State of Ohio Energy Efficiency Technical Reference Manual

Including
Predetermined Savings Values
and Protocols for Determining Energy and Demand Savings

Prepared for the Public Utilities Commission of Ohio
by Vermont Energy Investment Corporation
August 6, 2010
Updated by Michaels Energy
September 23, 2019

The 2010 Ohio TRM was prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation (VEIC), with contributions from the following:

Vermont Energy Investment Corporation
Cheryl Jenkins, Project Manager; cjenkins@veic.org
Sam Dent
Nick Lange
Leslie Badger
Chris Badger
255 S. Champlain St.
Burlington, VT 05401
(802) 658-6060 x1103; www.veic.org

Optimal Energy Inc.
Steve Bower
Matt Socks
Cliff McDonald
Sam Huntington
Alek Antczak
14 School Street, Suite 203-C
Bristol, VT 05443
(802) 453-5100; www.optenergy.com

Energy Futures Group Inc.
Chris Neme
Richard Faesy
P.O. Box 587
Hinesburg, Vermont 05461
(802) 482-5001

Cx Associates, LLC
Jennifer Chiodo
Eveline Killian
110 Main Street, Studio 1B
Burlington, VT 05401
(802) 861-2715 ; www.cx-assoc.com

Resource Insight Inc.
Paul Chernick
Five Water Street
Arlington, MA 02476
(781) 646-1505; www.resourceinsight.com

The 2020 Ohio TRM was updated for the Public Utilities Commission of Ohio by Michaels Energy, with contributions from the following:

Michaels Energy
Ryan Kroll, Project Manager; rmk@michaelenergy.com
Joel Pertzsch
Brian Uchtmann
Jon Hilyard
Sydnie Lieb
Isaac Thompson
Paige Markegard
400 Main St, Suite 200
La Crosse, WI, 54601
(608) 785-1900; www.michaelsenergy.com

Evergreen Economics
Stephen Grover
1500 SW 1st Ave, Suite 1000
Portland, OR 97201
(503) 894-8676; https://evergreenecon.com/

PWP Consulting
Phil Willems
11820 Silent Valley Lane,
North Potomac, MD 20878
(301) 762-3494; https://pwpconsulting.com/

2020 Ohio Technical Reference Manual
Table of Contents

I. Introduction

In 2009 VEIC was retained by the Public Utilities Commission of Ohio (PUCO) to prepare this Technical Reference Manual (TRM) for use by the electric and gas utilities in the state of Ohio (in response to the PUCO TRM Entry *In the Matter of Protocols for the Measurement and Verification of Energy Efficiency and Peak Demand Reduction Measures, Case No. 09-512-GE-UNC*, June 24, 2009). The resulting document outlined recommendations for the content of the 2010 Ohio TRM and a process for its maintenance and update. In 2019 Michaels Energy, in collaboration with Evergreen Economics, was retained to provide updates to the TRM.

In the development of these characterizations, information in the TRM document filed jointly by the Ohio electric utilities (*Technical Reference Manual (TRM) for Ohio Senate Bill 221, Energy Efficiency and Conservation Program and 09-512-GE-UNC,* October 15, 2009) was reviewed. This review included an engineering assessment of formulas found therein and an analysis of how the utilities' proposals compare with those used in other jurisdictions (after adjusting for expected differences due to climate, codes, programs, etc.). Documents and reference materials supporting utility assumptions were investigated, and the utilities were contacted to collect information on program design and delivery as well as technical support information and evaluations. Information from the electric and gas utilities' Portfolio Plans was reviewed, including savings by measure for the programs the electric utilities have proposed in their plans, and preliminary information on the make-up of mercantile customer projects. All significant questions arising out of the review were pursued, and findings and observations from these reviews were shared with the PUCO staff and the utilities.

We have attempted to provide characterizations or protocols here to guide savings calculations for all planned program measures for which there is reliable information to support claims. Measures have been characterized using all available best practice information, taking into account:

- Guidance promulgated by the Commission regarding underlying policy considerations that will shape the protocols, assumptions, and values included in the TRM
- Comparative research of best practice and appropriate use of assumptions from other jurisdictions when needed
- Adjustments made to measure characterizations to reflect the Ohio-specific market environment (climate, codes, other baselines, market penetration, etc.)
- The context of the energy efficiency program designs through which measures are delivered
- Compliance with potential RTO market requirements, including IPMVP protocols where practical and necessary

The characterizations and protocols for the measures included here are the result of these activities. Our analysis of assumptions for these characterizations rests on our understanding of the best-supported information available. In each case, we reviewed all Ohio and mid-West specific information available, including evaluations and support material provided by the Ohio utilities and information from other more-mature efficiency programs in the Ohio region that have undertaken evaluations and research to support their savings assumptions (including programs in Wisconsin, Pennsylvania, and Michigan). Ohio-specific information on market penetrations, weather-dependent assumptions, and local codes and practices was used. When Ohio-specific evaluations of other types of information was not available, or if we felt that results were not well supported or not applicable to the measures in question, we turned to best practice research and data from other jurisdictions, often from west- and east-coast states that have long-standing programs and who have allocated large amounts of funding to evaluation work and refinement of measure characterization parameters. As a result, much of the most-defensible information originates from these regions. In every case we used the most-recent well-designed and supported studies and only if it was appropriate to generalize their conclusions to the Ohio utilities' programs.

Purpose of the TRM

The TRM has been developed officially to help determine compliance with the energy efficiency and conservation requirements of Senate Bill 221 (SB 221) and the requirements of Case 09-512-GE-UNC. More broadly than this, as envisioned by the PUCO the TRM will serve a wide range of important users and functions, including:

- Utilities – for cost-effectiveness screening and program planning, tracking, and reporting
- Mercantile customers – for assessing energy savings opportunities
- The PUCO, the Independent Program Evaluator, and other parties – for evaluating utilities performance relative to statutory goals, and facilitating planning and portfolio review
- Markets, such as PJM's Reliability Pricing Model (its wholesale capacity market) and carbon markets – for valuing efficiency resources

Thus, the TRM is intended to serve as an important tool to support efficiency investments, both for planning and assessment of success in meeting goals. In addition, the TRM is intended to support the bidding of efficiency resources into resource markets, such as PJM's wholesale capacity market, and in setting and tracking future environmental and climate change goals. It provides a common platform for Ohio utilities to characterize measures within their efficiency programs, analyze and meaningfully compare cost-effectiveness of measures and programs, communicate with policymakers and stakeholders about program details, and it can guide future evaluation and measurement activity and help identify priorities for investment in further study, needed either at a regional or individual organizational level.

Use of the TRM – General Format

For each prescriptive measure, the TRM includes either specific deemed values or algorithms for deemed calculations. These algorithms contain a number of deemed underlying assumptions that when combined with some measure-specific information (e.g., equipment capacity) produce deemed calculated savings values. Values or algorithms are included for calculating:

- Gross annual electric energy savings
- Gross electric peak demand savings – peak coincidence determinations are based on the PUCO established summer on-peak period (3:00-6:00 p.m. weekdays, June through August)
- Gross annual fossil fuel energy savings - for electric efficiency measures that also save fossil fuels, as well as gas measures
- Other resource savings where appropriate (e.g., water savings, O&M impacts); for use in cost-effectiveness screening
- Incremental costs
- Measure lives

For those measures that appear to be consistent with an implementation strategy involving in-store coupons, prescriptive rebates, or buy downs (for example, efficient appliances, pool pumps, etc.), we have provided prescriptive deemed savings values rather than deemed calculation algorithms that require input variables for each purchase. This was not always consistent with the format of measure characterization in the Joint Utility TRM, but we believe this approach will be more convenient for program design and be equally accurate when all the savings are aggregated.

Conversely, for other measures that lend themselves more appropriately to calculations using site- or project-specific data (for example air sealing, shell insulation, duct sealing, etc.), we have assumed that a member of implementation staff or an associated contractor will be onsite to record the necessary information and use it to calculate savings using the algorithms we have provided. These types of measures are often very variable and so providing simple deemed savings values is not appropriate.

We have also provided detailed protocols for the Residential New Construction and Whole House Retrofit programs that provide guidance on the custom approach recommended for these programs. Both require the collection of site-specific information to be used to assess savings on a house-by-house basis. Detailed protocols are also provided for custom commercial and industrial (C&I) projects and for transmission and distribution (T&D) projects.

The TRM is intended to be a living document. There will be measures that are not characterized here; new measures will be added to programs and new program designs will be implemented; new information will be gathered through evaluations or research; and savings for current measures will change as the activity of the programs changes their markets (i.e., savings for CFLs will decrease over time as successful programs result in lamps being installed mostly in lower-use locations). The TRM update and maintenance process described in Appendix D has been designed to allow for frequent review and update of the TRM as needs demand. Data from reliable impact evaluations would be necessary to support savings claims until the measure has been incorporated into the TRM or updated.

Use of the TRM – Common Definitions and Assumptions

The savings estimates are expected to serve as representative, recommended values, or ways to calculate savings based on program-specific information. All information is presented on a per measure basis. In using the measure-specific information in the TRM, it is helpful to keep the following notes in mind.

- The TRM clearly identifies whether the measure impacts pertain to "retrofit", "time of sale",[1] or "early retirement" program designs.
- Additional information about the program design is sometimes included in the measure description, because program design can affect savings and other parameters.
- Savings algorithms are provided for each measure. For a number of measures, prescriptive values for each of the variables in the algorithm are provided along with the output from the algorithm. That output is the deemed savings assumption. For other measures, prescriptive values are provided for only some of the variables in the algorithm, with the term "actual" or "actual installed" provided for the others. In those cases – which one might call "deemed calculations"– users of the TRM are expected to use actual efficiency program data (e.g., capacities or rated efficiencies of central air conditioners) in the formula to compute savings. Note that the TRM often provides example calculations for measures requiring "actual" values. These are for illustrative purposes only.
- All estimates of savings are for annual savings (not lifetime savings).
- Unless otherwise noted, measure life is defined to be the life of an energy consuming measure, including its equipment life and measure persistence.
- Where deemed values for savings are provided, these represent average savings that could be expected from the average measures that might be installed in the region in 2010.
- For measures that are not weather-sensitive, peak savings are estimated whenever possible as the average of savings between 3 pm and 6 pm across all summer weekdays (the PUCO summer on-peak period).

[1] In some jurisdictions, this is called "replace on burn-out". We use the term "time of sale" because not all new equipment purchases take place when an older existing piece of equipment reaches the end of its life.

- Wherever possible, savings estimates and other assumptions are based on Ohio or regional data. However, a number of assumptions are based on sources from other regions of the country. While this information is not perfectly transferable, due to differences in definitions of peak periods as well as geography and climate and customer mix, it was used because it was the most transferable and usable source available at the time.
- Users will note that the TRM presents engineering equations for most measures. These were judged to be desirable because they convey information clearly and transparently, and they are widely accepted in the industry. Unlike simulation model results, they also provide flexibility and opportunity for users to substitute locally specific information and to update some or all parameters as they become available on an ad hoc basis. One limitation is that certain interaction effects between end uses, such as how reductions in waste heat from many efficiency measures impacts space conditioning, are not universally captured in this version of the TRM. Such interactive factors are included in calculations for lighting measures, and full protocols for their inclusion are given in the custom project protocols.
- Many C&I measures in the Joint Utility TRM were based on building energy simulations. This was typically done for complex, highly interactive measures, such as envelope improvements or chilled water resets. We agree that this is the best approach; it is prohibitively difficult to estimate energy savings from these types of measures with simplified algorithms. We conducted a review of the building prototype assumptions, which are primarily based on California's Database of Energy-Efficient Resources (DEER) prototypes with adjustments based on data published by the U.S. Energy Information Administration's (EIA) Commercial Building Energy Consumption Survey (CBECS) and a review by an engineering consulting company under contract to Duke Energy, and did not have any major concerns. The parameters used for the efficient case were also reviewed, and no issues significant enough to justify additional modeling work were identified. Two major changes were made in the presentation of the modeled measures in this TRM. First, we added the change in natural gas usage due to heating impacts for all relevant measures. Second, we disaggregated savings estimates by building type as well as climate zone. Many modeled measures show savings varying by up to a factor of four from one building type to another, and envelope measures often have significant heating impacts. These changes should increase the accuracy of the savings estimates and provide a more complete portrait of the measure's impacts. Finally, other values, such as incremental measures costs, that do not affect the modeling results were updated based on the latest available data.
- For early replacement measures across all sectors, we have provided two levels of savings:
  - An initial period during which the existing inefficient unit would have continued to be used had it not been replaced (and savings claimed between the existing unit and the efficient replacement),
  - The remainder of the measure life, where we assume that the existing unit would have been replaced with a standard baseline unit at the time of the deferred purchase. (and so savings are claimed between the standard baseline and the efficient replacement).
- In general, the baselines included in the TRM are intended to represent average conditions in Ohio. Some are based on data from the state, such as household consumption characteristics provided by the Energy Information Administration. Some are extrapolated from other areas, when Ohio data are not available. When weather adjustments were needed in extrapolations, weather conditions in all major Ohio cities were generally used as representative for their regions.

