$$ENERGY_{eff} = \sum_{j=1}^{m} (E\ LOAD_{j,eff} \times HOURS_{j,eff})$$

where

| | |
|---|---|
| $ENERGY_{eff}$ ≡ | Annual Efficient Energy Use - annual energy use with the efficiency improvement installed, calculated separately for each measure and each *energy source* (electric, gas). |
| $E\ LOAD_{j,eff}$ ≡ | Efficient Load (electric kW, gas therms) - efficient load for each system and subsystem with operating condition *j* (as defined below). For example, efficient load will need to be calculated differently for staged condenser fans that have different operating hours or multiple pumps that operate at varying speeds. |
| $HOURS_{j,eff}$ ≡ | Total Annual Operating – total annual operating hours for each system and subsystem with operating condition *j* (as defined below). |

For loads calculated based on metering of full load or on equipment specifications:

$$ENERGY_{eff} = \sum_{j=1}^{m} (FULL\ LOAD_{j,eff} \times LF_{j,eff} \times HOURS_{j,eff})$$

where

| | |
|---|---|
| $ENERGY_{eff}$ ≡ | Annual Efficient Energy Use - annual energy use with the efficiency improvement installed, calculated separately for each measure and each *energy source* (electric, gas). |
| $FULL\ LOAD_{j,eff}$ ≡ | Efficient Full Load - the maximum operating load of each efficient system and subsystem with operating condition *j* (as defined below). |
| $LF_{j,eff}$ ≡ | Load Factor - fraction of full load for each efficient system and subsystem with operating condition *j* (as defined below). Typically less than 1.00 unless the equipment was sized to run at 100% or rated capacity.<br><br>If needed, LF could be calculated from a regression curve kW and FULL LOAD for distinct operating conditions. This may arise when comparing efficient data with non-metered baseline LF ranges which are not based on a regression curve. |
| $HOURS_{j,eff}$ ≡ | Total Annual Operating Hours – total annual operating hours for each system and subsystem with operating condition *j* (as defined below). |
| $j$ ≡ | System Condition - refers to each distinct combination of system mode, number of hours, full load demand, and load factor for each system or subsystem. Refer to example below. |
| $m$ ≡ | Number of Terms – total number of terms needed to cover all conditions of affected systems and subsystems. |

**Efficient Case Coincident Electric Demand (kW)**

Document the efficient case coincident electric demand for each measure according to one of the following equations:

For variable loads:

$$C\ LOAD_{eff} = AVG\ PH\ LOAD_{eff}$$

Where

$AVG\ PH\ LOAD_{eff}$ = Average Efficient Load of all affected equipment during the *Performance Hours* of 3-6 pm, weekday, non-holidays from June 1 – August 31 for a total of 195 hours. Includes non-operating time during the *Performance Hours* and is equal to total energy use during the *Performance Hours* divided by the total *Performance Hours*.

For constant loads or loads without metered data:

$$C\ LOAD_{eff} = \sum_{k=1}^{n} \left(FULL\ LOAD_{k,eff} \times LF_{k,eff} \times CF_{k,eff}\right)$$

where

$C\ LOAD_{eff}$ = Average Coincident Efficient Load – Average Coincident Load of all affected efficient equipment during the *Performance Hours* of 3-6 pm, weekday, non-holidays from June 1 – August 31 for a total of 195 hours. Includes non-operating time during the *Performance Hours*.

$FULL\ LOAD_{k,eff}$ = Efficient Full Load - the maximum operating load of each efficient system and subsystem during the *Performance Hours* with operating condition $k$ (as defined below), exclusive of non operating time.

$LF_{k,eff}$ = Load Factor - fraction of Full Load for each efficient system and subsystem with operating condition $k$ (as defined below). Typically less than 1.00 unless the equipment was sized to run at 100% of rated capacity.

$CF_{k,eff}$ = *Coincidence Factor* - the Coincidence Factor is the fraction of time that each efficient system and subsystem is operating during the *Performance Hours* for operating condition $k$ (as defined below). The three typical conditions for CF are as follows: CF is unity if the equipment is continuously on during the *Performance Hours;* CF is zero for each system or subsystem that is not operating during the *Performance Hours*; otherwise, CF is the ratio of the 'on' time to the total number of performance hours.

$k$ = System Condition - refers to each distinct combination of the system mode, Full Load demand, and Load Factor for each system or subsystem operating during the *Performance Hours*. Refer to example below.

$n$ = Number of Terms – total Number of Terms needed to cover all operating modes of affected systems and subsystems during *Performance Hours*.

The analysis shall include documentation of how the load varies during the *Performance Hours*. For constant load equipment, the analysis shall be based on the equipment load and operating schedule during the performance hours. For variable load equipment, the analysis shall address variations in equipment load and operating schedule during the performance hours.

Additional analysis will typically be prepared to address the impact of the energy efficiency measure on customer peak demand. Such analysis is critical to calculating customer cost savings but should not be confused with the required calculation of the coincident demand during the performance hours.

**Baseline Case**

**Baseline Technology Methodology and Description**
Energy efficiency retrofit projects involve the replacement of existing equipment prior to the end of its useful life in order to achieve energy savings. Therefore, the existing equipment may be used to establish the project baseline. The analysis must account for the remaining life of the existing equipment, and if the analysis period extends beyond the remaining life of the existing equipment, the analysis shall account for increases in efficiency that would have occurred through autonomous efficiency improvements or equipment replacement that would have occurred at the end of the existing equipment life in the absence of early retirement. The baseline description shall detail the baseline technology(ies) affected by the measure; including make, model number, nameplate information, and equipment rated capacity, condition, age, lifetime, usage, operating schedule, and controls. The baseline shall also account for upgrades to the equipment that would have occurred during the analysis period absent the early retirement of the equipment.

