Common EM&V Methods and Savings Assumptions Project (Final Report)

For the Regional Evaluation Measurement & Verification Forum
(Facilitated and managed by Northeast Energy Efficiency Partnerships)

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Executive Summary

In mid-2009, Northeast Energy Efficiency Partnerships, Inc. (NEEP) engaged KEMA to execute this Common EM&V Methods and Savings Assumptions Project ("the Project") on behalf of the Regional Evaluation, Measurement and Verification Forum ("the Forum"). The Forum is a regional consortium that is facilitated and managed by NEEP and represents states in New England, New York, and the mid-Atlantic.

This project is comprised of three fundamental tasks or "Parts":

A. Review and document common evaluation, measurement and verification (EM&V) methods;
B. Review and compare energy and demand savings assumptions; and
C. Develop related advisory guidelines and recommendations.

In a broad sense, the project is intended to help improve and ensure the understanding, transparency, and credibility of both electric and gas energy efficiency resources implemented in the Northeast and mid-Atlantic region as well as the processes used to determine their savings. It is hoped that the advisory guidelines will promote greater consistency and collaboration by highlighting existing commonalities and areas with potential for more compatible savings approaches.

This Common EM&V Methods and Savings Assumptions Project is a study of current practice that culminates in advisory guidelines and EM&V methods for the Forum region. The recommended method is intended to be a basic level of EM&V rigor: the level at which one would achieve parity with prevailing, accepted practice. Alternative methods offer the means of achieving higher levels of rigor, acquiring information necessary for specific measure, program or regulatory environment. These alternative methods may be particularly well suited to more complex or uncertain applications. Program administrators may benefit from selecting a combination of the two approaches to meet a range of regulatory, wholesale market, and environmental objectives/requirements.

A Note on Terminology

The phrase "evaluation, measurement and verification (EM&V)" does not refer to a uniform, monolithic discipline. Properly speaking, as shown in the definitions from the Regional EM&V Forum Glossary below, M&V is a subset of evaluation.[1]

Evaluation - The conduct of any of a wide range of assessment studies and other activities aimed at determining the effects of a program, understanding or documenting program performance, program or program-related markets and market operations, program-induced changes in energy efficiency markets, levels of demand or energy savings, or program cost-effectiveness. Market assessment, monitoring and evaluation (M&E), and measurement and verification (M&V) are aspects of evaluation.

Measurement and Verification (M&V) - A subset of program impact evaluation that is associated with the documentation of energy savings at individual sites or projects using one or more methods that can involve measurements, engineering calculations, statistical analyses, and/or computer simulation modeling.

In common practice, "evaluation" and "measurement and verification" are frequently, but inaccurately, used interchangeably. Three additional definitions from the Forum's Glossary are incorporated by reference in this report:

CONFIDENCE - An indication of how close, expressed as a probability, the true value of the quantity in question is within a specified distance to the estimate of the value. Confidence is the likelihood that the evaluation has captured the true value of a variable within a certain estimated range.

PRECISION - The indication of the closeness of agreement among repeated measurements of the same physical quantity. It is also used to represent the degree to which an estimated result in social science (e.g. energy savings) would be replicated with repeated studies.

RIGOR - The level of effort expended to minimize uncertainty due to factors such as sampling error and bias. The higher the level of rigor, the more confident one is that the results of the evaluation are both accurate and precise.

This report adheres to the definitions above unless otherwise noted.

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[1] Regional EM&V Forum, Glossary of Terms, Version 1.0, March, 2009.

Study Approach

The early stages of the Project included a scoping task to define a "priority set of electric and gas efficiency measures" on which to focus the research of this study. Table 1 below presents the final list of fourteen (14) program types/measures selected by the Project Committee.