Cost-Benefit Considerations

This TRM is intended to be a resource to help assess the cost-effectiveness of the included energy efficiency measures. The specific cost-benefit methodologies in Ohio should be informed by the information contained in the TRM. This section is intended to provide clarity on the underlying assumptions that inform the avoided costs in the TRM, to allow their proper utilization in cost-benefit assessments.

The measure characterizations in this TRM include information and assumptions to support savings calculations for the range of program delivery options commonly used for the measure. Care has been taken to clearly define in the measure's description the types of program delivery that the measure characterization is designed to support. However, there are no universally accepted definitions for a particular program type, and the description of the program type(s) may differ by measure. Nevertheless, program delivery types can be generally defined according to the following table. These are the definitions used in the measure descriptions, and, when necessary, individual measure descriptions may further refine and clarify these definitions of program delivery type.

Table 1. Program Types and Attributes

Program	Attributes
Time of Sale (TOS)	Definition: A program in which the customer is incented to purchase or install higher efficiency equipment than if the program had not existed. This may include retail rebate (coupon) programs, upstream buy-down programs, online store programs or contractor based programs as examples.
	Baseline = Code minimum or industry standard efficiency equipment.
	Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.
	Example: CFL rebate
New Construction (NC)	Definition: A program that intervenes during building design to support the use of more-efficient equipment and construction practices.
	Baseline = Building code or federal standards.
	Efficient Case = The program's level of building specification
	Example: Building shell and mechanical measures
Retrofit (RF)	Definition: A program that upgrades existing equipment before the end of its useful life.
	Baseline = Existing equipment or the existing condition of the building or equipment. A single baseline applies over the measure's life.
	Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.
	Example: Air sealing and insulation
Early Replacement (EREP)	Definition: A program that replaces existing equipment before the end of its expected life.
	Baseline = Dual; it begins as the existing equipment and shifts to new baseline equipment after the expected life of the existing equipment is over.
	Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.
	Example: Refrigerators, freezers
Early Retirement (ERET)	Definition: A program that retires duplicative equipment before its expected life is over.
	Baseline = The existing equipment, which is retired and not replaced.
	Efficient Case = Zero because the unit is retired.
	Example: Appliance recycling
Direct Install (DI)	Definition: A program where measures are installed during a site visit.
	Baseline = Existing equipment.
	Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.

	Example: Lighting and low-flow hot water measures
Efficiency Kits (KITS)	Definition: A program where measures are provided free of charge to a customer in an Efficiency Kit.
	Baseline = Existing equipment.
	Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.
	Example: Lighting and low-flow hot water measures

The concept and definition of the baseline is a key element of every measure characterization and is directly related to the program delivery type. Without a clear definition of the baseline, the savings algorithms cannot be adequately specified and subsequent evaluation efforts would be hampered. As a result, each measure has a detailed description (and in many cases, specification) of the specific baseline that should be used to calculate savings. Baselines in this TRM fall into one of the following four categories, and are organized within each measure characterization by the program delivery type to which it applies.

1. **Building Code:** As defined by the minimum specifications required under state energy code or applicable federal standards.
2. **Existing Equipment**: As determined by the most representative (or average) example of equipment that is in the existing stock. Existing equipment baselines apply over the equipment's remaining useful life.
3. **New Equipment:** As determined by the equipment that represents standard practice in the current market environment. New equipment baselines apply over the effective useful life of the measure.
4. **Dual Baseline:** A baseline that begins as the existing equipment and shifts to new equipment after the expected life of the existing equipment is over

The TRM anticipates the effects of changes in efficiency codes and standards on affected measures. When these changes take effect, a shift in the baseline is usually required. This complicates the measure savings estimation somewhat, and will be handled in future versions of the TRM by describing the choice of and reasoning behind a shifting baseline assumption. In this version of the TRM, this applies to CFLs and T5/T8 Linear Fluorescents, and early retirement measures.

CFL and T5/T8 Linear Fluorescents and LED Baseline Assumptions

Specific reductions in savings have been incorporated for CFL and LED measures that relate to the shift in appropriate baseline due to changes in Federal Standards for lighting products. Federal legislation (stemming from the Energy Independence and Security Act of 2007) mandated a phase-in process that began in 2012 for all general-purpose light bulbs (defined as omnidirectional or A-lamps) between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase-out of the current style, or "standard", incandescent bulbs. From 2012, standard 100W incandescent bulbs could no longer be manufactured, followed by restrictions on standard 75W bulbs in 2013 and 60W and 40W bulbs in 2014. The baseline for the CFL and LED Omnidirectional Lamp measure in the corresponding program years therefore became bulbs (improved or "efficient" incandescent, or halogen) that met the new standard and have the same lumen equivalency. In addition, a backstop provision requires replacement baseline lamps meet 45 lumens/watt from 2020. To account for this shifting baseline, annual savings are reduced within the lifetime of the measure using a midlife baseline adjustment. The magnitude and timing of these adjustments are specified within each measure.

Specialty and Directional lamps were not included in the original definition of General Service Lamps in the Energy Independence and Security Act of 2007 (EISA). Therefore, the initial baseline is an incandescent / halogen lamp described in that measure.

However, a DOE Final Rule released on 1/19/2017 updated the EISA regulations to remove the exemption for these lamp types such that they become subject to the backstop provision defined within the original legislation. There is, however, uncertainty around the final application of the EISA backstop provision, particularly whether the expanded definition will hold, as well as uncertainty regarding how the market for these products would change absent the backstop. Therefore, the 2019 version of the LED Specialty Lamp measure delays application of the midlife adjustment associated with the backstop provision to 1/1/2024. However, TAC members commit to making appropriate mid-year adjustments to the measure characterization in the event that new information adds sufficient clarity and concludes any legal challenges to support making a change to this agreement. This means that, if within PY2019 it becomes clear that the EISA backstop *will* apply to the measures characterized herein, the timing of the midlife adjustment will be changed to be applied in 2021, consistent with the omnidirectional measure. Likewise, if it becomes clear that these lamp types will revert to being exempt, the midlife adjustment will be removed. In addition, the TAC and IL TRM Administrator must consider NTG and lifetime assumptions and, if consensus is reached, apply coordinated adjustments to the TRM at that time (if consensus is not reached the most recent NTG evaluation results for these measures will be applied). Any mid-year adjustments to the TRM and NTG would be applied for all installs beginning 30 days after agreement is reached, rather than waiting for the next TRM update.

In July 14, 2012, Federal Standards were enacted that were expected to eliminate T-12s as an option for linear fluorescent fixtures. Through v3.0 of the TRM, it was assumed that the T-12 would no longer be baseline for retrofits from 1/1/2016. However, due to significant loopholes in the legislation, T-12 compliant product is still freely available, and in Illinois T-12s continue to hold a significant share of the existing and replacement lamp market. Therefore, the timing of the sunsetting of T-12s as a viable baseline was pushed back in v7.0 to 1/1/2020, and will be revisited in future update sessions and incorporate findings from any baseline studies conducted through the year.

Early Replacement Baseline Assumptions

A series of measures have an option to choose an Early Replacement Baseline if the following conditions are met:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs

All other conditions will be considered Time of Sale.

Avoided Cost Assumptions

We assume that accounting for this step-down adjustment in annual savings is possible in the utilities' tracking systems. We have also provided the impact of the deferred replacement payment that would have occurred at the end of the useful life of the existing equipment. Avoided O&M costs are based on the net present value of the deferred and avoided maintenance costs.

- For this and other net present value calculations, we have assumed a 5% discount factor for all calculations.
- This factor, as well as assumed energy cost escalation rates, should be updated in the future.

II. Protocols for Custom Commercial & Industrial Projects

C&I Equipment Replacement – 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 equipment replacement measures that are not covered by other analysis methodologies in the TRM. An equipment replacement project is defined as equipment replaced at the end of its rated service life, or when it is replaced due to failure, obsolescence or a need for increased capacity. If the project is replacing equipment prior to the end of its rated service life for the purpose of achieving energy savings, it is classified as Retrofit and the "C&I Retrofit – Custom Measure Analysis Protocol" should be used to guide analysis.

This protocol is intended to address the energy impacts of the incremental energy efficiency improvements over what would have been installed as per applicable federal/state/local codes or standard industry practice. 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 equipment replacement 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 Metering

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 - Compressed Air System Replacement.

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[2].

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 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. For example: "Expand existing lab fume hoods by replacing two 10ft constant speed 10,000 CFM hoods with two 15ft modulating hoods controlled by smoke and temperature sensors."

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 metering 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.

[2] 2007 NAICS; North American Industry Classification System; http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007

Efficient Case

Efficient Technology Description and Documentation
Describe the new technology, measure, and/or change in operations, and how it saves energy. Document any relevant efficiency codes or federal/state/local standards that apply to the proposed efficient equipment and the ratings of the measure equipment in comparison with applicable standards. If the efficient measure was the result of a process improvement that provides additional benefits, such as waste reduction, clearly describe all of the ways that the new process saves energy and resources. This can include reductions in areas such as waste heat, O&M costs, labor costs, water consumption, or process waste.

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 *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:

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

Where:

$ENERGY_{eff} \equiv$ Annual Efficient Energy Use - annual energy use with the efficiency improvement installed, calculated separately for each measure and each *energy source* (electric, gas).

$E\ LOAD_{j.eff} \equiv$ 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.

$HOURS_{j.eff} \equiv$ 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:

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

Where:

$ENERGY_{eff} \equiv$	Annual Efficient Energy Use - annual energy use with the efficiency improvement installed, calculated separately for each measure and each *energy source* (electric, gas).
$FULL\ LOAD_{j.eff} \equiv$	Efficient Full Load - the maximum operating load of each efficient system and subsystem with operating condition *j* (as defined below).
$LF_{j.eff} \equiv$	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. 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.
$HOURS_{j.eff} \equiv$	Total Annual Operating Hours – Total Annual Operating Hours for each system and subsystem with operating condition *j* (as defined below).
$j \equiv$	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.
$m \equiv$	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:

$AVG\ PH\ LOAD_{eff} \equiv$	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:

$C\ LOAD_{eff} \equiv$	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*.
$FULL\ LOAD_{k.eff} \equiv$	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.
$LF_{k.eff} \equiv$	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.
$CF_{k.eff} \equiv$	*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.
$k \equiv$	System Condition - refers to each distinct combination of the system mode, Full Load demand, and Load Factor for each system or subsystem operating during the *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 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 Equipment Replacement projects is the equipment meeting the level of efficiency required by State Code[3], applicable Federal product efficiency standard[4] or standard practices, whichever is most stringent, in place at the time of installation. If there is no applicable State code or Federal Standard then the methodology for establishing standard practice shall be documented in the M&V plan as described in PJM Manual 18B[5] Section 8. The baseline description shall detail information regarding the baseline technology(ies) including make, model number, nameplate data and rated capacity of the equipment, operating schedule, and controls and how the baseline was determined.

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:

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

$E\ LOAD_{j.base} \equiv$ 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.

---

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

[4] ANSI/ASHRAE/IESNA Standard 90.1-2004, ISSN 1041-2336; www.ashrae.org

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

$HOURS_{j.base}$ ≡ 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 equipment specifications and metering of baseline operating conditions including load factor and operating hours:

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

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).

$LF_{j.base}$ ≡ 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:

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

Where:

$C\ LOAD_{base} \equiv$ 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*.

$FULL\ LOAD_{k.base} \equiv$ 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.

$LF_{k.base} \equiv$ 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[6].

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,

[6] 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

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[7].

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 Equipment Replacement measures, the average coincident demand, including non-operational hours, is typically determined by metering the post-installation condition and deriving the Coincidence Factor for the pre-installation condition from the metered data. However, in some cases, the use of a known or predetermined published Coincidence Factor, such as measure specific coincidence factors identified in other sections of the TRM is acceptable.