Retrofit of industrial processes typically yield multiple benefits including energy efficiency, increased *throughput*, reduced waste, improved product quality, new product features, etc. Because of the multiple benefits derived from industrial process improvements, the characterization of these measures does not cleanly fall into either the retrofit or equipment replacement category. In order to establish a rigorous industrial process retrofit baseline, the following should be considered:

Derived Baseline – based on documented Industry and Applicant Practice (as described below), the engineer performing the analysis shall develop a reasonable project baseline. Clearly describe why the baseline and characterization of the project as retrofit is appropriate and demonstrate how the derived baseline accounts for autonomous upgrades in practice over the analysis period.

Current Industry Practice – document current industry practice using articles from industry journals, EIA industry specific energy intensity figures,[746] and independent industry specific studies. Where information regarding industry practice is provided by manufacturers who sell production equipment within the industry, it shall be supported by independent research.

Applicant Practice – document the corporate practices of the applicant through annual reports, published papers, internal memos, and other documents that indicate the business practices of the applicant relative to current practice in the industry. Document the practices and equipment within the facility receiving the upgrade. For instance, if an injection molding manufacturer is replacing hydraulic machines with electric machines on an annual basis, using the hydraulic equipment as baseline may not be representative of the actual baseline. For production equipment replacements, a Process Integration Study[747] is a strong tool in documenting the project's focus on energy efficiency and the optimization of energy use.[748]

[746] Department of Energy, Energy Information Administration, Manufacturing Energy Consumption Survey, http://www.eia.doe.gov/emeu/mecs/contents.html
[747] Natural Resources Canada, Process Integration, A Systematic Approach for Optimisation of Industrial Processes, http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/fichier.php/codectec/En/2009-046/2009-046_en.pdf
[748] Department of Energy, Industrial Efficiency Report, 1993, http://www.fas.org/ota/reports/9330.pdf

Baseline Energy Intensity – for industrial process, the baseline should be defined in terms of *energy intensity* and normalized to reflect the expected variations in production over various production cycles[749].

Describe in detail the method used to establish the energy use under baseline conditions. If metering was used; explain the methodology, how this is representative of typical annual operation and how the collected data was normalized to annual operation as described in Section 4.

**Baseline Case Annual Energy Use**
Calculate the annual energy use for the baseline equipment and systems using the methodologies outlined in this protocol and all referenced and applicable standards.

The total baseline energy use shall be calculated separately for each *energy source* (e.g. electric and gas) according to the following equations.

For loads calculated from a regression analysis (e.g. kW vs. Temperature as described in Section 4) the following equation shall be used:

$$ENERGY_{base} = \sum_{j=1}^{m} \left(E\ LOAD_{j,base} \times HOURS_{j,base}\right)$$

where

| | |
|---|---|
| $ENERGY_{base}$ = | Annual Baseline Energy Use - Annual Energy Use for baseline equipment calculated separately for each measure and each *energy source* (electric, gas). |
| $E\ LOAD_{j,base}$ = | Baseline Load (electric kW, gas therms) - Baseline Load for each system and subsystem with operating condition *j* (as defined below). For example, Baseline Load will need to be calculated differently for staged condenser fans that have different operating hours or multiple pumps that operate at varying speeds. |
| $HOURS_{j,base}$ = | Total Annual Operating Hours – Total Annual Operating Hours for each system and subsystem with operating condition *j* (as defined below). |

For loads calculated based on metering of full load or on equipment specifications:

$$ENERGY_{base} = \sum_{j=1}^{m} \left(FULL\ LOAD_{j,base} \times LF_{j,base} \times HOURS_{j,base}\right)$$

where

| | |
|---|---|
| $ENERGY_{base}$ = | Annual Baseline Energy Use - Annual Energy Use for baseline equipment calculated separately for each measure and each *energy source* (electric, gas). |
| $FULL\ LOAD_{j,base}$ = | Baseline Full Load - the maximum operating load of each baseline system and subsystem with operating condition *j* (as defined below). |

[749] Ruth, Michael, Lawrence Berkeley National Laboratory, et. al. (2001) A Process-Step Benchmarking Approach to Energy Use at Industrial Facilities: Examples from the Iron and Steel and Cement Industries; Process_Step_Benchmarking_ACEEE_LBNL-50444.doc

| | |
|---|---|
| $LF_{j,base}$ = | Load Factor - fraction of Full Load for each baseline system and subsystem with operating condition *j* (as defined below). Typically less than 1.00 unless the equipment was sized to run at 100% of rated capacity. |
| $HOURS_{j,base}$ = | Total Annual Operating Hours – Total Annual Operating Hours for each system and subsystem with operating condition *j* (as defined below). |
| $j$ ≡ | System Condition - refers to each distinct combination of system mode, number of hours, Full Load demand, and Load Factor for each system or subsystem. Refer to example below. |
| $m$ = | Number of Terms – total Number of Terms needed to cover all conditions of affected systems and subsystems. |

**Baseline Case Full Load Demand**

Document the baseline case coincident electric demand for each measure according to one of the following equations:

For variable loads:
$$C\ LOAD_{base} = AVG\ PH\ LOAD_{base}$$

Where

| | |
|---|---|
| $AVG\ PH\ LOAD_{base}$ = | Average Baseline Load of all affected equipment during the *Performance Hours* of 3-6 pm, weekday, non-holidays from June 1 – August 31 for a total of 195 hours. Includes non-operating time during the *Performance Hours* and is equal to total energy use during the *Performance Hours* divided by the total *Performance Hours*. |

For constant loads or loads without metered data:

$$C\ LOAD_{base} = \sum_{k=1}^{n}(FULL\ LOAD_{k,base} \times LF_{k,base} \times CF_{k,base})$$

where

| | |
|---|---|
| $C\ LOAD_{base}$ = | Average Coincident Baseline Load – average coincident load of all affected baseline equipment during the *Performance Hours* of 3-6 pm, weekday, non-holidays from June 1 – August 31 for a total of 195 hours. Includes non-operating time during the *Performance Hours*. |
| $FULL\ LOAD_{k,base}$ = | Baseline Full Load - the maximum operating load of each baseline system and subsystem during the *Performance Hours* with operating condition *k* (as defined below), exclusive of non operating time. |
| $LF_{k,base}$ = | Load Factor - fraction of Full Load for each baseline system and subsystem with operating condition *k* (as defined below). Typically less than 1.00 unless the equipment was sized to run at 100% of rated capacity. |

$CF_{k,base} \equiv$ *Coincidence Factor* - the Coincidence Factor is the fraction of time that each baseline system and subsystem is operating during the *Performance Hours* for operating condition $k$ (as defined below). The three typical conditions for CF are as follows: CF is unity if the equipment is continuously on during the *Performance Hours;* CF is zero for each system or subsystem that is not operating during the *Performance Hours*; otherwise, CF is the ratio of the 'on' time to the total number of performance hours.

