in this Protocol

All reference notation uses are listed in this annex. This list does not preclude the utilization of other nomenclature combinations but is simply an informative listing.

TABLE 3 – REFERENCE NOTATION

$\mathrm{E}(*)$	Quantity of energy of an unspecified type
$\mathrm{ECD}(*)$	Delivered energy consumption of an unspecified energy type
$\mathrm{ECP}(*)$	Primary energy consumption of an unspecified energy type
$\mathrm{ECP}(\mathrm{e})$	Primary energy consumption of the energy type “electricity”
$\mathrm{ECP}(\mathrm{ng})$	Primary energy consumption of the energy type “natural gas”
$\mathrm{ECP}(\mathrm{st})$	Primary energy consumption of the energy type “steam”
$\mathrm{ECP}(\Sigma)$	Primary energy consumption of all energy types
$\mathrm{ECP}(\Sigma)_{\mathrm{b}}^{\mathrm{o}}$	Observed (actual) baseline period energy consumption
$\mathrm{ECP}(\Sigma)_{\mathrm{r}}^{\mathrm{o}}$	Observed (actual) reporting period energy consumption of all energy types
$\mathrm{ECP}(\Sigma)_{\mathrm{b}\mid\mathrm{r}}^{\mathrm{a}}$	Modeled baseline period primary energy consumption adjusted to reporting period conditions
$\mathrm{ECP}(\Sigma)_{\mathrm{r}\mid\mathrm{b}}^{\mathrm{a}}$	Modeled reporting period primary energy consumption adjusted to baseline period conditions
$\mathrm{ESD}(*)$	Delivered energy savings of an unspecified energy type
$\mathrm{ESP}(*)$	Primary energy savings of an unspecified energy type
$\mathrm{m}(*)$	Primary energy conversion multiplier for the unspecified type of energy
$\mathrm{ecm}(*)$	Energy conversion multiplier for the unspecified type of energy
$\mathrm{egm}(*)$	Electricity generation multiplier for the unspecified type of energy

Annex B - Informative: Energy Multipliers

- This section is unchanged from the 2017 version of the SEP M&V Protocol.

This annex provides unit conversion factors to convert from commonly available units to energy units in BTUs. If an alternative common energy unit is used, the user must document and apply correct unit conversion factors for the alternative unit.

This annex provides defaults value for calculating primary energy from delivered energy. Primary energy consumption (in BTU) is calculated by multiplying the delivered energy (in BTU) by a primary energy conversion multiplier ($m(*)$), which is the sum of the energy conversion multiplier ($ecm(*)$) and electricity generation multiplier ($egm(*)$).

TABLE 4 - CONVERSION FACTORS FOR DELIVERED ENERGY [1]

Energy Type	Measurement Units	Unit Conversion Factor		Energy Conversion Multiplier	Electricity Generation Multiplier
Steam: fired[2] boiler	pounds	Per steam tables[3]	BTU/lb	1.33	1.0
Steam: electric[4] boiler	pounds	Per steam tables[3]	BTU/lb	1.0	3.0
Hot water: fired[2] boiler	gallons x °F	8.34	BTU/(gal °F)	1.33	1.0
Hot water: electric[4] boiler	gallons x °F	8.34	BTU/(gal °F)	1.0	3.0

[1] These values calculated using mechanical engineering references such as Marks' Standard Handbook for Mechanical Engineers, 10th Edition. Eugene Avallone and Theodore Baumeister III.McGraw Hill. 1996.
[2] Multiplier calculated using 1/combustion efficiency, assuming efficiency of 75%
[3] Must know steam temperature and pressure. Values taken from steam tables should subtract out the enthalpy (BTU/lb) of water at inlet conditions. Also, need to know the steam quality if operating in a two-phase region. Steam tables used, whether online or in books, should be based on the International Association for the Properties of Water and Steam (IAPWS). The details of this formulation are found in "Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use" by W. Wagner and A. Pruss, 7 June 2002. (http://www.nist.gov/data/PDFfiles/jpcrd617.pdf)
[4] 3.0 is the default factor for primary energy to grid-delivered electrical energy. The facility should use the same factor for converting electricity from the grid throughout their calculations.