An example of Coincidence Factor derivation from metered data would be a stepped demand device such as a high efficiency compressor. Based on post-installation metering, a Coincidence Factor can be calculated and applied to the baseline equipment when the baseline operating schedule is the same as the efficient operating schedule. In this case, the Coincidence Factor is defined as the ratio of average metered demand for the *Peak Performance Hours* and max ‘equipment on’ demand when operating. If the

[7] 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

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. Where pre- and post-installation operating schedules are the same, use of pre- or post-logging of operating hours to prepare the analysis is adequate. 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[8]) and used as the 8760 weather file to model and/or normalize annual energy use for weather dependent measures. Modeling tools, such as eQuest[9], 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[10]) 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

[8] Typical Meteorological Data (TMY3) - http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/
[9] DOE2 eQuest simulation software - http://www.doe2.com/equest/
[10] NOAA local weather data - http://cdo.ncdc.noaa.gov/qclcd/QCLCD?prior=N

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 calculated baseline and the metered efficient case[11]. Post-installation metering shall include documentation of production output during metering periods; work with plant personnel to ensure logged production data accurately reflects changes in production over the metering period.

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.

Controls

Control settings and level of control shall be accounted for in the analysis. Clearly document the control points that affect energy use, the control set points, sequence of operation and accuracy of controls that would have been used in the baseline case. 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 most facilities.

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, document the methodology that is used to ensure that savings from the interactive effects are only accounted for once in the claimed savings.

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[12] and the associated cooling reduction.
>
> **Heating Increase**

[11] 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

[12] 2009 ASHRAE Handbook, Fundamentals, Chapter 18, page 18.3.

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.

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.

Measure Life

Document both the life of the baseline and efficient case equipment. 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[13]. 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.

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

Section 4: Documentation and Metering

Documentation and metering of custom projects are essential to developing reliable energy savings and Coincident Electrical Demand reduction claims.[14] 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[15]. Metering for Equipment Replacement projects is typically conducted post-installation to establish the Coincidence Factor, operating hours and Load Factor. Where measures include a control component, metering of these factors in the baseline condition is necessary to accurately establish the baseline.

Interval and Utility Data

Utility interval data is typically not useful in analyzing equipment replacement projects because the baseline condition is not represented in the utility billing data.

For completed mercantile projects in existing facilities, project documentation 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 measure16. 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 PJM17 Section 11 requirements.

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

[15] 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

[16] 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

[17] 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

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 harmonics[18]. 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 18B[19] and RLW Analytics Review of ISO New England Measurement and Verification Equipment Requirements[20]. 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

---

[18] 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

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

[20] 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

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 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 analysis21. 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

[21] 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

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 Electric Demand for baseline and efficient cases shall be calculated from post-installation meter data as the average demand 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.) shall be included in the project documentation. 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.

Where citing nameplate ratings in the analysis, provide documentation of the ratings.

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 Retrofit – 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 retrofit measures that are not covered by other analysis methodologies in the TRM. A retrofit project is defined as equipment replacement prior to the end of its rated service life in order to achieve energy savings. Where equipment is replaced due to failure or for other reasons (such as obsolescence or a need for increased capacity), the project is classified as Equipment Replacement and the "C&I Equipment Replacement – Custom Measure Analysis Protocol" should be used to guide analysis.

This protocol is intended to address the energy impacts of the operating energy efficiency improvements. 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 retrofit energy efficiency measure savings estimates.

The Analysis Protocol and Analysis Template are divided into four sections:
Section 1: Project Information
Section 2: Project Savings
Section 3: Project Variables
Section 4: Documentation and Metering

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 - Compressed Air System Improvements.

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[22].

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 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. For example: "Replace two 10ft constant speed 10,000 CFM fume hoods with modulating fume hoods controlled by smoke and temperature sensors."

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 metering 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.

Efficient Case

Efficient Technology Description and Documentation

[22] 2007 NAICS; North American Industry Classification System; http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007

Describe the new technology, measure, and/or change in operations, and how it saves energy. Document any relevant efficiency codes or federal/state/local standards that apply to the proposed efficient equipment and the ratings of the measure equipment in comparison with applicable standards. If the efficient measure was the result of a process improvement that provides additional benefits, such as waste reduction, clearly describe all of the ways that the new process saves energy and resources. This can include reductions in areas such as waste heat, O&M costs, labor costs, water consumption, or process waste.

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 *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:

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

Where:

$ENERGY_{eff} \equiv$ Annual Efficient Energy Use - annual energy use with the efficiency improvement installed, calculated separately for each measure and each *energy source* (electric, gas).

$E\ LOAD_{j.eff} \equiv$ 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.

$HOURS_{j.eff} \equiv$ 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:

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

Where:

$ENERGY_{eff} \equiv$	Annual Efficient Energy Use - annual energy use with the efficiency improvement installed, calculated separately for each measure and each *energy source* (electric, gas).
$FULL\ LOAD_{j.eff} \equiv$	Efficient Full Load - the maximum operating load of each efficient system and subsystem with operating condition *j* (as defined below).
$LF_{j.eff} \equiv$	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. 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.
$HOURS_{j.eff} \equiv$	Total Annual Operating Hours – total annual operating hours for each system and subsystem with operating condition *j* (as defined below).
$j \equiv$	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.
$m \equiv$	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:

$AVG\ PH\ LOAD_{eff} \equiv$	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:

$C\ LOAD_{eff} \equiv$ 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*.

$FULL\ LOAD_{k.eff} \equiv$ 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.

$LF_{k.eff} \equiv$ 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.

$CF_{k.eff} \equiv$ *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.

$k \equiv$ System Condition - refers to each distinct combination of the system mode, Full Load demand, and Load Factor for each system or subsystem operating during the *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 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,[23] 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[24] is a strong tool in documenting the project's focus on energy efficiency and the optimization of energy use.[25]

[23] Department of Energy, Energy Information Administration, Manufacturing Energy Consumption Survey, http://www.eia.doe.gov/emeu/mecs/contents.html
[24] 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
[25] 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[26].

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:

$ENERGY_{base} \equiv$	Annual Baseline Energy Use - Annual Energy Use for baseline equipment calculated separately for each measure and each *energy source* (electric, gas).
$E\ LOAD_{j.base} \equiv$	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.
$HOURS_{j.base} \equiv$	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:

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

[26] 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

Where:

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

$AVG\ PH\ LOAD_{base} \equiv$	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:

$C\ LOAD_{base} \equiv$ 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*.

$FULL\ LOAD_{k.base} \equiv$ 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.

$LF_{k.base} \equiv$ 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[27].

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,

[27] 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

development of an 8760 load shape will increase the accuracy of the analysis and the reliability of claimed demand reductions during peak periods[28].

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 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,

[28] 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

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[29]) and used as the 8760 weather file to model and/or normalize annual energy use for weather dependent measures. Modeling tools, such as eQuest[30], 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[31]) 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[32]. 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.

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.

---

[29] Typical Meteorological Data (TMY3) - http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

[30] DOE2 eQuest simulation software - http://www.doe2.com/equest/

[31] NOAA local weather data - http://cdo.ncdc.noaa.gov/qclcd/QCLCD?prior=N

[32] 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

Process flow charting for manufacturing and production is recommended to clarify energy use and demand impacts for each stage in the process[33].

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[34] 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.

[33] Doty, Commercial Energy Auditing Reference Handbook, p. 65
[34] 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[35]. 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

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

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

Documentation and metering of custom projects are essential to developing reliable energy savings and peak demand reductions claims.[36] 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[37].

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[38].

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.

---

[36] Parlin, Kathryn, et. al. (August, 2009 IEPEC) "Demand Reduction in the Forward Capacity Market, Verifying the Efficiency Power Plant"
[37] 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
[38] International Performance Measure and Verification Protocol Concepts and Practices for Determining Energy Savings in New Construction, Volume III, Part 1, January 2006.

For variable loads, three-phase power data loggers shall be used to collect electrical power data for systems and subsystems of the custom measure39. 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 harmonics40. 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 18B41 and RLW Analytics Review of ISO New England Measurement and Verification Equipment Requirements42. 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.

---

[39] 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

[40] 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

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

[42] 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

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 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[43]. 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

[43] 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

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.

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[44].

[44] 2007 NAICS; North American Industry Classification System; http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007

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 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:

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

Where:

$ENERGY_{eff} \equiv$ Annual Efficient Energy Use - Annual Energy Use with the efficiency improvement installed, calculated separately for each measure and each *energy source* (electric, gas).

$E\ LOAD_{j.eff} \equiv$ 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.

$HOURS_{j.eff} \equiv$ 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:

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

Where:

$ENERGY_{eff} \equiv$ Annual Efficient Energy Use - Annual Energy Use with the efficiency improvement installed, calculated separately for each measure and each *energy source* (electric, gas).

$FULL\ LOAD_{j.eff} \equiv$ Efficient Full Load - the maximum operating load of each efficient system and subsystem with operating condition *j* (as defined below).

$LF_{j.eff} \equiv$ 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.

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

$j \equiv$ System Condition - refers to each distinct combination of system mode, number of hours, full load demand, and load factor for each system or subsystem.

$m \equiv$ 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:

$AVG\ PH\ LOAD_{eff} \equiv$ 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:

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

Where:

$C\ LOAD_{eff} \equiv$ 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*.

$FULL\ LOAD_{k.eff} \equiv$ 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.

$LF_{k.eff} \equiv$ 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.

$CF_{k.eff} \equiv$ *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.

$k \equiv$ 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*.

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

The analysis shall 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[45], in place at the time of installation. Document any additional Federal or industry standards[46] 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:

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

Where:

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

$E\ LOAD_{j.base} \equiv$ 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.

$HOURS_{j.base} \equiv$ 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:

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

Where:

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

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

$FULL\ LOAD_{j.base} \equiv$ Baseline Full Load - the maximum operating load of each baseline system and subsystem with operating condition *j* (as defined below).

$LF_{j.base} \equiv$ 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.

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

$j \equiv$ System Condition - refers to each distinct combination of system mode, number of hours, Full Load demand, and Load Factor for each system or subsystem.

$m \equiv$ 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.

Baseline Case Coincident Electric Demand (kW)

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:

$AVG\ PH\ LOAD_{base} \equiv$ 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:

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

Where:

$C\ LOAD_{base} \equiv$ 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*.

$FULL\ LOAD_{k.base} \equiv$ Baseline Full Load - the maximum nameplate load of each baseline system and subsystem in operation during the *Performance Hours* with operating condition *k* (as defined below), exclusive of non operating time.

$LF_{k.base} \equiv$ 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 (e.g. high speed, low speed), Full Load demand, and Load Factor for each system or subsystem operating during *Performance Hours*.

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

The analysis shall 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 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 via whole building modeling. Ensure that the model addresses project variables as described in Section 3. Whole building models are designed to address interactive effects; the analyst shall ensure that the model accurately addresses such effects.

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[47].

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. Describe the modeling methods used and any uncertainty associated with the values used in the model. **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. Modeling for new construction projects is the expected method for accounting for these variables as described in Section 4.

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

[47] 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

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 model shall generate an 8760 load shape[48] that captures 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..

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 modeled measures, the average coincident demand, including non-operational hours, is generated through the hourly simulation of building demand for the baseline and efficient conditions during *Peak Performance Hours*.

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 projected operating hours for all affected equipment in the building – scheduled operating hours are the same for base and efficient case models except where necessary to model nonstandard efficiency measures[49]. 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.

---

[48] 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
[49] ASHRAE Standard 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings, Appendix G, Table G3.1, Section 4.

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
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[50]) and used as the 8760 weather file to model and/or normalize annual energy use for weather dependent measures. Modeling tools, such as eQuest[51], 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.

Production
This applies only to industrial new construction projects that include production measures. 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[52].

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.

Controls
Control settings and level of control shall be accounted for in the analysis in accordance with ASHRAE Standard 90.1 2007, Appendix G. Clearly document the control points that affect energy use, the control setpoints, sequence of operation and accuracy of controls that are required for the baseline case in Appendix G. Clearly document the changes in these conditions for the efficient case and how they are modeled. 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 most facilities.

[50] Typical Meteorological Data (TMY3) - http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/
[51] DOE2 eQuest simulation software - http://www.doe2.com/equest/
[9] 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 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, document the methodology that is used to ensure that savings from the interactive effects are only accounted for once in the claimed savings.

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[53] 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.

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.

Measure Life

Document both the life of the baseline and efficient case equipment. 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[54]. 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

---

[53] 2009 ASHRAE Handbook, Fundamentals, Chapter 18, page 18.3.