$k \equiv$ System Condition - refers to each distinct combination of the system mode, Full Load demand, and Load Factor for each system or subsystem operating during *Performance Hours*. Refer to example below.

$n \equiv$ Number of Terms – total Number of Terms needed to cover all operating modes of affected systems and subsystems during *Performance Hours*.

The analysis shall include documentation of how the load varies during the *Performance Hours*. For constant load equipment, the analysis shall be based on the equipment load and operating schedule during the *Performance Hours*. For variable load equipment, the analysis shall address variations in equipment load and operating schedule during the *Performance Hours.*

Additional analysis will typically be prepared to address the impact of the baseline equipment on customer peak demand. Such analysis is critical to calculating customer cost savings but should not be confused with the required calculation of the coincident demand during the *Performance Hours*.

**Savings**

Savings shall be calculated from the efficient case and baseline case energy and demand calculations from above. Address project variables as described in Section 3 and aggregate so that interactive effects are accurately accounted for in the analysis.

**Annual Energy Savings (kWh for electrical, therms for gas)**

$$ENERGY_{saved} = ENERGY_{base} - ENERGY_{eff}$$

where

$ENERGY_{base}$ and $ENERGY_{eff}$ are defined above.

**Coincident Electrical Demand Reduction (kW) =**

$$C\,LOAD_{saved} = C\,LOAD_{base} - C\,LOAD_{eff}$$

where

$C\,LOAD_{base}$ and $C\,LOAD_{eff}$ are defined above.

## Section 3: Project Variables

Accurately capturing and documenting the variables that affect annual energy use and savings as well as those affecting peak period demand coincidence are critical elements in developing meaningful and reliable energy savings estimates. The savings analysis shall consider and address the variables over the life of the measure for both the baseline and efficient case. Uncertainty in variables shall be quantified and the savings analysis shall clearly demonstrate transparency and reasonableness in definition and application of variables affecting energy savings[750].

The variables below are common to many custom energy analyses. Document the variables that affect the energy use of the project for both the baseline and efficient scenarios and delineate the methods used for data collection (i.e. meter data, trend logs, manufacturer data, customer interviews, production logs, etc.) and any uncertainty associated with the values used in the analysis. ALL savings calculations must be *normalized* to reflect consistent application of the assumed variables for the project under both baseline and post installation conditions over the full range of operating conditions for the affected systems.

**Load Characterization**
Accurate characterization of the baseline and efficient energy use involves a comprehensive analysis of all variables that affect the loads over the analysis period. Concepts that are commonly used in performing energy analysis are discussed below. In all cases it is the intent of this document to require that the variations in load due to all factors (weather, production, schedule, etc) are accounted for in the analysis.

**Load Shape**
The load shape reflects variations in load over the course of a year, with specific attention paid to the peak periods defined by the affected utility and/or regional transmission organization. The load shape should capture the expected period at which the load will operate at full load (full load hours) as well as all part load and non-operating or standby-modes. For highly variable loads, development of an 8760 load shape will increase the accuracy of the analysis and the reliability of claimed demand reductions during peak periods[751].

**Load Factor**
Load factor is the ratio of maximum energy demand to the average electric demand for the affected end use. Analysis of loads across a representative sample of operating conditions can generate a single load factor for constant load applications. For variable load applications, a series of load factors must be developed to accurately represent the variations in energy use under the variety of loading conditions that occur over the range of operating cycles in a typical calendar year. Variable load analysis shall address the variations in load factor over a one year period for all dependent variables.

**Peak Load Factor**
Peak load factor describes the variation between the maximum connected load of the equipment and the highest actual load of the equipment. In some cases the peak load factor is unity. For oversized equipment it is frequently less than one. In some rare instances where equipment is operated above its rated load, the peak load factor may be greater than one.

**Coincidence Factor**
Coincidence Factor is the coincidence of the demand savings during the *peak performance hours*. For custom measures, the average coincident demand, including non-operational hours, is typically directly determined by metering the pre- and post-installation condition and a coincidence factor is not used in the calculations. However, in some cases, the use of a known or predetermined published coincidence factor to calculate the coincident peak reduction for a project may be appropriate.

Another example of the use of an explicit coincidence factor arises in cases where the baseline demand was not metered and the efficient demand was metered. For a stepped demand device such as a high efficiency compressor, for example, a coincidence factor can be calculated and applied to the baseline equipment to address the fact that the baseline operating schedule used in the calculations should be the same as the efficient operating schedule. In this case, the coincidence factor is defined as the ratio of average metered

---

[750] Anne Arquit Niederberger, PhD, A+B International (2005), Baseline Methodologies for Industrial End-Use Efficiency Presentation. Presented at World Bank; Anne_Arquit_Niederberger_Industry_EE_CDM_Dec_05.xls
[751] Patil, Yogesh, et. al. (Aug, 2009) "Taking Engineering Savings to the Next Level, presented at IEPEC 2009 http://www.ers-inc.com/images/articles/Papers/takingsavingstonextlevel.pdf

demand for the peak performance hours and max 'equipment on' demand when operating. If the equipment is operating continuously for the full peak performance hours, then the coincidence factor is 1.00.