Table 1: Priority Set of Program Types/Measures

Program Types/Measures	
Residential	
Central A/C	Gas Boilers/Furnaces
Comprehensive Multi-Measure (R)	Lighting (R)
Commercial/Industrial	
Comprehensive Multi-Measure (NC)	Lighting (R)
Custom Measures (R/NC)	Motors (NC/TR)
Gas Boilers/Furnaces	Prescriptive Chillers (NC/TR)
HVAC (NC/TR)	Unitary/Split HVAC (NC/TR)
Lighting (NC)	VSDs (R/NC)

For Part A: Common EM&V Methods, KEMA interviewed a sample of Forum program administrators (both from the evaluation staff and implementation staff) and national experts to identify and define the methods participants use for calculating preliminary (ex-ante) savings, determining the inputs to those calculations, verifying installation, calculating evaluated (ex-post) savings[2], for dealing with the issues of uncertainty and precision and for documenting their efforts. KEMA also reviewed a sample of work products from recent evaluations undertaken within the Forum's region and a selection of the most commonly referenced existing guidance documents. This research provides a snapshot of evaluation theory and practice among Forum members and an external reference point to inform the development of regional guidelines.

In Part B: Savings Assumptions, KEMA performed a technical review of existing documentation on gross energy and demand savings determination methods, assumptions, and algorithms across the region for the priority set of fourteen electric and gas efficiency measures. This effort culminated in comparative tables of commonalities and differences in savings assumptions and algorithms and specific methods recommendations for improving consistency.

[2] This project reviewed types of methods to determine net savings, but does not make recommendations for net savings methods. This issue is being addressed separately in another EM&V Forum project.

Finally, Part C: Guidelines employed the results of Parts A and B activities to develop a recommended set of guidelines for fourteen priority measures, including recommendations for crosscutting EM&V parameters. These broad guidelines are intended to establish the basis for common EM&V methods and levels of rigor to be implemented consistently in the region.

EM&V Methods (Part A): Trends, Themes & Conclusions

This section of the Executive Summary provides a high-level overview of evaluation, measurement, and verification procedures used within and outside the Forum region. This overview is derived from surveys conducted with Forum program administrators, a review of selected evaluation studies or work-products, and a review of a select set of EM&V guidelines promulgated by external organizations.

The survey of program administrator and evaluator practices found some fundamental commonalities. Respondents uniformly reported a structured approach to estimating and tracking savings, verifying installations, measuring savings, and validating inputs to calculations. The data requirements for these activities were comparable across the respondent pool, even if individual data points may have had different names for different respondents. These structures and inputs for calculating savings are typically codified into a resource, generically called a technical reference manual (TRM).

They also noted that there are a variety of drivers for their selected EM&V methods or approaches, including regulatory requirements, customer and shareholder interests, external market participation, and to inform their own decision making. While there is no comprehensive reference documentation for EM&V analogous to TRMs for savings calculation, respondents generally reported that their methodologies are consistent in some respects with external requirements such as those issued by ISO-NE and PJM for their forward capacity markets. Within this bounded realm of agreement, there are a wide variety of terms, definitions, and methodological approaches.

The review of recent evaluation work products confirmed the survey findings, that there is general agreement in principle as to the need for and practice of evaluation, measurement and verification, but that the specifics vary by participant and situation. Forum participants use a variety of methods to evaluate, measure, and verify savings. In comparison, KEMA's review of existing guidelines from other regions and organizations revealed recommendations for consistent methodologies and levels of rigor within clearly defined categories.

TRENDS

More Aggressive Goals and Budgets. The role of energy efficiency has evolved greatly over the last five and especially in the last two years. The scope of programs and the scale of program budgets are increasing greatly. Very aggressive state wide goals have been developed or are under consideration. Survey respondents stated the below as some of the current drivers behind upcoming changes they have planned to EM&V practices:

- More formal evaluations in response to state policy
- Increasing evaluation budgets along with program budgets
- Greater focus on measured data and a changing industry for C&I

With greater budgets, respondents see 'attribution' becoming a more important issue going forward. With technology rapidly advancing, and increasing number of consumers purchasing energy efficient technologies without incentives, it is becoming more challenging to attribute savings to program activities.

Participation in Forward Capacity Markets. Energy efficiency resources are being accepted on par with supply options by the regional organizations responsible for system reliability, as noted in the discussion of the FCM above. These requirements are expanding the scope of evaluation efforts to include increased analysis of demand and peak day impacts.