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

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 Modeling

Documentation and modeling of custom new construction projects are essential to developing reliable energy savings and peak demand reductions claims.[55] The following guidelines support the accurate estimation of energy and demand savings.

Modeling
Computer modeling is an acceptable method of analysis using an 8760 model which meets the requirements of ASHRAE 90.1 Appendix G and the requirements of the LEED Reference Guide for Green Building Design and Construction, Energy and Atmosphere Credit One, Option 1, Whole Building Simulation.

Process measures, such as industrial process or data center efficiency that are additional to the building design modeled under ASHRAE 90.1 Appendix G shall be either included in the simulation using customized algorithms, or modeled separately using measure specific analysis tools. The results of measure specific analysis shall be accounted for in the building model and any custom simulations should be documented in accordance with the TRM and the Custom Analysis Template (Appendix B).

Calculations
Computer simulation of energy efficiency measures using 8760 hourly simulation models such as eQuest, or customized spreadsheet analysis or other energy analysis tools shall be employed to calculate energy savings. The algorithms of the modeling software must be designed to address the modeled measures.

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

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. Document the assumptions and calculations for baseline and efficient Coincident Electric Demand (kW) 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.) shall be included in the project documentation. 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.

Reporting

The following shall be reported:

- All information required in this protocol
- Custom Analysis Template (Appendix B) Section 1 and Documentation Worksheet (Appendix C) only
- Documentation as required by LEED Reference Guide for Green Building Design and Construction, Energy and Atmosphere Credit One, Option 1, Whole Building Simulation.
- 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.

III. TRM Maintenance and Update Process

The Ohio Technical Reference Manual is designed to be a living document – it will benefit from an objective and thoughtful update process. Defining a process that coordinates with the needs of users, evaluators, and regulators is critical. Below we outline a process for the update of information and recommendations on the coordination of the timing of this process with other critical activities.

Proposed TRM Update Process

Once a TRM has been developed, it is vital that it is kept up to date, appended, and maintained in a timely and effective manner. There are three main points in time when a TRM is most likely to require changes:

- New measure additions – As new technologies become cost effective, they will need to be characterized and added to the manual. In addition, new program delivery design may result in the need for new measure characterization.
- Existing measure updates – Updates will be required for a number of reasons. Examples include: the federal standard for efficiency of a measure is increased; the qualification criteria are altered; the

measure cost falls; or a new evaluation provides a better value of an assumption for a variable. In addition, as programs mature, characterizations need to be updated as changes in the market require changes in calculation assumptions. In such cases, these changes must be identified and appropriate changes made to the TRM.

- Retiring existing measures – When the economics of a measure become such that it is no longer cost effective, or the free rider rate is so high that it is not worth supporting, the measure should be retired.

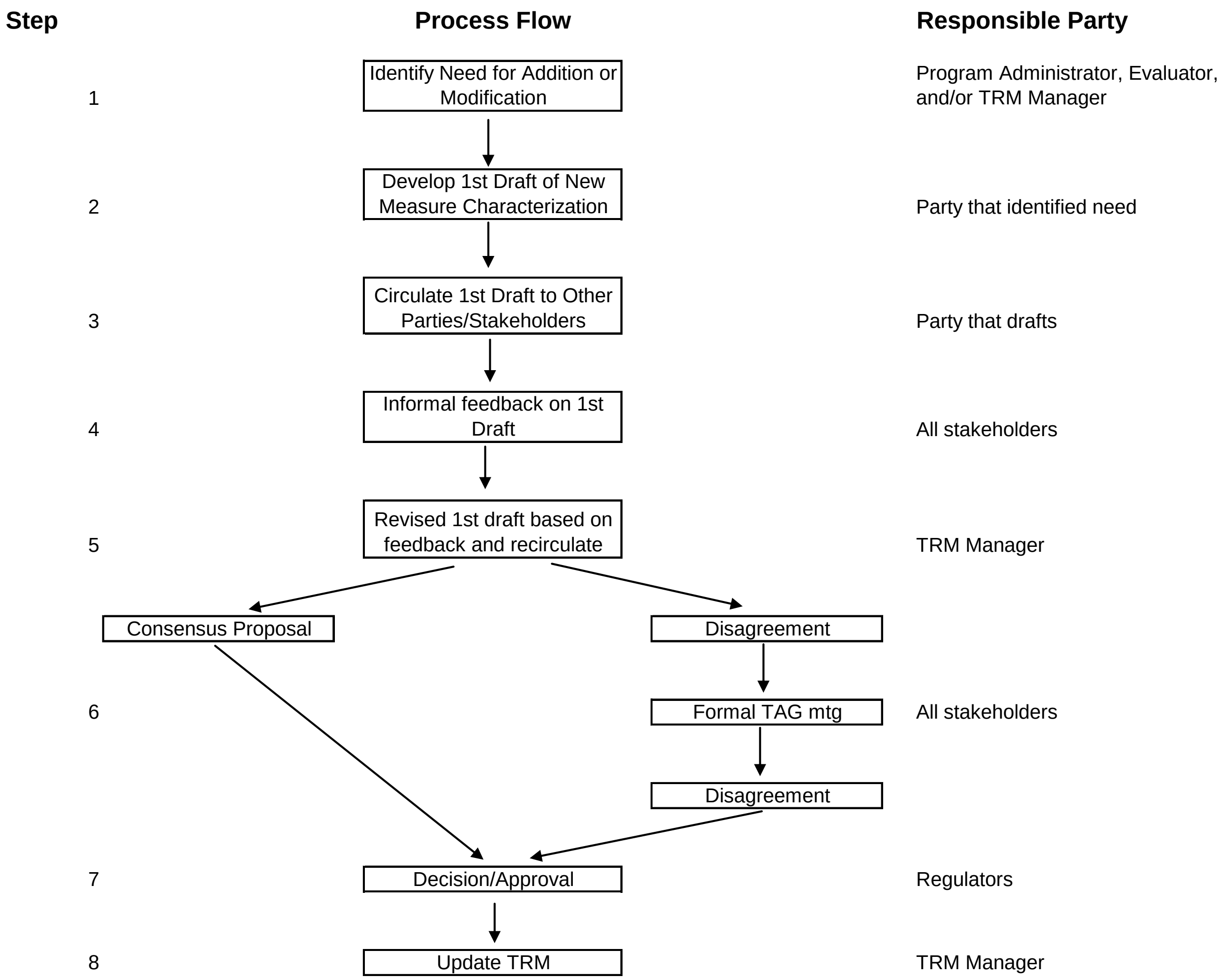
It is important to maintain a record of changes made to the TRM over time. It is therefore recommended to establish and maintain a Master Manual, containing all versions of each TRM in chronological order, and an abridged User Manual, in which only the current versions of active measures are included. Archiving older information in this fashion can be designed into the electronic interface (if developed), and only the current version of the User Manual is publically available on the site.

The flowchart presented below outlines steps that will result in effective review and quality control for TRM updates. One critical component is the establishment of a Technical Advisory Group (TAG) to provide a forum for discussing and resolving technical concerns.

This process requires a number of different roles to ensure effectiveness, sufficient review, and independence. The specific parties who will hold these roles in the Ohio TRM maintenance context will be clarified in discussion with the Commission. The following list of key responsibilities is given as a starting place for this conversation:

- Program administrators / utilities (consultants)
    - Identifies need for new or revised measure characterization – usually due to program changes or program/market feedback
    - Researches and develop first draft measure characterizations – for needs that the utilities identify
    - Develops second draft measure characterizations following feedback on first draft from all parties
    - Gives feedback on draft measure characterizations from other parties
    - Participates in Technical Advisory Group (TAG) for formal discussion and dispute resolution when needed
    - Gives input to regulators if TAG process does not resolve all issues

Flowchart for Proposed TRM Update Process



- Independent TRM Manager (Consultant)
  - Identifies need for revised measure characterization (usually based on knowledge of local or other relevant evaluation studies)
  - Researches and develops first draft measure characterizations – for needs identified either by itself or Evaluation consultant
  - Gives feedback on first draft measure characterizations from other parties
  - Develops second draft measure characterizations following feedback on first draft from all parties

    - Leads Technical Advisory Group (TAG) for formal discussion and dispute resolution when needed
    - Provides input to regulators if TAG process does not resolve all issues
    - Makes recommendation for TRM revision to PUCO
    - Manages and updates TRM manuals (after PUCO approval of changes)
- Third-party Evaluation consultant
    - Identifies need for revised measure characterization (usually based on local evaluation studies it has conducted or managed)
    - Input on draft measure characterizations developed by other parties
    - Participates in TAG meetings when appropriate
    - Performs program evaluation - includes statewide market assessment and baseline studies, savings impact studies (to measure the change in energy and / or demand use attributed to energy efficiency), and other energy efficiency program evaluation activities
    - Verifies annual energy and capacity savings claims of each program and portfolio
    - Ensures proper utility use of TRM in annual savings verification process
- Commission staff
    - Hires and manages TRM and Evaluation consultant(s)
    - Approves any changes to TRM – includes serving as final arbiter in any disagreements between utilities and TRM consultant

The process outlined above also assumes that there are several potential stages of "give and take" on draft modifications to the TRM. At a minimum, there is at least one round of informal feedback and comment between the program administrators and the independent reviewer (TRM Manager or otherwise). Other parties could be invited to participate in this process as well. In the event that such informal discussions do not resolve all issues, the participants may find it beneficial to establish a Technical Advisory Group (TAG) to provide a more formal venue for resolution of technical disputes prior to any submission to the regulators. This group would include representation from the program administrators, the evaluators (when deemed useful), the TRM Manager, and Commission staff. The mission of such a group would be to discuss and reach agreement on any unresolved issues stemming from new measure proposals, savings verifications, or evaluations. They could also review and comment on the methodology and associated assumptions underlying measure savings calculations and provide an additional channel for transparency of information about the TRM and the savings assessment process.

Coordination with Other Savings Assessment Activities

As drafted, the Ohio Administrative Code requires the Commission/Staff to report whether an electric utility's or mercantile customer's actions match their proposed program portfolio; whether the utility's or mercantile customer's proposed program portfolio would produce actual savings; and whether actual savings were achieved. Although the TRM will be a critically important tool for both DSM planning and estimation of actual savings, it will not, by itself, ensure that reported savings are the same as actual savings. There are two principal reasons for this:

1. **The TRM itself does not ensure appropriate estimation of savings**. One of the responsibilities of the Independent Program Evaluator will be to assess that the TRM has been used appropriately in the calculation of savings.
2. **The TRM may have assumptions or protocols that new information suggests are outdated**. New information that could inform the reasonableness of TRM assumptions or protocols can surface at any time, but they are particularly common as local evaluations or annual savings verification processes are completed. Obviously, the TRM should be updated to reflect such new information. However, it is highly likely that some such adjustments will be made too late to affect the annual savings estimate of a utility or mercantile customer for the previous year, particularly given the PUCO's interim decision to not adjust savings estimates retroactively (TRM Entry Appendix A). Thus, there may be a difference between savings estimates in annual compliance reports and the "actual savings" that the PUCO may consider acceptable from a regulatory perspective. However, such updates should be captured in as timely a fashion as possible.

These two issues highlight the fact that the TRM needs to be integrated into a broader process that has two other key components: an annual savings verification process and on-going evaluation.

Savings verification ensures that information is being tracked accurately and in a manner consistent with the TRM. However, as important as it is, verification does not ensure that reported savings are "actual savings". TRMs are never and can never be perfect. Even when the verification process documents that assumptions have been appropriately applied, it can also highlight questions that warrant future analysis that may lead to changes to the TRM. Put another way, evaluation studies are and always will be necessary to identify changes that need to be made to the TRM. Therefore, in addition to annual savings verification processes, evaluations will periodically be made to assess or update the underlying assumption values for critical components of important measure characterizations.

In summary, there should be a strong, sometimes cyclical relationship between the TRM development and update process, annual compliance reports, savings verification processes, and evaluations. As such, we recommend coordinating these activities. A preliminary timeline established from such a coordinated process is given in the table below.