Energy Type	Measurement Units	Unit Conversion Factor		Energy Conversion Multiplier	Electricity Generation Multiplier
Chilled water[5]: fired[2], absorption chiller	ton-hours	12,000	BTU/ton-hour	1.25	1.0
Chilled water[5]: fuel, engine driven compressor	ton-hours	12,000	BTU/ton-hour	0.83	1.0
Chilled water[5]: electric[4]	gallons x ^{o}F	8.34	BTU/(gal ^{o}F)	0.24	3.0
Compressed air[6]	cubic feet (ft$^{3)}$	10.93	BTU/ft^{3}	1.0	3.0
Grid-based electricity	kWh	3,412	BTU/kWh	1.0	3.0
Solar-based electricity	kWh	3,412	BTU/kWh	1.0	1.0
Wind-based electricity	kWh	3,412	BTU/kWh	1.0	1.0
Geothermal based electricity	kWh	3,412	BTU/kWh	1.0	1.0
Solar or geothermal hot water or steam	BTU	1		1.0	1.0
Agricultural residues[7]	pounds	6,800 - 10,000	BTU/lb	1.0	1.0
Herbaceous crops[7]	pounds	7,791	BTU/lb	1.0	1.0
Woody crops[7]	pounds	8,852	BTU/lb	1.0	1.0

[5] Multiplier calculated using 1/COP. COP = coefficient of performance. It measures the relationship between the heat supplied or removed from a system and the work output from the system.

[6] Compressed air default value assumes a motor driven compressor at 100 psi only. The value of compressed air as an energy source under other conditions can be calculated using site-specific conditions of delivered pressure, the efficiency of the compression equipment for the compression ratio needed at the delivered pressure, the altitude, the efficiency of the part load control mechanisms and controls, and the efficiency of the motor(s), engines, or turbines driving the compression equipment.

[7] Biomass Unit Conversion factors (Higher Heating Values) should be taken from the Oak Ridge National Laboratory *Biomass Energy Data Book – Appendix A*. This reference also outlines a methodology for accounting for material moisture content.

Energy Type	Measurement Units	Unit Conversion Factor		Energy Conversion Multiplier	Electricity Generation Multiplier
Forest residues[7]	pounds	7,082	BTU/lb	1.0	1.0
Urban residues[7]	pounds	5,600 - 11,800	BTU/lb	1.0	1.0
Other biogas / biomass / biofuel[7]	Varies	See Appendix A of ORNL *Biomass Data Book*	Convert to BTU	1.0	1.0
Still gas[7]	ft^3	1,584	BTU/ft^3	1.0	1.0
Digester gas[7]	ft^3	619	BTU/ft^3	1.0	1.0
Natural gas[7]	therms	100,000	BTU/therm	1.0	1.0
Hydrogen gas[7]	ft^3	343	BTU/ft^3	1.0	1.0
Liquid hydrogen[7]	pounds	60,964	BTU/lb	1.0	1.0
Coal[7]	See invoice	See invoice for higher heating value	Convert to BTU	1.0	1.0
Petroleum coke[7]	pounds	13,460	BTU/lb	1.0	1.0
Propane[7]	pounds	21,597	BTU/lb	1.0	1.0
Crude oil[7]	gallons	138,350	BTU/gal	1.0	1.0
Conventional gasoline[7]	gallons	124,340	BTU/gal	1.0	1.0
Low-sulfur gasoline[7]	gallons	121,848	BTU/gal	1.0	1.0
U.S. conventional diesel[7]	gallons	137,380	BTU/gal	1.0	1.0
Low-sulfur diesel[7]	gallons	138,490	BTU/gal	1.0	1.0

Annex C - Informative: Special Cases in Energy Accounting

- This section is unchanged from the 2017 version of the SEP M&V Protocol having been moved from section 5.1.4 to this Annex.