Federal Initiatives. Federal funding for Smart Grid projects and American Recovery and Reinvestment Act projects is flowing into the region. These federal initiatives complement program administrator activities but come with their own evaluation requirements. By funding parallel, but not necessarily coordinated, activities in the market, they may create new challenges for evaluators, especially in regard to attribution of claimed or observed savings.

Emerging Carbon Markets. At present there is no national cap and trade system in the United States[3]. The Regional Greenhouse Gas Initiative in the Northeast and Mid Atlantic is the first mandatory market-based CO_2 control effort in the US. This effort, and possible federal requirements for an energy efficiency and renewable energy portfolio standard, may have implications for the evaluation and verification of energy efficiency efforts going forward. Versions of S. 548 (Markey Waxman) included provisions for the Department of Energy to

[3]A national market-based SO2 cap and trade program has existed in the United States since its introduction through the 1990's Clean Air Act amendments.

accept and review compliance reports and establish evaluation, measurement and verification (EM&V) protocols to support a potential energy efficiency standard.[4]

THEMES

Confusion. Despite the recent promulgation of a glossary of EM&V terms, inclusion of definitions of terms in the survey that respondents had in advance, and regardless of the length of experience of the respondent, there appeared to be some confusion over terms. The review of existing evaluation guidelines show that program administrators in the region operate under multiple evaluation guidelines with varying degrees of overlap in terms of scope and authority. Definition and nomenclature in many cases are similar enough to be confusing without being clear enough to readily identify the operative reference document. We found that some terms that are not equivalent were used interchangeably, for example “M&V” and “billing analysis.” We also found that some terms, such as “Option A,” referring to a protocol for measurement and verification, had different meanings depending on the context. The “Option A” terminology derives from IPMVP, has a similar but not identical definition in the ISO-NE & PJM M&V requirements, and may be used to mean the use of stipulated, as opposed to measured, values. A key challenge for this process is that there is no one regulatory authority with jurisdiction over all uses of evaluation products. This creates the situation where regional guidelines can only be implemented through a process of separate jurisdictions adopting, in their own time and through their own processes, functionally equivalent, if not identical guidelines.

Consistency. The survey and review of the evaluation results did not reveal any methodological approaches that were in and of themselves invalid. Rather this research found inconsistent application of tools across the spectrum of measures and measure inputs. For example, billing analysis can be an excellent tool for measuring energy impacts, however, may not be adequate as the sole method for measuring demand impacts despite reported use for this purpose

Frequency & Focus. KEMA’s review of evaluation activities in the Forum region and review of survey responses showed that the frequency and focus of evaluation varies across measures and individual measure parameters. In some cases, measures have been thoroughly reviewed multiple times by the same program administrator. In others the evaluation addressed specific parameters on cycle, for example in the case of lighting where hours of use were studied in one

[4] Statement of Patricia Hoffman, Acting Assistant Secretary for Electricity Delivery and Reliability, United States Department of Energy Before the Committee on Energy and National Resources, United States Senate, April 22, 2009.

year and coincidence was the focus in the next. Another approach was to rely on previous evaluation efforts where the stakeholders agree there has been no substantive change, in cases of this approach in the same service territory, or where stakeholders agree that the findings in one territory can reasonably applied to another.

In practice, except in case of new or significantly changed measures, evaluation studies often do not attempt a comprehensive review of all measure parameters in one evaluation project. As noted in the Cross Cutting Guidelines (see Sections 4.1.1 et. seq.) the recommend approach includes flexibility to adjust the methods, as in the case of verification, or the timing, as in the case of baselines, to accurately reflect the needs of the stakeholders and the phase of program development. Residential lighting evaluation efforts in the Northeast offer an example of this flexible approach. Evaluation efforts for these measures of late have been focused almost exclusively on determination of net-to-gross ratios. Due to the longevity of programs in this region, the number and quality of evaluation studies, and the relative stability of the market and technology, this focus has been accepted by the stakeholders.