Annual Verification and TRM Update Timeline

<table>
<tr><th></th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td rowspan="2">Utility</td><td colspan="2">Draft annual savings report</td><td colspan="3">No TRM submittal during SV</td><td></td><td colspan="6">Draft new or updated measure characterizations developed and submitted to TRM Manager; participate in TAG</td></tr>
<tr><td colspan="3"></td><td colspan="2">SV response</td><td>Prior year data finalized</td><td colspan="6" rowspan="2">Technical Advisory Group (TAG) negotiations and evaluation</td></tr>
<tr><td rowspan="2">Evaluator</td><td></td><td></td><td colspan="3">Savings verification (SV)</td><td></td></tr>
<tr><td></td><td></td><td colspan="3">No TRM review during SV</td><td></td><td colspan="6">Refers need for TRM updates to TRM Manager; provides input on characterizations</td></tr>
<tr><td>TRM Manager</td><td></td><td></td><td colspan="3">No TRM during savings verification</td><td></td><td colspan="6">Propose/develop new or updated measure characterizations; review drafts provided by utilities; participate in TAG</td></tr>
</table>

PUCO						Make final savings determination	Participate in TAG meetings; approve final TRM

In this example, it assumed that updates to the TRM occur only in the second half of the year. One option is to establish two specific update deadlines: one in September and the other at the end of December. The first would ensure that the best available data are available for utility planning for the following year. The second would ensure that best available assumptions are in place prior to the start of the new program year. In general, we would expect the number of additions or revisions in the September TRM update to be much greater than the number in December. Nevertheless, providing for two rounds of TRM review each year gives the opportunity to have updated savings assumptions reviewed and approved more often, reducing the time that a program administrator might be at risk of providing services using not-yet-approved measure characterizations. The rationale for not updating the TRM during the first half of the year is that time is usually devoted, in part, to documenting, verifying and approving savings claims from the previous year. For example, the program administrator will likely require two months to produce its annual savings claim for the previous year. An independent reviewer will then require two to three months to review and probe that claim, with considerable back and forth between the two parties being very common. Typically, final savings estimates for the previous year are not finalized and approved until mid-year. Program administrators and evaluators would be unlikely to have the time or focus for considering changes to measure characterizations during this time.

IV. Appendices

A. Prototypical Building Energy Simulation Model Development

B. Custom Analysis Template

C. Documentation Summary Worksheet for Custom Projects

Appendix A – Prototypical Building Energy Simulation Model Development

Many of the savings values from the TRM are derived from DOE-2.2 simulations of typical commercial buildings. These prototypes were originally developed for the TRM document filed jointly by the Ohio electric utilities (*Technical Reference Manual (TRM) for Ohio Senate Bill 221, Energy Efficiency and Conservation Program and 09-512-GE-UNC*, October 15, 2009). They are based on building prototypes originally developed to calculate savings for California's Database for Energy Efficient Resources (DEER), with certain parameters adjusted to Ohio building practice based on Duke Energy program experience and a review of the U.S. Energy Information Administration's (EIA) Commercial Buildings Energy Consumption Survey (CBECS). The following sections provide a description of the prototypical buildings and a summary of key modeling assumptions.

Commercial Building Prototype Model Development

Commercial sector prototype building models were developed for a series of small commercial buildings with packaged rooftop HVAC systems, including assembly, big box retail, fast food restaurant, full service restaurant, grocery, light industrial, primary school, small office and small retail buildings. A large office prototype was also included to analyze measures associated with built-up HVAC systems. The following sections describe the prototypical simulation models used in this analysis.

Assembly

A prototypical building energy simulation model for an assembly building was developed using the DOE-2.2 building energy simulation program. The characteristics of the prototype are summarized in Table 2.

Table 2. Assembly Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	34,000 square feet Auditorium: 33,240 SF Office: 760 SF
Number of floors	1
Wall construction and R-value	Concrete block, R-5
Roof construction and R-value	Wood frame with built-up roof, R-12
Glazing type	Multipane Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Auditorium: 1.9 W/SF Office: 1.55 W/SF
Plug load density	Auditorium: 1.2 W/SF Office: 1.7 W/SF
Operating hours	Mon-Sun: 8am – 9pm
HVAC system type	Packaged single zone, no economizer
HVAC system size	Based on ASHRAE design day conditions, 10% over sizing assumed.
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 80 cooling, 65 heating

A computer-generated sketch of the prototype is shown in Figure 1.

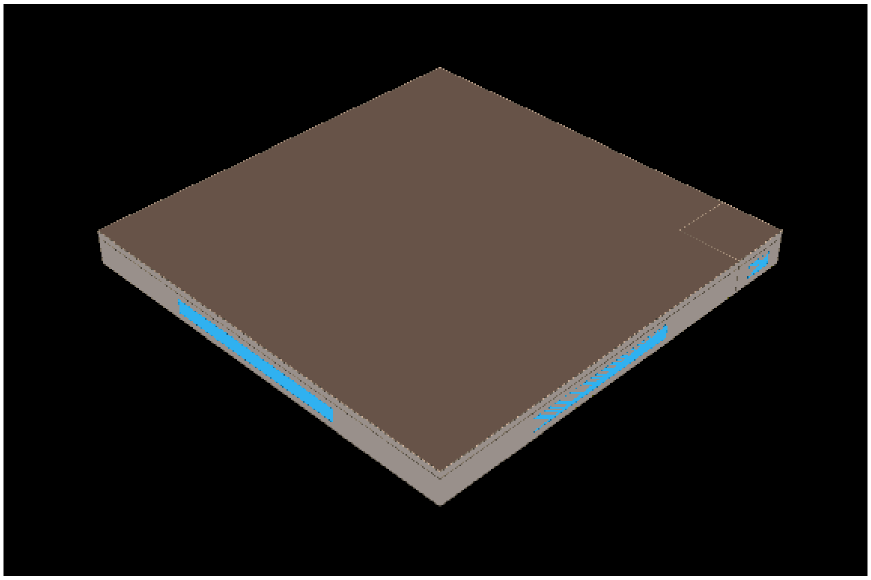


Figure 1. Assembly Building Rendering

Big Box Retail

A prototypical building energy simulation model for a big box retail building was developed using the DOE-2.2 building energy simulation program. The characteristics of the prototype are summarized in Table 3.

Table 3. Big Box Retail Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	130,500 square feet Sales: 107,339 SF Storage: 11,870 SF Office: 4,683 SF Auto repair: 5,151 SF Kitchen: 1,459 SF
Number of floors	1
Wall construction and R-value	Concrete block with insulation, R-7.5
Roof construction and R-value	Metal frame with built-up roof, R-13.5
Glazing type	Multipane; Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Sales: 2.15 W/SF Storage: 0.85 W/SF (Active) 0.45 W/SF (Inactive) Office: 1.55 W/SF Auto repair: 1.7 W/SF Kitchen: 2.2 W/SF
Plug load density	Sales: 1.15 W/SF Storage: 0.23 W/SF Office: 1.73 W/SF Auto repair: 1.15 W/SF Kitchen: 3.23 W/SF
Operating hours	Mon-Sun: 10am – 9pm
HVAC system type	Packaged single zone, no economizer

Characteristic	Value
HVAC system size	Based on ASHRAE design day conditions, 10% over sizing assumed.
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 80 cooling, 65 heating

A computer-generated sketch of the prototype is shown in Figure 2.

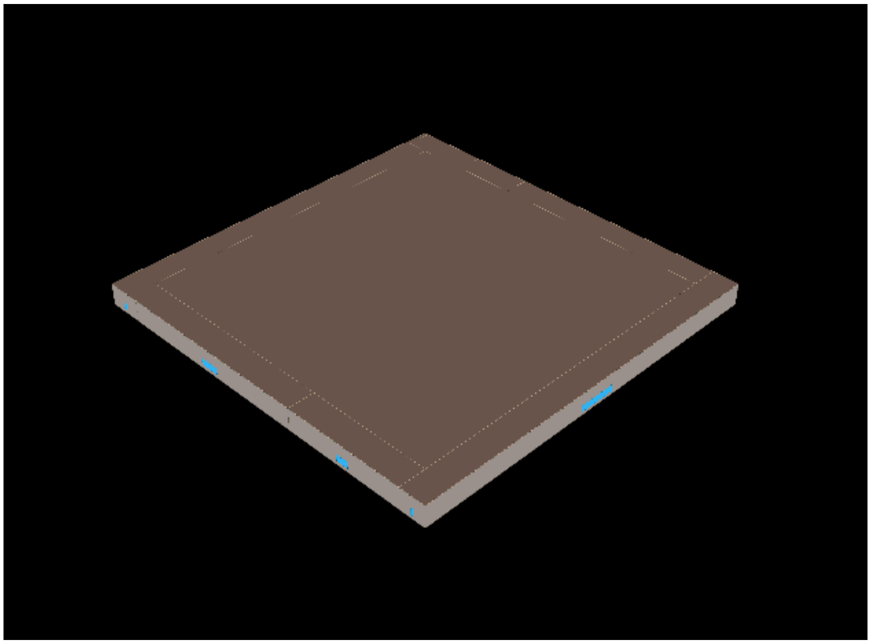


Figure 2. Big Box Retail Building Rendering

Fast Food Restaurant

A prototypical building energy simulation model for a fast food restaurant was developed using the DOE-2.2 building energy simulation program. The characteristics of the prototype are summarized in Table 4.

Table 4. Fast Food Restaurant Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	2000 square feet 1000 SF dining 600 SF entry/lobby 300 SF kitchen 100 SF restroom
Number of floors	1
Wall construction and R-value	Concrete block with brick veneer, R-7.5
Roof construction and R-value	Concrete deck with built-up roof, R-13.5
Glazing type	Multipane Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Dining: 1.7 W/SF Entry area: 1.7 W/SF Kitchen: 2.2 W/SF Restroom: 0.9 W/SF

Characteristic	Value
Plug load density	0.6 W/SF dining 0.6 W/SF entry/lobby 4.3 W/SF kitchen 0.2 W/SF restroom
Operating hours	Mon-Sun: 6am – 11pm
HVAC system type	Packaged single zone, no economizer
HVAC system size	Based on ASHRAE design day conditions, 10% over sizing assumed.
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 80 cooling, 65 heating

A computer-generated sketch of the prototype is shown in Figure 3.

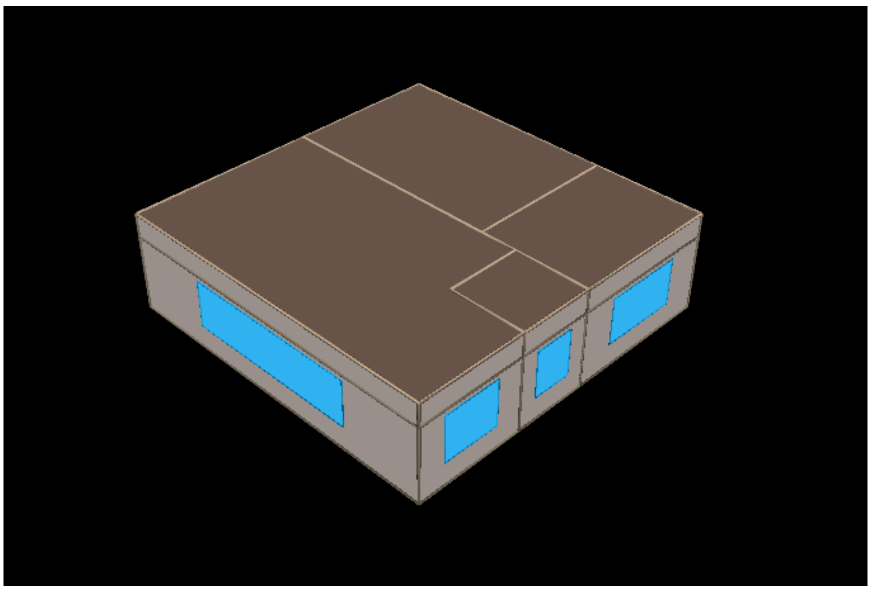


Figure 3. Fast Food Restaurant Building Rendering

Full-Service Restaurant

A prototypical building energy simulation model for a full-service restaurant was developed using the DOE-2.2 building energy simulation program. The characteristics of the full service restaurant prototype are summarized in Table 5.

Table 5. Full Service Restaurant Prototype Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	2000 square foot dining area 600 square foot entry/reception area 1200 square foot kitchen 200 square foot restrooms
Number of floors	1
Wall construction and R-value	Concrete block with brick veneer, R-7.5
Roof construction and R-value	Wood frame with built-up roof, R-13.5
Glazing type	Multipane; Shading-coefficient = 0.84

Characteristic	Value
	U-value = 0.72
Lighting power density	Dining area: 1.7 W/SF Entry area: 1.7 W/SF Kitchen: 2.2 W/SF Restrooms: 1.5 W/SF
Plug load density	Dining area: 0.6 W/SF Entry area: 0.6 W/SF Kitchen: 3.1 W/SF Restrooms: 0.2 W/SF
Operating hours	9am – 12am
HVAC system type	Packaged single zone, no economizer
HVAC system size	Based on ASHRAE design day conditions, 10% over sizing assumed.
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 80 cooling, 65 heating

A computer-generated sketch of the full-service restaurant prototype is shown in Figure 4.