Energy Accounting of Energy Export and Energy Product

- This section is unchanged from the 2017 version of the SEP M&V Protocol

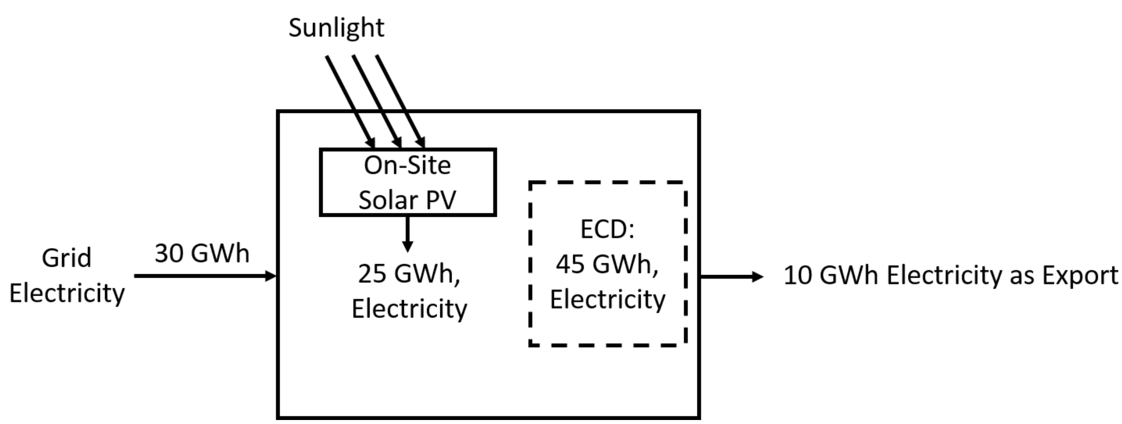
Energy delivered away from the facility boundaries shall be accounted for as either an energy export or energy product.

ENERGY EXPORT

- This section is unchanged from the 2017 version of the SEP M&V Protocol

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 primary energy basis. A facility may not be counted as a net negative consumer of any energy type. An energy export is converted to primary energy using the same multiplier as the energy type that was delivered to the facility (m1(*) in Equation 3).

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. The energy streams are converted to energy consumption on a primary energy basis. See figure below.



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

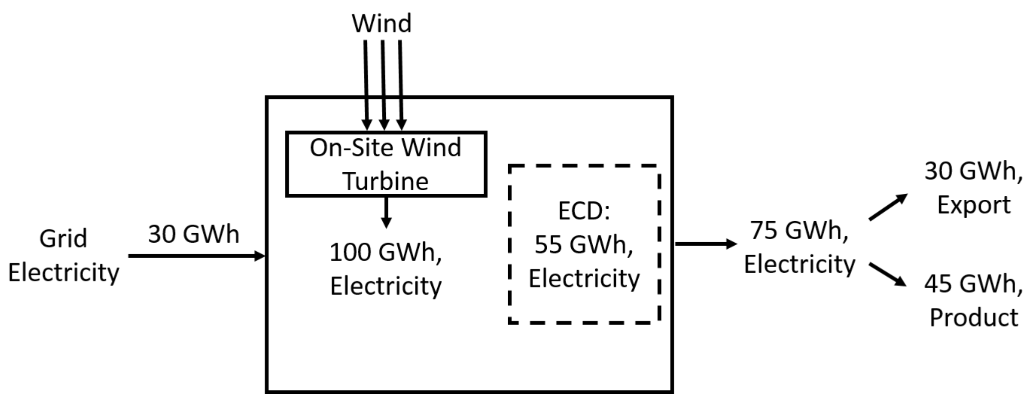
$$\mathrm{ECP(e)} = (3.0\ \mathrm{x}\ 30\ \mathrm{GWh}) + (1.0\ \mathrm{x}\ 25\ \mathrm{GWh}) - (3.0\ \mathrm{x}\ 10\ \mathrm{GWh}) = 85\ \mathrm{GWh}$$

ENERGY PRODUCT

- This section is unchanged from the 2017 version of the SEP M&V Protocol

For each energy type, if a net zero level is reached on a primary 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. An energy product is converted to primary energy using the same multiplier as the energy type that was generated or extracted on-site within the facility boundaries (m2(*) in Equation 3).

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. The energy streams are converted to energy consumption on a primary energy basis. See figure below.



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

$$\text{ECP(e)} = (3.0\text{ x }30\text{ GWh}) + (1.0\text{ x }100\text{ GWh}) - (3.0\text{ x }30\text{ GWh}) - (1.0\text{ x }45\text{ GWh}) = 55\text{ GWh}$$