CONCLUSIONS

One Reference Standard

We find that there would be value derived from a comprehensive and consistent set of guidelines for evaluation across the region. Based on the responses to the survey instrument, secondary research, and decades of experience in the field of EM&V across many jurisdictions, we anticipate Forum members would derive at least the following benefits from implementation of regional EM&V guidelines:

- Clear and consistent standards for program evaluations cross jurisdictional lines: Some program administrators operate similar programs in more than one state and may face different evaluation requirements.
- Reduced transaction costs for evaluation: In the absence of clear and consistent guidelines, each evaluation activity, even of the same feature of the same measure, starts from the beginning. Program administrators must draft an RFP to meet the current operative requirements, proposers must confirm a host of requirements, (e.g. confidence and precision) and determine the cost of meeting them, and the design of the research must be tailored to meet the regulatory drivers of the day.
- Increased opportunity for leveraging evaluation efforts: Data acquisition is an expensive activity. In the absence of consistent guidelines, the data collected for one utility or

program may not be applicable for another. It also creates a situation where small samples in many areas may provide less rigor for the results than one large sample over the same area would.

- Increased influence outside the region: In the event a national requirement for energy efficiency is enacted, members of the Forum will be in a better position to help define national EM&V standards. They will be able to take a leadership position on the national stage, with experience in the development and implementation of evaluation guidelines that transcend state boundaries. The alternative is to be a group of small individual voices advocating each for their own methods. Combined, the states in the Forum represent twice the load of California. Individually, their voices may not be heard.

These are only a few of the benefits we anticipate. We also expect that a regional approach would increase the quality of evaluation results, would make the Forum's evaluation requirements more attractive to vendors, and would reduce the overall cost of evaluation, freeing up more funding for program implementation.

The Challenges of Consistency

Challenges. While the overarching goals and objectives of these guidelines are supported by Forum participants, there are a number of important challenges that need to be considered in applying the guidelines on a state by state basis. First, while there are some common policy concerns across the states that drive energy efficiency investments, states tend to prioritize their policy concerns differently, and as such there are significant differences in the magnitude and comprehensiveness of state efficiency programs (i.e., the number of programs, size of programs and program budgets), and associated EM&V resources that states can expend. Additionally, for each state, the EM&V life cycle varies by program (e.g., frequency of conducting evaluations), so the need for resources in any given year varies. For these reasons, there are inherent differences in the rigor of evaluation efforts across the region. For example, some states participating in wholesale forward capacity markets are likely to be more concerned with rigorous demand savings than those that do not, or some may simply place less emphasis on focusing EM&V efforts around FCM requirements, while others focus more on meeting economic and climate change goals (i.e. energy savings), or meeting policies to procure all cost-effective energy efficiency.

In addition to differing policy frameworks and timetables, each state has its own set of regulatory processes and collaborative arrangements. These differences make it challenging to move states towards greater consistent use of EM&V practices in a timely and consistent manner. In short, the process is complicated and nuanced. These challenges do not make it impossible or undesirable to make progress toward more consistent EM&V methods, but they are real issues that need to be addressed and considered by states in adopting these guidelines, with the recognition that moving towards greater consistency will take some time.

Key Caveats. While the Guidelines are developed for specific measures, several caveats are important to consider in their application:

1) The guidelines recommend approaches to evaluate the savings from specified individual measures and program types that are based on new or replacement measures. The particular measures and programs types presented were intended to provide bounds that address common program offerings and may not apply to all programs. Other program designs may necessitate use of methods that do not fit into the methodological approaches presented in the guidelines. Further, a common strategy is to do in-depth studies of individual savings parameters for a particular class of measures, an approach that can enhance the reliability of savings estimates in the long run, but, because it ignores other parameters, this approach may be inconsistent with the basic level of rigor in the guidelines. As such, it should be noted that these guidelines are targeted at studies that are intended to comprehensively estimate the multiple impact parameters that drive savings, and are not consistently applicable to focused studies that are intended to zero in on individual parameters or subsets of parameters.