**Operating Conditions**
Characterize all variable operating conditions that affect the load over the analysis period. Typical operating variables are outlined below. Additional factors may be required to accurately characterize variability in equipment operations and the energy savings resulting from energy efficiency measures over the full range of operating conditions.

**Operating Hours**
Establish the baseline and post-installation operating hours for all affected equipment using logging, metering, and/or DDC trending for a representative period of not less than one week. Address all variations in operating schedule over an annual operating cycle including, but not limited to weekends, holidays, and shift or occupancy changes that are a result in cyclical changes in operations over the course of a year. (For example retail applications may have longer operating hours in November and December). Project analysis shall clearly identify all operating, non-operating, and standby hours, the related loads, the periods for which those conditions apply and the basis for the assumptions in the analysis. Special attention should be paid that the hours of *Coincident Peak* (3:00 – 6:00 weekdays from June 1 through August 31) are detailed.

**Weather**
For weather-dependent projects, the analysis shall address the impact of annual weather, including temperature, humidity, and solar incidence (where applicable) on energy consumption. All savings (energy and demand) should be normalized to the TMY3 (Typical Meteorological Year) that corresponds to the nearest TMY3 weather site using modeling and/or regression analysis. TMY3 data should be obtained from National Renewable Energy Laboratory (NREL[752]) and used as the 8760 weather file to model and/or normalize annual energy use for weather dependent measures. Modeling tools, such as eQuest[753], currently use TMY2 data. TMY3 data is based on more-recent and more accurate data and is available for many more locations; TMY3 data is available for over 1,000 locations, where TMY2 data is available for fewer than 300 locations.

Projects with hourly correlation of metered or utility billed usage to local weather conditions should be done using National Oceanic and Atmospheric Administration (NOAA[754]) or NREL data. NOAA weather data is available for a small fee downloadable from the Internet and is typically the most accurate and complete historical local weather data set. NREL data is free but typically has some gaps in the data and is emailed in response to specific requests. Caution should be exercised when using non-government generated weather data as it may not meet accepted standards for quality and accuracy.

**Production**
Project analysis shall reflect variations in production over the cycles within the analysis period. Variations can include such things as the number of shifts or changes in quantity or type of product manufactured.

For industrial process measures, production documentation shall normalize energy use based on the energy intensity of the process (i.e. energy use per unit of output) over the lifetime of the measure for both the baseline and efficient cases. Measurement of output should be based on physical measures of output (i.e. ton of steel or paper) and capture variations in both production levels and manufactured product types over the analysis period for both the baseline and efficient case[755]. For metered projects, document production output during metering periods; work with plant personnel to ensure logged production data accurately reflects changes in production over the metering period.

[752] Typical Meteorological Data (TMY3) - http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/
[753] DOE2 eQuest simulation software - http://www.doe2.com/equest/
[754] NOAA local weather data - http://cdo.ncdc.noaa.gov/qclcd/QCLCD?prior=N
[755] Ruth, Michael, Lawrence Berkeley National Laboratory, et. al. (2001) A Process-Step Benchmarking Approach to Energy Use at Industrial Facilities: Examples from the Iron and Steel and Cement Industries; Process_Step_Benchmarking_ACEEE_LBNL-50444.doc

Assumptions regarding economic climate, changes in production levels, and shifts all affect calculated energy savings over the life of the measures. Develop reasonable assumptions regarding these variables and ensure the application of these variables is clearly identified in both the analysis and project documentation. Identify the uncertainty introduced into the energy savings estimates as a result of these assumptions.

Process flow charting for manufacturing and production is recommended to clarify energy use and demand impacts for each stage in the process[756].

**Controls**
Control settings and level of control shall be accounted for in the analysis. Clearly document the baseline control points that affect energy use, the control setpoints, sequence of operation and accuracy of controls. Clearly document the changes in these conditions for the efficient case. Include relevant information such as commissioning of control points, potential manual overrides of control sequences and anticipated control point calibration over the life of the measure.

**Occupancy**
Where occupancy affects energy use and varies over time, capture the variations in occupancy and their effects over the analysis period. At a minimum there is typically an 'occupied' and an 'unoccupied' mode for any facility.

Assumptions regarding economic climate and shifts in hours of occupancy affect calculated energy savings over the life of the measures. Develop reasonable assumptions regarding these variables and ensure the application of these variables is clearly identified in both the analysis and project documentation. Identify the uncertainty introduced into the energy savings estimates as a result of these assumptions

**Interactive Effects**
Analysis shall explicitly account for interactive effects between measures. For projects that include both prescriptive and custom measures, account for the energy use reduction from the prescriptive measure in the custom measure analysis. As prescriptive measures include interactive effects themselves, it will be necessary to remove the interactive effects from the prescriptive measure before including the energy use reduction in the custom measure analysis. Document the methodology that is used to ensure that savings from the interactive effects are only accounted for once in the claimed savings.

Interactive effects should be accounted for even if the technologies involved in the interactive effects are not the subject of energy efficiency improvements or claims under other programs, otherwise savings for custom measures may be overclaimed. The energy analyst should be aware of and request information about other changes or maintenance at the facility that may not be directly related to the custom measure project, or any other claimed project, and shall account for these changes in the analysis if appropriate.

One common set of interactive effects is the impact of electrical energy efficiency measures within a facility on that facility's heating and/or cooling load. These shall be addressed as follows:

**Waste Heat**
For efficiency upgrades that reduce the rejection of waste heat into air conditioned spaces (i.e. evaporator fans in a refrigerated enclosure), quantify the reduction in heat rejection[757] and the associated cooling reduction.

**Heating Increase**
For efficiency upgrades that reduce the rejection of waste heat into heated spaces, quantify the additional heating fuel required to offset the change and maintain temperature within the space[14]. The analysis shall address heating system efficiency and include basis for assumptions regarding fossil fuel increases.

[756] Doty, Commercial Energy Auditing Reference Handbook, p. 65
[757] 2009 ASHRAE Handbook, Fundamentals, Chapter 18, page 18.3.