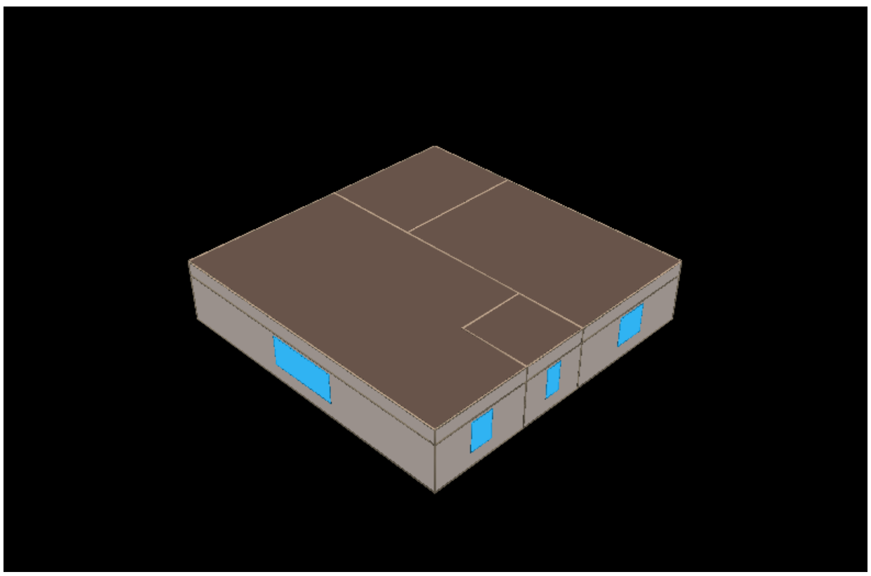


Figure 4. Full Service Restaurant Prototype Rendering

Grocery

A prototypical building energy simulation model for a grocery building was developed using the DOE-2.2 building energy simulation program. The characteristics of the prototype are summarized in Table 6.

Table 6. Grocery Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	50,000 square feet Sales: 40,000 SF Office and employee lounge: 3,500 SF Dry storage: 2,860 SF 50 °F prep area: 1,268 SF 35 °F walk-in cooler: 1,560 SF

Characteristic	Value
	- 5 °F walk-in freezer: 812 SF
Number of floors	1
Wall construction and R-value	Concrete block with insulation, R-5
Roof construction and R-value	Metal frame with built-up roof, R-12
Glazing type	Single pane clear
Lighting power density	Sales: 3.36 W/SF Office: 2.2 W/SF Storage: 1.82 W/SF 50°F prep area: 4.3 W/SF 35°F walk-in cooler: 0.9 W/SF - 5°F walk-in freezer: 0.9 W/SF
Equipment power density	Sales: 1.15 W/SF Office: 1.73 W/SF Storage: 0.23 W/SF 50°F prep area: 0.23 W/SF + 36 kBtu/hr process load 35°F walk-in cooler: 0.23 W/SF + 17 kBtu/hr process load - 5°F walk-in freezer: 0.23 W/SF+ 29 kBtu/hr process load
Operating hours	Mon-Sun: 6am – 10pm
HVAC system type	Packaged single zone, no economizer
Refrigeration system type	Air cooled multiplex
Refrigeration system size	Low temperature (-20°F suction temp): 23 compressor ton Medium temperature (18°F suction temp): 45 compressor ton
Refrigeration condenser size	Low temperature: 535 kBtu/hr THR Medium temperature: 756 kBtu/hr THR
Thermostat setpoints	Occupied hours: 74°F cooling, 70°F heating Unoccupied hours: 79°F cooling, 65°F heating

A computer-generated sketch of the prototype is shown in Figure 5.

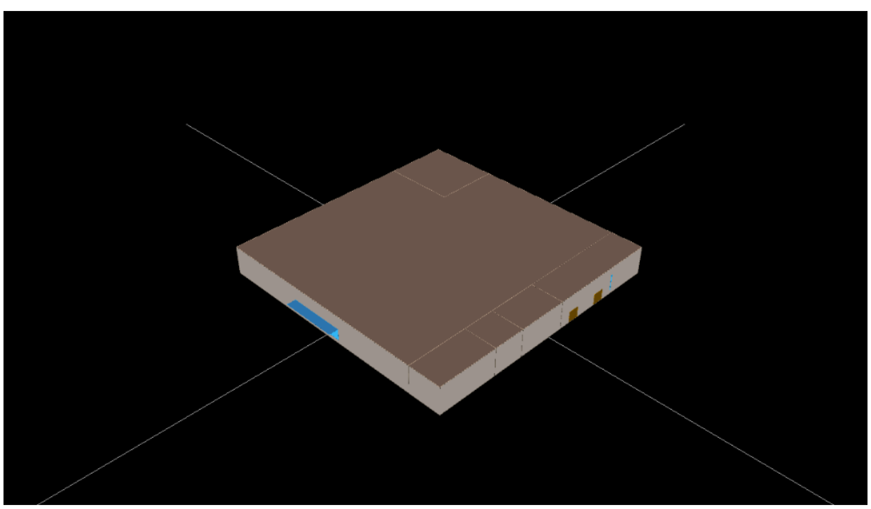


Figure 5. Grocery Building Rendering

Large Office
A prototypical building energy simulation model for a large office building was developed using the DOE-2.2 building energy simulation program. The characteristics of the prototype are summarized in Table 7.

Table 7. Large Office Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	350,000 square feet
Number of floors	10
Wall construction and R-value	Glass curtain wall, R-7.5
Roof construction and R-value	Built-up roof, R-13.5
Glazing type	Multipane; Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Perimeter offices: 1.55 W/SF Core offices: 1.45 W/SF
Plug load density	Perimeter offices: 1.6 W/SF Core offices: 0.7 W/SF
Operating hours	Mon-Sat: 9am – 6pm Sun: Unoccupied
HVAC system types	1. Central constant volume system with perimeter hydronic reheat, without economizer; 2. Central constant volume system with perimeter hydronic reheat, with economizer; 3. Central VAV system with perimeter hydronic reheat, with economizer
HVAC system size	Based on ASHRAE design day conditions, 10% over sizing assumed.
Chiller type	Water cooled and air cooled
Chilled water system type	Constant volume with 3 way control valves,
Chilled water system control	Constant CHW Temp, 45 deg F setpoint
Boiler type	Hot water, 80% efficiency
Hot water system type	Constant volume with 3 way control valves,
Hot water system control	Constant HW Temp, 180 deg F setpoint
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 80 cooling, 65 heating

Each set of measures was run using each of three different HVAC system configurations – a constant volume reheat system without economizer, a constant volume reheat system with economizer and a VAV system with economizer. The constant volume reheat system without economizer represents system with the most heating and cooling operating hours, while the VAV system with economizer represents a system with the least heating and cooling hours. This presents a range of system loads and energy savings for each measure analyzed.

A computer-generated sketch of the prototype is shown in Figure 6. Note, the middle floors, since they thermally equivalent, are simulated as a single floor, and the results are multiplied by 8 to represent the energy consumption of the 8 middle floors.

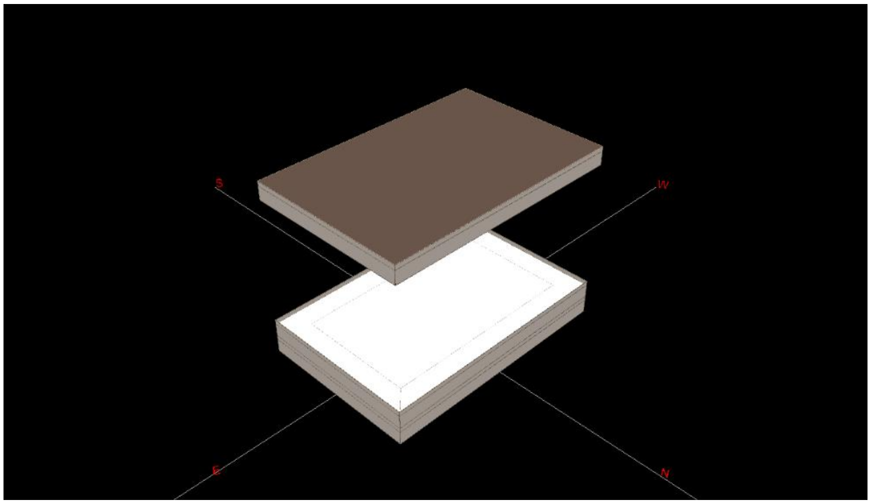


Figure 6. Large Office Building Rendering

Light Industrial
A prototypical building energy simulation model for a light industrial building was developed using the DOE-2.2 building energy simulation program. The characteristics of the prototype are summarized in Table 8.

Table 8. Light Industrial Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	100,000 square feet total 80,000 SF factory 20,000 SF warehouse
Number of floors	1
Wall construction and R-value	Concrete block with Brick, no insulation, R-5
Roof construction and R-value	Concrete deck with built-up roof, R-12
Glazing type	Multipane; Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Factory – 2.25 W/SF Warehouse – 0.7 W/SF
Plug load density	Factory – 1.2 W/SF Warehouse – 0.2 W/SF
Operating hours	Mon-Fri: 6am – 6pm Sat Sun: Unoccupied
HVAC system type	Packaged single zone, no economizer
HVAC system size	Based on ASHRAE design day conditions, 10% over sizing assumed.
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 80 cooling, 65 heating

A computer-generated sketch of the prototype is shown in Figure 7.

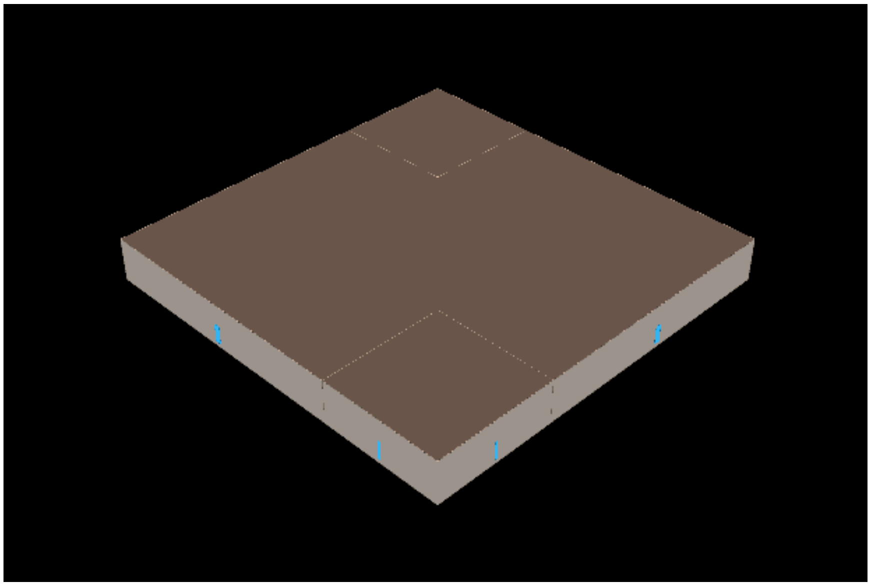


Figure 7. Light Industrial Building Rendering

Primary School

A prototypical building energy simulation model for an elementary school was developed using the DOE-2.2 building energy simulation program. The model is really of two identical buildings oriented in two different directions. The characteristics of the prototype are summarized in Table 9.

Table 9. Elementary School Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	2 buildings, 25,000 square feet each; oriented 90° from each other Classroom: 15,750 SF Cafeteria: 3,750 SF Gymnasium: 3,750 SF Kitchen: 1,750 SF
Number of floors	1
Wall construction and R-value	Concrete with brick veneer, R-7.5
Roof construction and R-value	Wood frame with built-up roof, R-13.5
Glazing type	Multipane Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Classroom: 1.8 W/SF Cafeteria: 1.3 W/SF Gymnasium: 1.7 W/SF Kitchen: 2.2 W/SF
Plug load density	Classroom: 1.2 W/SF Cafeteria: 0.6 W/SF Gymnasium: 0.6 W/SF Kitchen: 4.2 W/SF
Operating hours	Mon-Fri: 8am – 6pm Sun: 8am – 4pm
HVAC system type	Packaged single zone, no economizer

Characteristic	Value
HVAC system size	Based on ASHRAE design day conditions, 10% over sizing assumed.
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 80 cooling, 65 heating

A computer-generated sketch of the prototype is shown in Figure 8.