2) In application, the methods used on a program/measure specific basis may vary depending on the proportion or weight of a program's expected savings as a percent of total portfolio of savings. Regardless of what the mix of policy concerns is, in deciding what level of rigor to pursue in each individual study, it is important to focus on the sources of uncertainty bearing on the overall program portfolio (not necessarily the individual components), and to strategically allocate EM&V resources accordingly.

3) The guidelines do not make any recommendations with regard to evaluation timing or the transferability of evaluated results in different applications. These are complex issues that have significant implications with regard to the resources required to perform 'primary' EM&V across all programs/measures. KEMA found that current practice included application of evaluation results from one service territory to another service territory within the same state, and that some studies are designed for use across the Forum region. However, this study did not discover evidence that validity implications of data transferability have been explicitly, consistently, and transparently addressed, nor that standards exist to

define the appropriate cycle of review for various measure inputs. KEMA recommends that the Forum undertake research to inform guidelines on transferability and review cycles to help ensure that the results are valid, appropriate, and reasonable.

Savings Uncertainty and Validity

Savings certainty is based on a range of parameters including: confidence/precision requirements for statistical sampling, and other sources of error such as measurement error, equipment accuracy, and parameter bias. Most M&V manuals (ISO-NE, PJM, FEMP, ASHRAE) include guidelines for controlling measurement error, equipment accuracy and parameter bias. In an effort to expand the uncertainty dialogue beyond statistical precision, this report includes a section on Other Sources of Uncertainty and Threats to Validity. The evaluation community is only beginning to grasp the importance and implications this issue. The Forum is calling for a more balanced treatment of the true sources of uncertainty bearing on evaluation results, and KEMA hopes that Section 4.1.5 will draw attention to the vast number of threats to validity beyond statistical precision.

Understanding – let alone achieving – the statistical precision requirements across the region today is a real challenge. This issue is discussed at greater length in Section 2.6. For many years, the standard precision target for evaluated annual energy savings based upon requirements in the 1978 Public Utility Regulatory Policies Act (PURPA). Now standards defined in regional capacity markets are emerging as key precision objectives. There is a host of complicating factors including: differences between the ISO-NE and PJM requirements; appropriately defining the domain for the analysis; balancing the importance and cost of increased confidence and precision with the impact or requirements; and compensating for a variety of sources of error.

Statistical methods provide the opportunity to characterize the whole from observations of a part. As energy efficiency's role in system operations, and the amount of money involved, increases so does the importance of accurately and appropriately characterizing its impacts. The discussion and recommendations in Section 2.6 (with the recommendations reiterated in Section 4.1.4) are offered as a starting point for what is likely to be an iterative decision making process.

Regional Readiness

Some of the prerequisite conditions necessary for developing a geographically broad-based approach exist in the study region. These include the presence of external drivers (the forward capacity markets), a substantial investment in the activity in question (evaluation), duplicative or closely similar activities being undertaken by multiple parties, overlapping spheres of influence, confusion in the marketplace, and uncertainty about future requirements. Precedent exists in developing common EM&V protocols and savings assumptions in the energy efficiency industry, that being in the northwest region, where the Northwest Regional Technical Forum (RTF) developed and maintains EM&V protocols [5] and an on-line savings assumptions database for four states in the NW region. In California, the Public Utilities Commission approved a comprehensive set of consistent Savings Protocols by which the state's large utilities must comply. This report references the important and relevant experience of other regional/state protocols in developing the Guidelines herein, and are examples of relative success in improving consistency and creating a common currency for energy efficiency savings.

While there are indeed challenges to adopting common EM&V approaches across the Forum, largely driven by individual state focus on meeting state specific goals and needs, we believe that the barriers to adoption of a regional EM&V protocol are surmountable, and that the effort is worthwhile. The NW and California processes were driven by regional entities in the case of the NW and the regulator in the case of California. The process for accomplishing more coordination in the Northeast may need additional support to be successful.