For projects with multiple measures, the procedure for interactive effects is to calculate savings for the longest lived measure first, then consider that measure's impact on the next longest-lived measure, and so on. This is because a short-lived measure can affect savings from a long-lived measure, but only for part of its life. Since tracking system limitations require that annual measure savings remain constant for all years, this is the only way to ensure proper lifetime savings and total resource benefits are captured. As an example; calibrating DDC controls can increase savings at the time of chiller replacement. Since DDC control calibration has a relatively short measure life, the DDC calibration will affect the savings of the new chiller only for the first few years of its lifetime. When the calibration measure expires, the consumption of the new chiller will increase and the savings associated with the chiller measure will decrease for the remainder of the chiller's lifetime. If DDC calibration is calculated first, the chiller savings in the project will be overstated.

**Measure Life**
Document both the life of the baseline and efficient case equipment. If the baseline equipment measure life does not extend over the entire analysis period, the analysis shall include assumptions regarding replacement of baseline equipment at the end of its life. The efficient case analysis is typically performed over the lifetime of the efficiency measures. Where the analysis period and the efficiency measure life are not the same, describe the rationale for the analysis period and assumptions regarding replacement equipment for measures with lives that are shorter than the analysis period.

**Persistence**
Persistence factors may be used to reduce lifetime measure savings in recognition that initial engineering estimates of annual savings may not persist long term[758]. The persistence factor accounts for uncertainties and for normal operations over the life of the measure. For instance if energy efficient motors are installed as part of a process and the customer's standard procedure is to have motors rewound upon failure, the energy efficiency associated with the efficient motor would only persist until the expected time when the motor is rewound. Persistence is also affected by measures being removed or failing prior to the end of its normal engineering lifetime, improper maintained over the life of the measure, control overrides or loss of calibration (controls only), etc.

**Related Variables:**
Related variables are those which are not included in the energy and demand calculations, but may be required for project cost-effectiveness screening by the utility(ies). Document the following variables for the project:

**Operation &Maintenance (O&M) Impacts**
Where O&M practices would have resulted in changes to the baseline during the analysis period, account for such practices in the establishment of baseline and efficiency case energy use.

**Water Consumption Impacts**
Quantify any changes in water consumption attributable to the project.

**Cost**
Document the cost of each measure. Include invoices, bids and other documentation to substantiate project cost data. Identify portions of the cost which are for equipment being purchased for redundancy or backup and will not generate savings in the project. Related costs such as the costs for audits, design, engineering, permits, fees or M&V should be reported separately from the costs associated with the design and installation of energy efficiency improvements.

**Other Variables**
As needed - clearly document all variables affecting the energy use of the project that have not been covered in this document.

## Section 4: Documentation and Metering

[758] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February 19, 2010

Documentation and metering of custom projects are essential to developing reliable energy savings and peak demand reductions claims.[759] The following guidelines support the accurate estimation of energy and demand savings.

**Data and Metering**

Document how the data will be collected and utilized in the savings analysis in a Measurement and Verification (M&V) Plan. The Custom Analysis Template (Appendix B) can be used as a tool to document the M&V plan and analysis[760].

**Interval and Utility Data**

Utility interval data may be used in the analysis where available and applicable. Interval data is deemed applicable when the order of magnitude of the custom measure can be distinguished from the other loads on the meter. If the load on the utility meter is highly variable, the custom measure would need to be a larger portion of the overall load in order for the savings to be determined from the utility data. Typically interval data is available in 15 minute increments; the shortest period available for interval data should be used in the analysis. Where interval data is used, the analysis shall follow the requirements of IPMVP Option C – Whole Building Analysis[761].

For measures which affect gas usage only, utility data is typically the primary means of quantifying savings. However, use of upstream metering equipment such as flow meters is encouraged to improve the accuracy of gas savings calculations.

For completed mercantile projects in existing facilities, analysis shall include two - three years of utility billing information from years PRIOR to measure installation and up to three years of utility data post-installation in accordance with PUCO requirements.

**Meter Data**

Accuracy of all metering and measurement equipment shall be documented in the M&V Plan.

Document the metering methods including equipment type, location of metering equipment, and equipment set up process, as well as metering duration and timeframe for which data was collected. Capture all variables that affect energy use of the measures during the metering period as outlined in Section 3. Describe how the metered data, including timeframe and operational factors at the time of metering, relate to the operational conditions that occur over the course of a year. Provide photographs of meter installation and clear documentation of meter numbers and the associated equipment names of the equipment being metered in the project documentation. Meter data files should clearly identify the equipment to which the meter data applies.

For variable loads, three-phase power data loggers shall be used to collect electrical power data for systems and subsystems of the custom measure762. For constant loads, accurate spot reading of the load coupled with runtime logging is an acceptable metering methodology. Temperature and time of use loggers can be used to meter proxy variables, equipment status, and runtimes. Ensure that proxy variable metering yields calculated kW values in compliance with PJM Section 11 requirements.

Three-phase power data loggers shall record: amperage, voltage, power factor, and kW on all phases as well as the totals for each variable. All electrical power metering shall adequately account for

---

[759] Parlin, Kathryn, et. al. (August, 2009 IEPEC) "Demand Reduction in the Forward Capacity Market, Verifying the Efficiency Power Plant"

[760] IPMVP, Volume III, Part I, January 2006, Chapter 3, page 7 through 10, and PJM Manual 18B, April 2009, section 2, page 10 through 14

[761] International Performance Measure and Verification Protocol Concepts and Practices for Determining Energy Savings in New Construction, Volume III, Part 1, January 2006.

[762] PJM Manual 18B: Energy Efficiency Measurement and Verification, Rev. 0, Section 11, Effective date: April 23, 2009; PJM M&V Manual approved 4_09.pdf

harmonics763. Logging shall capture equipment load under representative operating conditions. The time period of logging shall be adequate to represent variations in load that will occur over the analysis period. Where feasible, use metering or data logging to capture variables affecting load during the metering period. Where variables cannot be captured using meters or data loggers, institute and clearly document a method for accurately capturing variables, validating non-metered data, and aligning it with metered data. Metering periods shall be a minimum of one week, including a weekend, for constant load equipment and at least two weeks, including weekends, for variable load equipment, but as noted above, must be long enough to capture representative variations in load expected over the entire analysis period.