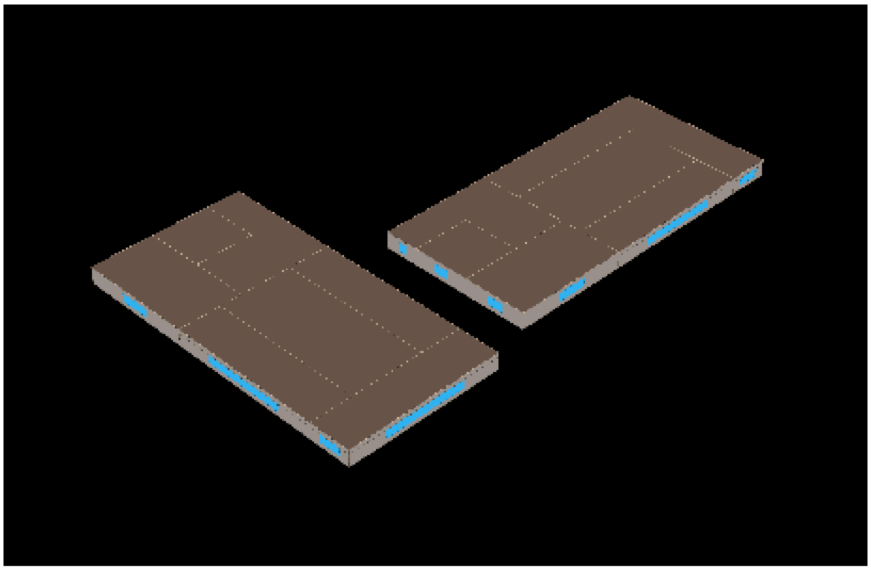


Figure 8. School Building Rendering

Small Office

A prototypical building energy simulation model for a small office was developed using the DOE-2.2 building energy simulation program. The characteristics of the small office prototype are summarized in Table 10.

Table 10. Small Office Prototype Building Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	10,000 square feet
Number of floors	2
Wall construction and R-value	Wood frame with brick veneer, R-7.5
Roof construction and R-value	Wood frame with built-up roof, R-13.5
Glazing type	Multipane; Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Perimeter offices: 1.55 W/SF Core offices: 1.45 W/SF
Plug load density	Perimeter offices: 1.6 W/SF Core offices: 0.7 W/SF
Operating hours	Mon-Sat: 9am – 6pm Sun: Unoccupied
HVAC system type	Packaged single zone, no economizer
HVAC system size	Based on ASHRAE design day conditions, 10% over sizing assumed.

Characteristic	Value
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 80 cooling, 65 heating

A computer-generated sketch of the small office prototype is shown in Figure 9.

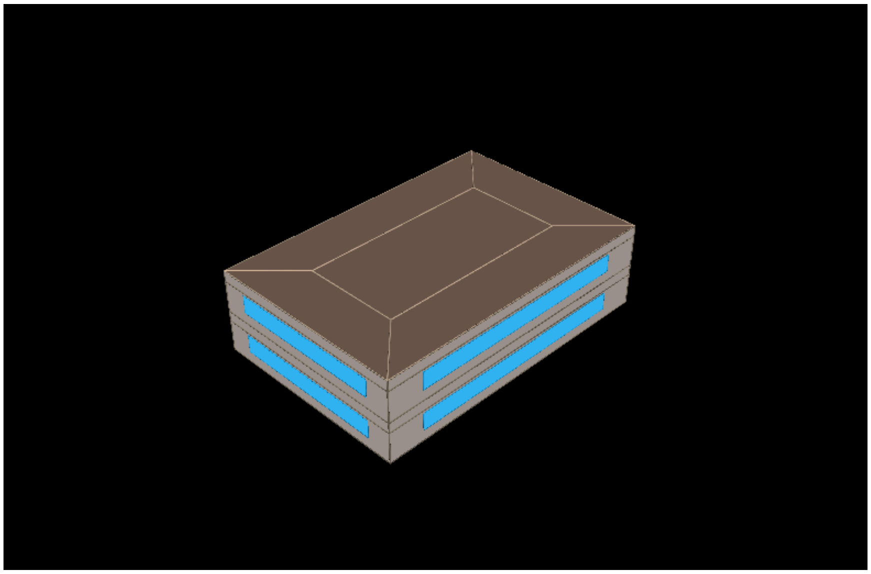


Figure 9. Small Office Prototype Building Rendering

Small Retail
A prototypical building energy simulation model for a small retail building was developed using the DOE-2.2 building energy simulation program. The characteristics of the small retail building prototype are summarized in Table 11.

Table 11. Small Retail Prototype Description

Characteristic	Value
Vintage	Existing (1970s) vintage
Size	6400 square foot sales area 1600 square foot storage area 8000 square feet total
Number of floors	1
Wall construction and R-value	Concrete block with brick veneer, R-7.5
Roof construction and R-value	Wood frame with built-up roof, R-13.5
Glazing type	Multipane; Shading-coefficient = 0.84 U-value = 0.72
Lighting power density	Sales area: 2.15 W/SF Storage area: 0.85 W/SF (Active) 0.45 W/SF (Inactive)
Plug load density	Sales area: 1.2 W/SF Storage area: 0.2 W/SF
Operating hours	10 – 10 Monday-Saturday 10 – 8 Sunday
HVAC system type	Packaged single zone, no economizer

Characteristic	Value
HVAC system size	Based on ASHRAE design day conditions, 10% over sizing assumed.
Thermostat setpoints	Occupied hours: 75 cooling, 70 heating Unoccupied hours: 80 cooling, 65 heating

A computer-generated sketch of the small retail building prototype is shown in Figure 10.

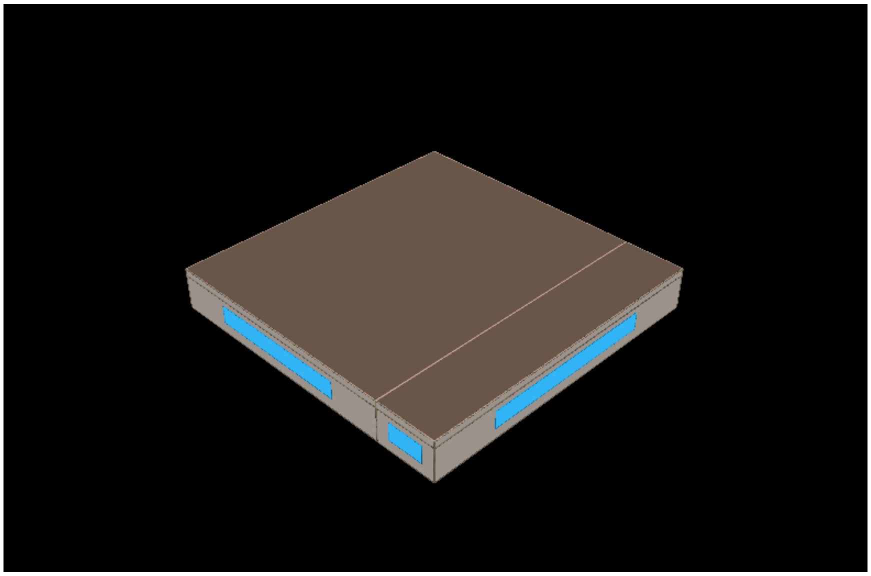


Figure 10. Small Retail Prototype Building Rendering

Weighting of Results

The simulation models provide results at a level of detail that sometimes surpass the normal data collection procedures from customer incentive applications and other EDC data collection. Thus, weights were assigned to individual simulation results, and the weighted averages were reported in the TRM sections where the added complexity of using building type-specific factors was unwarranted. The weights used for analysis were derived from Duke Energy data.

For the commercial building analysis, the weights assigned to each of the building types are shown below:

Table 12. Commercial Building Type Weights

Building Type	Weight
Assembly	0.118
Big Box	0.017
Fast food	0.017
Full Service	0.042
Light industrial	0.008
Primary school	0.059
Small office	0.176
Small retail	0.563

Note, the large office and grocery store models were used to analyze specific measures unique to the HVAC system and equipment types used in these buildings. Results relevant to these building types were reported separately and not included in the weighted averages.

Appendix B – Custom Analysis Template

A. Project Information[56]

Project Name

Date

Project, measure, metering and analysis information shall reflect the project as installed and operating. Directions to the user of the template are in this font throughout the document. Analysts should use a different font to document the project information. Submit all required utility and/or PUCO documentation, the completed Custom Analysis Template and associated documentation as indicated herein and in the TRM. List project documentation in the Documentation Summary Worksheet (Appendix C).

This template complements the Technical Reference Manual requirements for custom measure analysis. Refer to the appropriate TRM protocol to ensure adequate documentation of the custom analysis. The Sections in this template are labeled A – E as they do not directly correspond to the four sections in the TRM.

Table 13

Program Name	
Customer Name	
Site Name if Different	
Site Address	
Building or Site Type	
NAICS Code	
Customer Business/Product	
Building Size	
Project Start Date	
Start Date of Measure Installation	
Project Completion Date	
Applicable Codes &/or Standards	
Electric Utility & Account Number	
Meter Number	

[56] Section A of this document is based on a Measurement and Verification Template developed by Energy Resource Solutions for NYSERDA in 2010.

Annual Electric Energy Use on Affected Meter	Pre-installation Annual kWh: Pre-installation maximum billed kW:
Rate	
Gas Utility & Account Number	
Meter Number	
Annual Gas Energy Use on Affected Meter	Pre-installation Annual Consumption Therms:
Rate	

Add rows as needed to provide the necessary information regarding any other energy sources are affected by this project (ie. Fuel oil or renewable energy)

Principal Customer Contact Name	
Title	
Phone	
Email	
Utility Representative Name	
Title	
Phone	
Email	
Custom Energy Analyst Contact	Technical lead for this custom analysis.
Name	
Title	
Company	
Phone	Office: Cell:
Email	
Mailing Address	
Additional Project Contact	
Role	
Title	
Company	
Phone	
Email	

Add lines as needed

Project Description

Describe the project and how it saves energy. Complete the following Project Savings Summary table based on the results of the savings analysis per Section D below.

Table 14. Project Savings Summary

Measure Number	Measure Name	Electic Energy Savings (kWh/yr)	Coincident Demand Savings (kW)	Gas Savings (therms/yr)	Other Fuel Impacts
1					
2					
3					
Total Savings for All Measures					

Add information regarding other fuel impacts if the project impacts unregulated fuels such as fuel oil, renewable, etc. and indicate units in the header. Delete columns that are not applicable to the project, except electric efficiency projects must include Electric Energy and Coincident Demand columns. Add rows as needed to address all measures associated with the project. Show any increases in energy as a result of the project as a negative number (negative savings).

B. Measure Information

Document the following information for each project measure. Duplicate Section B for each unique measure. Include all information necessary to describe the equipment and how it operates, including manufacturer's information. Reference case studies of similar systems wherever possible. Reference supporting documentation in the Documentation Summary Worksheet. Duplicate the following sections as needed.

Measure Number and Name

Measure Description

Describe the new technology, measure, and/or change in operations, and how it saves energy.

Measure Performance in Comparison with Relevant Codes and Standards

Document the relevant efficiency codes or federal/state/local standards that apply to the proposed efficient equipment and the ratings of the measure equipment in comparison with applicable standards.

Additional Benefits

If the efficient measure was the result of a process improvement that provides additional benefits, such as waste reduction, clearly describe all of the ways that the new process saves energy and resources. This can include reductions in areas such as waste heat, O&M costs, labor costs, water consumption, or process waste.

Baseline Description

Describe the baseline condition. Reference the TRM requirements. Complete Documentation Summary Worksheet to document industrial process baselines for retrofit projects.

Relevant Codes and Standards

For New Construction and Equipment Replacement Projects the Baseline is the applicable code and/or standard. Clearly cite the reference code or standard used to establish baseline efficiency levels including year of issue, chapters or sections referenced for the project and the specific requirements of the code and/or standard and how it was applied in the project analysis. If this information is fully documented under Section B.1.1, reference that section here.