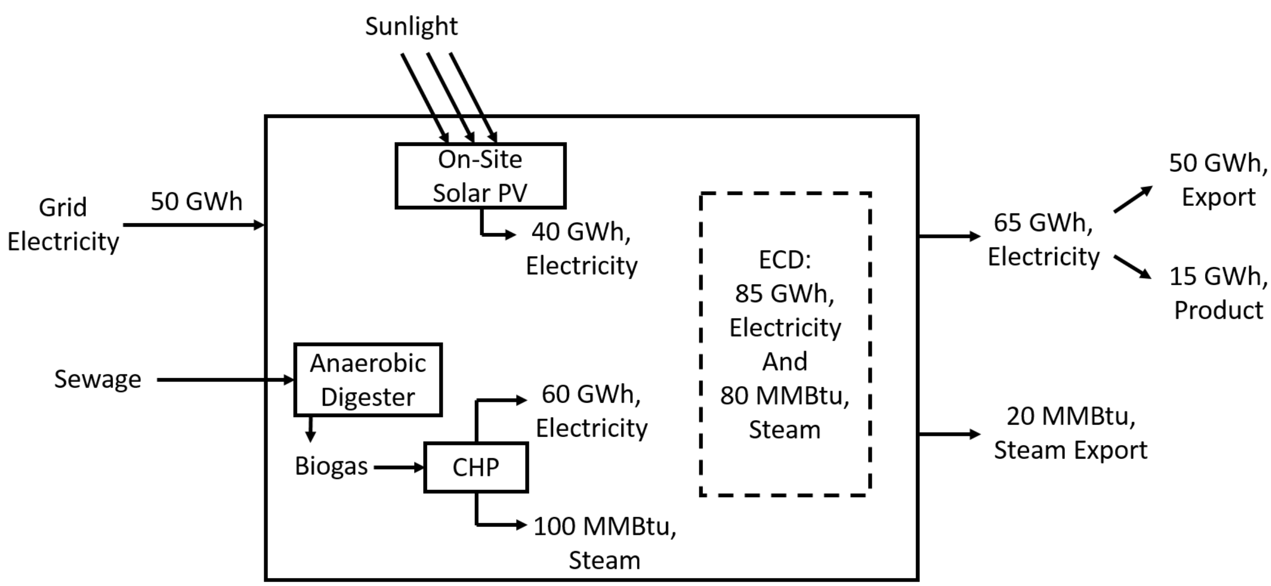
On-site Extraction or Generation of Energy from Natural Resources

- This section is unchanged from the 2017 version of the SEP M&V Protocol

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. Annex B provides multipliers for various types of energy extracted or generated from natural resources.

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. The energy streams are converted to consumption on a primary energy basis. See Annex B for conversion and primary energy multipliers for electricity and steam, as well as the conversion to common units. See figure below.



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

$$\mathrm{ECP(e)} = (3.0 \times 50\ \mathrm{GWh}) + (1.0 \times 60\ \mathrm{GWh}) + (1.0 \times 40\ \mathrm{GWh}) - (3.0 \times 50\ \mathrm{GWh}) - (1.0 \times 15\ \mathrm{GWh}) = 85\ \mathrm{GWh}$$

Steam: $\mathrm{ECD(st)} = 100\ \mathrm{MMBtu} - 20\ \mathrm{MMBtu} = 80\ \mathrm{MMBtu}$

$$\mathrm{ECP(st)} = (1.00 \times 100\ \mathrm{MMBTU}) - (1.00 \times 20\ \mathrm{MMBTU}) = 80\ \mathrm{MMBTU}$$

In the case that energy from an on-site extracted or generated natural resource is mixed with a delivered energy type, such as sawdust produced from the processing of timber mixed with coal in a boiler or natural gas mixed with on-site generated biogas in a gas turbine, both energy types shall be metered before they are consumed.

EXAMPLE: A sawmill uses sawdust along with coal in a boiler to raise steam within the facility boundaries. Coal deliveries are invoiced with the total weight and heating value. The sawdust is weighed and the heating value is determined from the Oak Ridge National Laboratory's *Biomass Energy Data Book*.[8] The energy consumption is calculated and converted to common units using information from Annex B.

Waste Heat Recovery

- This section is unchanged from the 2017 version of the SEP M&V Protocol

Waste heat recovery is considered an energy performance improvement action and not explicitly included in the energy accounting. Implementation of waste heat recovery may result in a reduction of energy consumption of one or more energy types that cross into the facility boundaries resulting in energy performance improvement. Alternatively, waste heat recovery may increase delivery of energy away from the facility boundaries.

EXAMPLE: In the baseline period a facility purchases 100 barrels of oil and uses 75 barrels to generate steam in a boiler and 25 barrels of oil to heat water for domestic purposes. After implementing a boiler waste heat recovery system used to preheat water fed to the water heater, the hot water heater only needs to consume 10 barrels of oil to meet the hot water demand. Assuming all other factors remain constant, the reporting period energy consumption will be 15 barrels of oil less than in the baseline period.

Feedstock and Resulting Energy Types

- This section is unchanged from the 2017 version of the SEP M&V Protocol

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

[8] Biomass Unit Conversion factors (heating values) shall be taken from the Oak Ridge National Laboratory *Biomass Energy Data Book – Appendix A* if possible. This reference also outlines a methodology for accounting for material moisture content.