Integrating/averaging three phase power meters are desirable. Power metering accuracy requirements are outlined in PJM Manual 18B764 and RLW Analytics Review of ISO New England Measurement and Verification Equipment Requirements765. Metering intervals shall be the smallest time interval that will permit acquisition of data over the minimum required metering period. For short-cycling or modulating systems, 30-second or 1-minute data intervals are preferred, with a maximum recommended interval of 5 minutes. For constant load systems, the metering interval can be longer. No metering interval should exceed 15 minutes. Clearly document how meter intervals and meter periods capture the expected load variations for the project.

Meters and data loggers shall be synchronized to the NIST time clock, and differences between the time at the facility and the NIST time setting should be noted when the meters are installed.

**DDC/PLC Monitor Data**

Use of DDC and PLC monitoring software trends in the analysis is acceptable provided that the sensors are calibrated on site using calibrated test instruments and the results documented by the energy analyst before the metering period commences. Review and submission of annual equipment calibration records for DDC sensors and metering equipment is a less desirable, but acceptable alternative to calibration of DDC equipment as part of the project. Timestamps for trends should be set up to coincide with those of any concurrently deployed data loggers to enable accurate data analysis.

**Load Profiles**

For measures with well established and reliable load profiles, the load profile can be a useful tool for determining savings. Load profiles are most reliable when used for common measures in typical applications, such as office lighting projects. Typically, load profiles should not be relied on where project peak demand savings exceed 20 kW.

## General Procedures for Data Analysis

### Data Cleaning

It is usually necessary to 'clean' the raw data before proceeding with the analysis. The following data cleaning tasks are typically required.

Ensure that the timestamps match between datasets (e.g. for concurrent kW and temperature datasets), and that any gaps in the data which are not representative of typical operation have been addressed by interpolation or other means. Interpolated or derived data shall be flagged, and the method used to fill in data gaps shall be described.

Note that in preparing the data for use in the 8760 analysis, there will likely be blocks of time during the metering period that will be analyzed differently. For example, during regular business hours, a load may

[763] PJM Manual 18B: Energy Efficiency Measurement and Verification, Rev. 0, Section 11, Effective date: April 23, 2009; PJM M&V Manual approved 4_09.pdf
[764] PJM Manual 18B: Energy Efficiency Measurement and Verification, Rev. 0, Effective date: April 23, 2009; PJM M&V Manual approved 4_09.pdf
[765] RLW Analytics, Review of ISO New England Measurement and Verification Equipment Requirements, Final Report, April 24, 2008 Prepared for: Northeast Energy Efficiency Partnerships' Evaluation and State Program Working Group; RLW Metering Report.pdf

be temperature dependent, and the data will be analyzed using a regression analysis of kW vs. outdoor air temperature, whereas the same piece of equipment on the weekend may have a constant standby load, and is thus schedule driven and non-temperature dependent on the weekends. Different blocks of the 8760 hours in a year will be populated from the separate analyses of the distinct blocks of meter data.

**Annualization and Analysis Approach**

The recommended approach to annualization of meter data and savings calculations is an 8760 analysis[766]. This approach inherently captures seasonality and peak period variability on an hourly basis and is therefore more accurate than other traditional methods such as binned analysis.

Typical approaches to analyzing custom measures include:

- Demand vs. temperature analysis for temperature dependent measures.
- Daily operating profiles for schedule-driven measures
- Cyclical production profiles for production-related measures

These methods should address part load performance, and may employ different metrics such as:

- Demand vs. percent capacity
- Demand/Ton vs. percent capacity
- Demand vs. hours
- Demand per ton, pound, cubic foot or quantity

## Calculations

Clearly document all calculations. Indicate how the meter data is used in the analysis and why this is appropriate for the measure. Meter data used in the analysis shall be clearly distinguished from data not used in the analysis.

Computer simulation of energy efficiency measures based on meter data using 8760 hourly simulation models such as eQuest, or customized spreadsheet analysis or other energy analysis tools can be employed to calculate energy savings. The algorithms of the modeling software must be designed to address the custom measure. Minimum documentation requirements include model output reports stating unmet load hours for the baseline and efficient case, hourly energy use and demand, and electronic copies of the model or spreadsheet analysis files.

Annual kWh and therms for baseline and efficient cases shall be the annualized and normalized per the equations in Section 2 using the methods described above. Coincident Electrical Demand (kW) for baseline and efficient cases shall be calculated from meter data as the average kW over the *Performance Hours* as indicated in Section 2. Calculation documentation shall include definitions and reference sources for all variables and assumed factors in Section 3.

## Documentation

Analysis shall be documented with comprehensive, well labeled supporting information including, but not limited to:

Manufacturer literature documenting connected load for both the baseline and the installed equipment or manufacturer data documenting the information necessary to calculate peak demand (such as horsepower, voltage, efficiency, etc.). Manufacturer data shall be clearly marked to indicate the specific equipment model number and data that is applicable to the project and used in the calculations.

[766] Patil, Yogesh, et. al. (Aug, 2009) "Taking Engineering Savings to the Next Level, presented at IEPEC 2009; http://www.ers-inc.com/images/articles/Papers/takingsavingstonextlevel.pdf

Where citing nameplate ratings in the analysis, provide a single photograph of the nameplate clearly showing the cited information and identifying the specific equipment to which the name plate information is applicable.

Manufacturer data shall be adjusted to reflect actual site operating conditions. Document calculation of the adjusted connected load reflecting metered on site conditions.