Measure Variables

Describe the variables that impact project energy use, the impacts of the measure on any of the variables and how the values for the variables and energy use were established. Common variables are listed below, add or delete as needed to accurately describe the variables associated with the measure. Add quantitative information regarding the project variables in Table 15. Measure Variables. Document all equipment information for the sections below using the Documentation Summary Worksheet.

Equipment Loading

Describe the equipment loading, variations in loading, percent loading and load profiles during the performance hours.

Operating Conditions

Seasonal and Daily Variability in Schedule

Describe any seasonality that affects the measure (production, school schedules, etc.) Provide documentation of data sources and assumptions used in the analysis.

Production

For industrial process measures, document units of production used for baseline and efficient cases, product variations included and the daily and seasonal variation in production.

Weather

Describe any weather dependence of the measure.

Controls

Describe equipment controls, any differences in baseline and efficiency case controls and how control sequences are accounted for in the analysis.

Interactive Effects

Describe interactive effects including waste heat, additional heating required and interactions with other measures or systems that will impact energy consumption.

Measure Life

State recommended measure life and reference for basis of recommendation.

Table 15. Measure Variables

Variable	Applies (Y/N)	Values Used and Engineering Units	Source (eg. metering, customer interview, production log, etc.)
Equipment Loading			
Operating Schedules			
Production Schedules			
Occupancy Schedules			
Weather			
Production			
Controls			
Interactive Effects			

C. Metering and Data Collection

Prepare a metering plan for the project using this section of the document and indicating the intended analysis approach in Section D. Upon completion of metering and analysis, update this document to reflect actual findings and final analysis approach.

Metering Approach

Discuss the approach to energy and demand metering including load shape and coincident demand determination from meter data. Describe when metering occurred and how it is deemed to represent the post installation, annual operating conditions. Provide justification and supporting documentation for all assumptions and metering techniques using the Documentation Summary Worksheet.

Data Collection Methodology

Indicate the primary method(s) used to obtain the data needed for TRM Section 2 equations.

Power Metering ____

Data logging _________________________________

DDC/PLC _______________________________

Interval Data ________________________________

Customer Interview ________________________________

Other (describe) ________________________________

Table 16. Project Data Acquisition

Data Collection Method [1]			
When data was collected (pre/post) installation			
Measure(s) Affected			
Equipment monitored			
Parameter measured			
Measurement equipment			
Observation frequency			

Metering duration			
Sensor type			
Accuracy of sensors			
Overall accuracy of meter system			
Verify whether meter was synchronized to NIST			

[1] Indicate data collection method(s) across the top; not all rows apply for all data collection methods. Duplicate table as needed to capture all data collection methods used for the measures associated with this project

Equipment Calibration
Discuss calibration procedures used to maintain calibration of any metering and/or logging equipment used in the metering process. Where DDC and/or PLC devices and systems were used to obtain project data, describe the calibration protocol and document the results in the Documentation Summary Worksheet.

Data Cleaning and Data Reduction
Discuss steps taken to align timestamps, fill gaps in raw data and address other data issues such as inaccurate or inconclusive readings. Depending on the level of verification required by the program, include raw, cleaned, and analyzed datasets as appropriate in the Documentation Summary Worksheet.

D. Energy and Demand Analysis

Energy and Demand Analysis Approach

Describe the energy and demand savings calculation approach for each measure. Present formulae; the basis for each variable should be documented in Sections B and C above. If modeling is used, describe the simulation tool and modeling approach. Describe the approach to determining the coincident demand savings for electric efficiency measures. All project and measure analysis documentation shall be submitted as part of the project documentation in the Documentation Summary Worksheet.

Calculation Methods
Describe the calculation methods and tools used to develop the savings analysis for the project. Include a discussion of how interactive effects were handled in the analysis. Refer to the TRM for more details on interactive effects.

Computer Modeling
Describe the approach to computer modeling, software used including, year, version and source, the modeling parameters addressed and the confidence in the model results relative to predictions of annual energy use reduction. Document the software year, version, source, and supporting documentation for software algorithms in the Documentation Summary Worksheet.

Energy and Demand Savings Analysis

Complete this section for each of the measures named above in accordance with Sections 2 through 4 of the C&I Custom Measure TRM for Retrofit and/or Equipment Replacement and report the final results in the Projects Savings Summary in Section A above. Perform the savings analysis according to the following algorithm.

Step 1. Enter the system description and conditions into Table 18 using the example below as a guide. Include all modes of operation that occur throughout the course of a year. For variable loads and schedules, enter ‘variable’ in the Hours, Coincidence Factor, and Load Factors columns.

Table 17. System Conditions Example

j	subsystem	annual hours	CF coincidence factor	system mode	full load kW	LF load factor
1	compressors	700	variable	max	10	variable
2	compressors	1500	variable	unloaded	10	variable
3	bank 1 and 2 cooling tower fans	700	variable	max	8	variable
4	bank 1 only cooling tower fans	1500	variable	unloaded	4	variable
5	condenser water pump	2200	1.00	max	20	1.00
6	condenser water pump	2200	1.00	unloaded	20	1.00

Table 18. System Description - Measure 1

	Subsystem	Hours	Coincidence Factor	System mode	Full load kW [1]	Load Factor [2]
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						

[1] Nameplate kW.

[2] Typically less than 1.00 unless the equipment was sized to run at full speed.

Step 2. Use the equations in TRM Section 2 to calculate the following quantities in Table 19. Calculated Energy Consumption and Demand Summary below: $\textbf{Energy}_{\textbf{eff}}$, $\textbf{Energy}_{\textbf{base}}$, $\textbf{C Load}_{\textbf{eff}}$, $\textbf{C Load}_{\textbf{base}}$ and the corresponding savings $\textbf{Energy}_{\textbf{saved}}$ and $\textbf{C Load}_{\textbf{saved}}$. Where the Hours, Coincidence Factor, and Load Factor are variable in Step 1 above, such as for weather dependent systems or other variable loads and schedules, a comprehensive 8760 analysis approach is required for affected terms in the equations. For subsystems ‘J’ which are constant and fully defined in the table above, it is acceptable to calculate these terms directly without using an 8760 analysis.

Table 19. Calculated Energy Consumption and Demand Summary [1]

	Baseline Case	Efficient Case	Annual Energy Savings	Notes
Measure 1				
Annual Energy Use Electric				
Coincident Electric Demand				

Annual Gas Use				
Measure 2				
Annual Energy Use Electric				
Coincident Electric Demand				
Annual Gas Use				

[1] Add rows for additional measures and for reporting impacts on unregulated energy sources. Indicate NA if a listed energy source is not affected. Electric measures must have both energy and coincident demand analysis completed.

E. Additional Information

Provide supporting documentation for all information referenced in Section E using the Documentation Summary Worksheet.

Project Cost

Document the cost of each measure by supplying electronic copies of quotes and invoices. For equipment replacement and new construction projects, the measure cost is the incremental cost above the baseline equipment. For retrofit projects the cost is inclusive.

Table 20. Calculated Cost [1]

	Baseline Case (leave blank for Retrofit)	Efficient Case	Incremental Cost of Efficient Measure (total inclusive cost for Retrofit)	Notes
Measure 1				
Measure 2				
Measure 3				

[1] Add rows for additional measures.

Non-energy Impacts

Document the non-energy impacts of the project such as impacts on O&M, water consumption etc. and the costs associated with those impacts.

Uncertainty

Discuss sources of uncertainty in energy use and demand reduction calculations other than metering error. Address assumption and potential impact of deviations in actual conditions from assumed conditions on energy savings. Discuss deviations from the original metering plan and quantify the impacts on the calculated savings.

Accuracy

The overall engineering accuracy of this analysis is: +/-________ %

Signature of Energy Analyst

____

Date of Submitted Report

____

Appendix C – Documentation Summary Worksheet for Custom Projects

Appendix A

Documentation Summary Worksheet for Custom Projects

Instructions:

1. Documentation is required for all sections and subsections shown in Columns A - C. Add rows as needed in order to completely document the project according to the requirements of the applicable Custom TRM and the Custom Analysis Template.
2. Indicate by "X" in columns D & E whether the documentation applies to the Baseline, Efficient or Both cases.
3. Indicate the measures to which the documentation applies in Column F, such as "M-1, M-2…". Use "P" for documentation that applies to the overall project.
4. Indicate filenames of submitted documents in Column H. Include the measure number in the filename.
5. Provide files listed in this table in electronic format with the project submission.

Documentation Requirements			**Case to which documentation applies**		**Measure(s) to which documentation applies**	**Description**	**Filename with Extension (.pdf, .xlsx, .inp, etc.)**
Section	Category	Subcategory	Efficent	Baseline			
Section A - Project Information							
	Custom Analysis Template						
Section B - Measure Level							
	Reference Data and Studies						
		Applicable Codes or Standards					
		Case Studies and Industry Standards					
		Applicant Practice (Industrial Retrofit)					
	Equipment Specific Information						
		Manufacturer Performance Data					
		Nameplate Data					
		Operating Variables					
		Field Metered Load Data					
Section C - Metering and Data Collection							
	Metering Techniques						
	Calibration Logs (DDC)						
	Metering Datasets						
		Analyzed					
		Raw†					
		Cleaned†					
Section D - Energy and Demand Analysis							
	Analysis Files						
		Modeling Files					
		Calculations Spreadsheets					
	Savings						
		Savings Analysis Calculations					
		Savings Equations Source					
Section E - Additional Information							
	Project Costs						
	Non-Energy Impacts						

† Raw and Cleaned datasets are not typically required for savings claims However, they should be available to Program Evaluation staff if requested.

Appendix A

Documentation Summary Worksheet for Custom Projects

EXAMPLE:

Documentation Requirements			**Case to which documentation applies**		**Measure(s) to which documentation applies**	**Description**	**Filename with Extension (.pdf, .xls, .doc, .jpg other)**
Section	Category	Subcategory	Efficent	Baseline			
Section A - Project Info							
	Custom Analysis Template				P	Template for Chiller project	CAT_Chiller_Date.doc
Section B - Measure Level							
	Reference Data and Studies						
		Applicable Federal Standards	x	x	M-1	ASHRAE 90.1-2004	ASHRAE90.1_M-1.pdf
		Applicable Local Codes	x	x	M-1	Vermont Guidelines 2005	VTG2005_pp10-15_M-1.pdf
		Case Studies and Industry Standards		x	P	ACEEE study	ACEE Study_Base_Eff.pdf
	Equipment Specific Information						
		Manufacturer Performance Data - Efficient Model	x		M-1, M-4	Cut sheet compressor efficiency and EWT performance; pump part load efficiency	MFR_M-1_EFF.pdf, MFR_M-4_EFF.pdf
		Manufacturer Performance Data - Baseline Model		x	M-1, M-4	Cut sheet compressor efficiency and EWT performance; pump part load efficiency	MFR_M-1_BASE.pdf, MFR_M-4_BASE.pdf
		Nameplate Data	x			Photo of installed nameplate	Efficient_Nameplate_M-1.jpg
		Operating Variables - schedule	x		P	Occupied and unoccupied operating schedules	Eff_sched_Base_Eff.doc
		Operating Variables - part load curves	x		M-1	Compressor part load curves	Part_Load_kW_M-1.pdf
		Field Metered Load Data	x	x	P	Compressor, condenser fans, EWT, pump speed field data	Field_Data_Baseline_and_Efficient.xls
Section C - Metering and Data Collection							
	Metering Techniques		x				
	Calibration Logs (DDC)		x				
	Metering Datasets						
		Raw	x	x	P	Baseline and efficient raw data: compressor, condenser fans, pump speed	RAW_base_eff.xls
		Cleaned	x	x	P	Baseline and efficient cleaned data: compressor, condenser fans, pump speed	CLEANED_base_eff.xls
		Analyzed	x	x	P	Data used in analysis: compressor, condenser fans, pump speed	ANALYZED_base_eff.xls
Section D - Energy and Demand Analysis							
	Analysis Files						
		Modeling Files	na	na	-	Analysis spreadsheets used in lieu of modeling software	
		Calculations Spreadsheets	x	x	P	Baseline and Analysis calculations (ref. TRM Section 2 equations)	baseline_calcs.xls, efficient_calcs.xls
	Savings						
		Savings Analysis Calculations	x	x	P	Savings calculations (ref. TRM Section 4 equations)	savings_calcs.xls
		Savings Equations Source	x	x	P	AEE study with equations	AEE_chiller_savings_equations.pdf
Section E - Additional Information							
	Project Costs		x		P	Invoices	invoices.pdf
	Non-Energy Impacts		na	na		There were no non-energy impacts	