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 100 barrels of oil and uses 75 barrels of oil to produce gasoline, which is sold as a commodity, while consuming the other 25 barrels of oil within the facility boundary in a boiler. As a byproduct of the refining process, 50 MMBTU of process gas is produced on-site. This process gas is consumed within the facility boundaries. The energy accounting shall include 25 barrels of oil and 50 MMBTU of process gas. The production quantity of gasoline shall be considered as a relevant variable in the energy consumption adjustment model.

Annex D - Informative: Example of CO_2 Emissions Savings Determination

- This section is not found in the 2017 version of the SEP M&V Protocol and is new to the 50001 Ready M&V Protocol.

EXAMPLE: A wastewater treatment facility installs solar PV panels during the Achievement Period. The facility consumes Electricity, Natural Gas, and Biogas. Emissions factors are taken from eGrid 2014 and Table C-1 of Title 40 CFR.

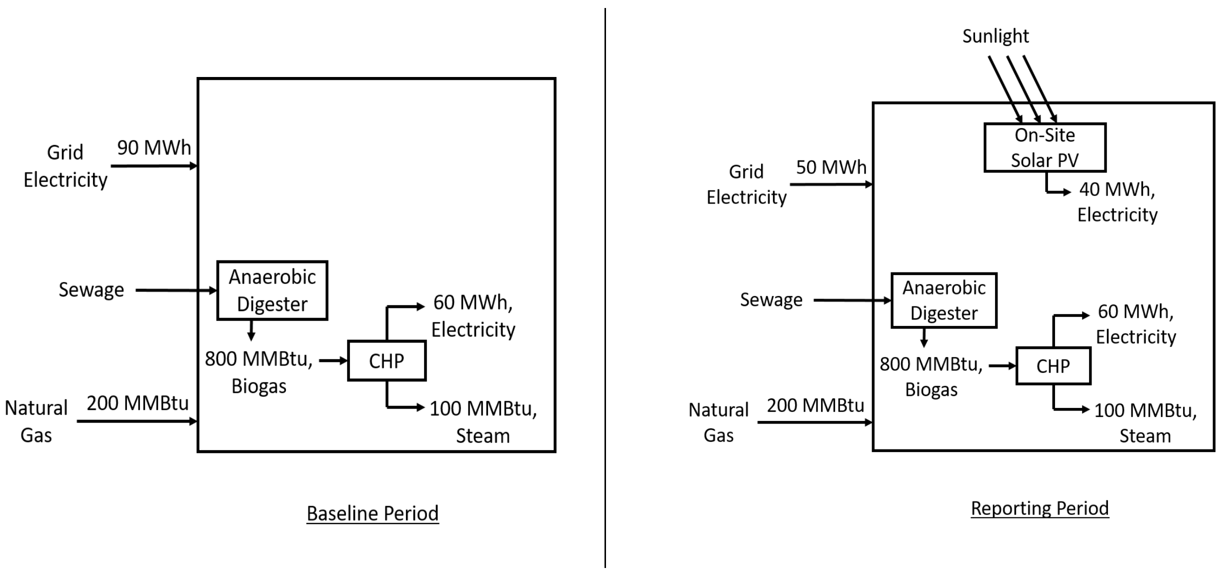
<u>Emissions Factors</u>

Grid Electricity (EF_{GE}) = $1122.9 \frac{\cancel{\text{lbs}}\ \text{CO}_2}{\text{MWh}}\ x\ \frac{1\ \text{MT}}{2204.62\ \cancel{\text{lbs}}} = 0.5093 \frac{\text{MT CO}_2}{\text{MWh}}$

Natural Gas (EF_{NG}) = $53.06\ \frac{\cancel{\text{kg}}\ \text{CO}_2}{\text{MMBtu}}\ x\ \frac{1\ \text{MT}}{1000\ \cancel{\text{kg}}} = 0.05306 \frac{\text{MT CO}_2}{\text{MMBtu}}$

Biogas (EF_{BG}) = $52.07\ \frac{\cancel{\text{kg}}\ \text{CO}_2}{\text{MMBtu}}\ x\ \frac{1\ \text{MT}}{1000\ \cancel{\text{kg}}} = 0.05207 \frac{\text{MT CO}_2}{\text{MMBtu}}$