**Reporting**

The following metrics and details shall be reported:

- All information required in this protocol
- M&V Plan/Analysis Template
- Regression $R^2$ values for fits of demand vs. proxy variables.
- Cleaned meter data (raw data shall be included as an appendix) clearly indicating which data was used in the savings analysis
- Discussion of approach to anomalies, outliers, interpolations and extrapolations in the analysis
- Assessment of the level of uncertainty associated with the energy and demand calculated savings.
- Project commissioning can reduce energy use and is recommended. If the project was commissioned, submit a copy of the commissioning report.

## C&I New Construction – Custom Measure Analysis Protocol

This protocol defines the requirements for analyzing and documenting commercial and industrial energy efficiency measures. It applies to custom measures filed under Utility Programs and those prepared for Mercantile Customers. This protocol addresses new construction projects that are not covered by other analysis methodologies in the TRM. A new construction project is defined as a new building, major renovation and/or an addition as defined in the applicable building codes.

This protocol is intended to address the energy impacts of the incremental energy efficiency improvements over what would have been built as per applicable state and local codes. Projects that include duplex, redundant and/or spare equipment shall calculate the energy savings based only on the operating equipment and systems.

This analysis protocol is supplemented by a glossary and an Analysis Template (Appendix B). Words used herein that are defined in the glossary are in italics. The Analysis Template is a tool that can guide applicants in preparing and presenting the documentation to support custom new construction energy efficiency measure savings estimates.

The Analysis Protocol is divided into four sections:
Section 1: Project Information
Section 2: Project Savings
Section 3: Project Variables
Section 4: Documentation and Modeling

### Section 1: Project Information

**Project Title**
Provide a unique title for the project so that it is easily distinguishable from other projects prepared by the same customer and from projects with similar scope. Example: Company XYZ Building A – New Compressed Air System Installation.

**Customer Name**
Provide the name of the company undertaking the energy efficiency improvements.

**Customer Contact**
Provide the contact information including name, title, mailing address, phone, and email for the primary customer contact on this project.

**Site (Location)**
Provide the full address of the site at which the project is being implemented. If the customer has an additional business location that is involved with the project, include additional customer site information as needed.

**Sector/Industry Description and NAICS Code**
Describe the sector and industry in which the custom measure is being applied. Sectors include: Industrial, Commercial, Institutional, and Multi-family. Industry should specify the end use for commercial and institutional projects (e.g. office, restaurant, dormitory) and the specific industry for manufacturing projects[767].

**Utility(ies) Information**
The name of the affected utility(ies) serving the customer. Provide all relevant account and meter information for electric and gas accounts and meters affected by the project.

**Program**
Identify the program under which this project will be submitted and why the project falls under the program. Projects submitted under existing utility programs should identify the program under which the project application

[767] 2007 NAICS; North American Industry Classification System; http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007

will be filed and the utility-specific identifier for the project. Projects being submitted under the Mercantile Program should so indicate.

**Project/Technology Description**
Describe the energy using equipment and systems affected by the project in lay terms. Include specific information regarding industrial process technologies.

**Project Implementation Schedule**
Define the implementation schedule for the project, including start and completion dates.

**Measures Included in the Project**
All energy efficiency measures included in the project shall be clearly identified and savings calculations and estimates shall be clearly documented for each measure in accordance with this protocol.

**Affected Energy Sources (Electric, Gas, Other)**
Identify all affected energy sources (electric, gas, propane, oil, solar, etc.) for the project, provide a brief description of how the source energy use is affected and quantify the impacts in the analysis.

**Analysis Firm(s) and Contact(s)**
Provide information regarding the firm performing the engineering analysis of the custom project. Provide the name(s) of the contacts for the firm(s) and contact information including company name, individual(s) name, address, phone, and email.

## Section 2: Energy Consumption and Demand

This section defines the requirements for calculating baseline and efficient case energy consumption and demand, as well as the method for calculating savings. Calculations shall address all project variables in accordance with the requirements of Section 3 and undertake the analysis in accordance with the documentation and modeling requirements in Section 4.

The equations used in this protocol assume that the project has a single measure. If the project has multiple measures, these calculations shall be repeated for each measure in such a way as to capture interactive effects.

This protocol is designed to address the whole building analysis of a new construction project. Modeling shall use an 8760 model which meets the requirements of ASHRAE 90.1 Appendix G as described in Section 4.

**Efficient Case**

**Efficient Technology Description and Documentation**
Describe the measures, technologies and controls and how they are designed to optimize building energy performance. Document the relevant efficiency code that applies to the building and any additional federal/state/local standards that may apply to proposed efficient equipment that is not addressed in the code.

**Efficient Case Annual Energy Use**
Calculate the annual energy use for the proposed equipment using the methodologies outlined in this protocol and all referenced and applicable standards.

The total efficient energy use shall be calculated separately for each type of *energy source* (e.g. electric and gas) according to the following equations.

For loads calculated from a regression analysis (e.g. kW vs. Temperature as described in Section 4) the following equation shall be used:

$$ENERGY_{eff} = \sum_{j=1}^{m} (E\ LOAD_{j,eff} \times HOURS_{j,eff})$$

Where

| | |
|---|---|
| $ENERGY_{eff}$ = | Annual Efficient Energy Use - Annual Energy Use with the efficiency improvement installed, calculated separately for each measure and each *energy source* (electric, gas). |
| $E\ LOAD_{j,eff}$ = | Efficient Load (electric kW, gas therms) - Efficient Load for each system and subsystem with operating condition *j* (as defined below). For example, Efficient Load will need to be calculated differently for staged condenser fans that have different operating hours or multiple pumps that operate at varying speeds. |
| $HOURS_{j,eff}$ = | Total Annual Operating – Total Annual Operating Hours for each system and subsystem with operating condition *j* (as defined below). |

For loads calculated based on full load or on equipment specifications:

$$ENERGY_{eff} = \sum_{j=1}^{m} (FULL\ LOAD_{j,eff} \times LF_{j,eff} \times HOURS_{j,eff})$$

where

| | |
|---|---|
| $ENERGY_{eff}$ = | Annual Efficient Energy Use - Annual Energy Use with the efficiency improvement installed, calculated separately for each measure and each *energy source* (electric, gas). |
| $FULL\ LOAD_{j,eff}$ = | Efficient Full Load - the maximum operating load of each efficient system and subsystem with operating condition *j* (as defined below). |
| $LF_{j,eff}$ = | Load Factor - fraction of Full Load for each efficient system and subsystem with operating condition *j* (as defined below). Typically less than 1.00 unless the equipment was sized to run at 100% of rated capacity. |
| $HOURS_{j,eff}$ = | Total Annual Operating Hours – Total Annual Operating Hours for each system and subsystem with operating condition *j* (as defined below). |
| $j$ ≡ | System Condition - refers to each distinct combination of system mode, number of hours, full load demand, and load factor for each system or subsystem. |
| $m$ = | Number of Terms – total Number of Terms needed to cover all conditions of affected systems and subsystems. |

Document the inputs and outputs to the building model as described in the LEED Reference Guide for Green Building Design and Construction, Energy and Atmosphere Credit One, Option 1, Whole Building Simulation and as described in Section 4.

**Efficient Case Coincident Electric Demand (kW)**

Document the efficient case coincident electric demand for each measure according to one of the following equations:

For variable loads:

$$C\ LOAD_{eff} = AVG\ PH\ LOAD_{eff}$$

Where

| | |
|---|---|
| $AVG\ PH\ LOAD_{eff}$ = | Average Efficient Load of all affected equipment during the *Performance Hours* of 3-6 pm, weekday, non-holidays from June 1 – August 31 for a total of 195 hours. Includes non-operating time during the *Performance Hours* and is equal to total energy use during the *Performance Hours* divided by the total *Performance Hours*. |

For constant loads:

$$C\ LOAD_{eff} = \sum_{k=1}^{n} (FULL\ LOAD_{k,eff} \times LF_{k,eff} \times CF_{k,eff})$$

where

| | |
|---|---|
| $C\ LOAD_{eff}$ = | Average Coincident Efficient Load – Average Coincident Load of all affected efficient equipment during the *Performance Hours* of 3-6 pm, weekday, non-holidays from June 1 – August 31 for a total of 195 hours. Includes non-operating time during the *Performance Hours*. |
| $FULL\ LOAD_{k,eff}$ = | Efficient Full Load - the maximum operating load of each efficient system and subsystem operating during the *Performance Hours* with operating condition *k* (as defined below), exclusive of non operating time. |
| $LF_{k,eff}$ = | Load Factor - fraction of Full Load for each efficient system and subsystem with operating condition *k* (as defined below). Typically less than 1.00 unless the equipment was sized to run at 100% of rated capacity. |
| $CF_{k,eff}$ = | *Coincidence Factor* - the Coincidence Factor is the fraction of time that each efficient system and subsystem is operating during the *Performance Hours* for operating condition *k* (as defined below). The three typical conditions for CF are as follows: CF is unity if the equipment is continuously on during the *Performance Hours;* CF is zero for each system or subsystem that is not operating during the *Performance Hours*; otherwise, CF is the ratio of the 'on' time to the total number of performance hours. |
| $k$ = | System Condition - refers to each distinct combination of the system mode (e.g. high speed, low speed), Full Load demand, and Load Factor for each system or subsystem operating during the *Performance Hours*. |
| $n$ = | Number of Terms – total Number of Terms needed to cover all operating modes of affected systems and subsystems during *Performance Hours*. |

The analysis shall take into account that not all system components are expected to operate during all of the *Performance Hours*. For example on a cooling tower some of the cooling tower fans could periodically be staged in the "off" position while the compressors could be operating at 100% load. In these cases the system load during *Performance Hours* will not equal the sum of the loads for all system components.

Document the modeled measure inputs and outputs specifically for the *Performance Hours*.

The analysis shall include documentation of how the load varies during the *Performance Hours*. For constant load equipment, the analysis shall be based on the equipment load and operating schedule during the performance hours. For variable load equipment, the analysis shall address variations in equipment load and operating schedule during the *Performance Hours*.

Additional analysis will typically be prepared to address the impact of the energy efficiency measure on customer peak demand. Such analysis is critical to calculating customer cost savings, but should not be confused with the required calculation of the Coincident Demand during the *Performance Hours*.

**Baseline Case**

**Baseline Technology Methodology and Description**
Baseline for new construction projects is the equipment meeting the level of efficiency required by State Code[768], in place at the time of installation. Document any additional Federal or industry standards[769] that may apply to proposed efficient equipment that is not addressed in the code. The baseline description shall detail information regarding the mandated minimum efficiencies used in developing the code compliant building model at the component level.

**Baseline Case Annual Energy Use**
Calculate the annual energy use for the baseline equipment and systems using the methodologies outlined in this protocol and all referenced and applicable standards.

The total baseline energy use shall be calculated separately for each *energy source* (e.g. electric and gas) according to the following equations.

For loads calculated from a regression analysis (e.g. kW vs. Temperature as described in Section 4) the following equation shall be used:

$$ENERGY_{base} = \sum_{j=1}^{m}(E\ LOAD_{j,base} \times HOURS_{j,base})$$

where

$ENERGY_{base}$ = Annual Baseline Energy Use - Annual Energy Use for baseline equipment calculated separately for each measure and each *energy source* (electric, gas).

$E\ LOAD_{j,base}$ = Baseline Load (electric kW, gas therms) - Baseline Load for each system and subsystem with operating condition *j* (as defined below). For example, Baseline Load will need to be calculated differently for staged condenser fans that have different operating hours or multiple pumps that operate at varying speeds.

$HOURS_{j,base}$ = Total Annual Operating Hours – Total Annual Operating Hours for each system and subsystem with operating condition *j* (as defined below).

For loads calculations based on equipment specifications:

---

[768] International Code Council, 2007 Ohio Building Code; http://publicecodes.citation.com/st/oh/st/b2v07/index.htm?bu2=undefined