On-Site Solar (EF_S) = $0 \frac{\text{MT CO}_2}{\text{MWh}}$



$$\text{Baseline Period CO}_2\ \text{Emissions} = (EF_{GE}\ x\ 90\ \text{MWh}) + (EF_{NG}\ x\ 200\ \text{MMBtu}) + (EF_{BG}\ x\ 800\ \text{MMBtu})$$

$$\text{Baseline Period CO}_2\ \text{Emissions} = \left(0.5093 \frac{\text{MT CO}_2}{\text{MWh}}\ x\ 90\ \text{MWh}\right) + \left(0.05306 \frac{\text{MT CO}_2}{\text{MMBtu}}\ x\ 200\ \text{MMBtu}\right) +$$

$$\left(0.05207\frac{\text{MT CO}_2}{\text{MMBtu}}\ x\ 800\ \text{MMBtu}\right)$$

$$\text{Baseline Period CO}_2\ \text{Emissions}\ = 98.105\ \text{MT CO}_2$$

$$\text{Reporting Period CO}_2\ \text{Emissions}\ = (EF_{GE}\ x\ 50\ \text{MWh}) + (EF_{NG}\ x\ 200\ \text{MMBtu}) + (EF_{BG}\ x\ 800\ \text{MMBtu}) + (EF_S\ x\ 40\ \text{MWh})$$

$$\text{Reporting Period CO}_2\ \text{Emissions}\ = \left(0.5093\frac{\text{MT CO}_2}{\text{MWh}}\ x\ 50\ \text{MWh}\right) + \left(0.05306\frac{\text{MT CO}_2}{\text{MMBtu}}\ x\ 200\ \text{MMBtu}\right) + \left(0.05207\frac{\text{MT CO}_2}{\text{MMBtu}}\ x\ 800\ \text{MMBtu}\right) + \left(0\frac{\text{MT CO}_2}{\text{MWh}}\ x\ 40\ \text{MWh}\right)$$

$$\text{Reporting Period CO}_2\ \text{Emissions}\ = 77.733\ \text{MT CO}_2$$

$$\text{CO}_2\ \text{Emissions Savings} = 98.105\ \text{MT CO}_2 - 77.733\ \text{MT CO}_2 = 20.372\ \text{MT CO}_2$$

NOTE: The electricity and steam produced by the CHP are not included in the equation above. The CO_2 is accounted for at the source of emission generation (i.e. the biogas and natural gas combusted in the CHP system).

Annex E - Normative: Terminology

- This section is not found in the 2017 version of the SEP M&V Protocol and is new to the 50001 Ready M&V Protocol.
    - This Annex will be removed from the 50001 Ready M&V Protocol when a common EnMS terminology website is provided by the U.S. DOE.

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”)

Coefficient of Determination (R^2): a measure of the proportion of variance of a predicted outcome.
Note 1: with a value of 0 to 1, the coefficient of determination is calculated as the square of the correlation coefficient (R) between the sample and predicted data.

Delivered energy: energy arriving at the boundary(ies)
Note 1: delivered energy includes primary energy produced (such as oil from a well) or renewable energy used within the facility boundaries to produce derived energy (such as solar, wind, or geothermal energy used to generate electricity on-site) as they arrived from outside the facility boundaries.
Source: ISO 50047:2016 3.3 – modified (removed “of an organization”, changes made to Note 1)

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 performance: measurable results related to energy efficiency, energy use, and energy consumption

Note 1: In the context of energy management systems, results can be measured against the organization's energy policy, objectives, targets and other energy performance requirements.
Note 2: Energy performance is one component of the performance of the energy management system.
Source: ISO 50001:2011, 3.12 modified (removed Notes 1 and 2)

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

Facility: area occupied by an organization at a particular location
Note 1: A facility may be a subset of a location
Note 2: A facility subset may not be an energy system (e.g., a steam system)
Source: MSE 50021:2015, 3.4

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)

Organization: company, corporation, firm, enterprise, authority or institution, or part or combination thereof, whether incorporated or not, public or private, that has its own functions and administration and that has the authority to control its energy use and consumption
Note 1: an organization can be a person or a group of people
Source: ISO 50001:2011, 3.22

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)

Primary energy: energy that has not been derived from another type of energy

Regression: the analysis or measure of the association between one variable (the dependent variable) and one or more other variables (the independent variables)

Note 1: regression models can be formulated in an equation in which the independent variables have parametric coefficients, which may enable future values of the dependent variable to be predicted.

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 energy performance improvement
Source: MSE 50021: 2015, 3.6 16 - modified (removed SEP)

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