Savings Assumptions (Part B): Prevailing Themes

Section 3 of this report presents the Part B effort and includes measure-specific sections which provide a measure overview, summary of research sources, the prevailing savings algorithm(s) with commentary, a comparative table of savings assumptions used by Forum states or program administrators (with commentary), and recommendations to improve consistency in

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[5] From the Charter of the Regional Technical Forum of the Pacific Northwest Electric Power and Conservation Planning Council: Background: In 1995, the Bonneville Power Administration (Bonneville) began to shift responsibility for financing and acquiring conservation savings over to its utility customers. This shift in responsibility was intended to reduce Bonneville's costs and permit utilities to better tailor their programs to local situations. Congress recognized that one implication of this shift would likely be a more diversified approach to conservation acquisition across the region. Consequently, in 1996 it directed Bonneville and the Northwest Power Planning Council (Council) to convene a Regional Technical Forum (RTF) to develop standardized protocols for verifying and evaluating conservation savings. This is necessary because the historical program costs and savings may not be applicable to radically redesigned conservation programs. Congress further recommended that the RTF's membership include individuals with technical expertise in conservation program planning, implementation, and evaluation and that its services be made available to all utilities in the Northwest.

savings assumptions. While Sections 3.3.1 through 3.3.14 contain measure-specific recommendations, some common themes, which are technical in nature, resound throughout, such as:

Combine Coincidence Factors. Some measure/entities disaggregate the demand factors that are used to derive seasonal coincident peak demand impact from a non-coincident or connected demand impact. Such factors include discrete load, diversity, and coincidence factors. A single, combined factor that reflects local loading, diversity, and coincidence effects would simplify computations and permit "apples to apples" comparison of coincidence factors across states/regions.

Develop Localized Assumptions. While nearly all measures examined herein have potential for regional standardization of savings methods, there are few measures for which savings assumptions or stipulated values are truly portable, i.e. appropriate for use across all markets, geographies, technologies, etc. Just as weather-dependent measures require savings assumptions that reflect typical meteorological conditions, other measures require similar consideration. Regional consistency does not mean adopting identical assumptions; it will be appropriate to develop localized assumptions for hours-of-use and peak coincidence for most measures in order to reflect local characteristics of climate, demographics, and behavior.

Standardize or Expand Dimensions. Depending upon the nature of the measure or savings algorithm, researchers see benefit in some selective standardization or expansion of the breadth of savings assumptions. For instance, residential programs that currently use a single, whole-home estimate of lighting hours-of-use might benefit from expanding to room-level (e.g. bedroom, kitchen, garage) hours-of-use resolution. Conversely, commercial motor measures with discrete savings assumptions for dozens of facility types might benefit from standardizing on a more manageable set of buildings.

Eliminate or Utilize Loading Factors. For several of the priority measures, one of the recommendations is to eliminate a discrete "loading factor" from the savings algorithm. Also evident in "Combine Coincidence Factors", this recommendation strives to eliminate unnecessary complexity from prescriptive savings algorithms. In principle, all measures employing "Equivalent Full Load Hours" as the time term in the equation should recognize that the EFLH already handles part-loading effects. One of the technical manuals reviewed would need to *add* a loading factor to the efficient motors algorithm in the interest of accuracy and consistency with this recommendation.

Stipulate or Calculate. Amongst the more basic priority measures such as lighting, some entities use stipulated savings values. In general, stipulated estimates are in the minority, but the method offers consistent, reasonable, and quick savings estimation for highly standard measures. While a regional consistency effort might necessitate a decision between stipulated or calculated estimates, a compromise seems appropriate for lighting measures. Demand reductions by lighting technology are logical stipulations as inputs, and a consistent algorithm would allow for localized tuning of hours and coincidence for savings impacts. Ultimately, stipulated savings values for lighting should be based upon calculations that include clear assumptions for fixture wattage, hours, in-service rate, coincidence, etc.

Recognize Delivery Mechanism. It is important to recognize that savings methods and assumptions can differ substantially by program delivery system. For instance, residential "retail" lighting programs require broader assumptions regarding hours of use due to uncertainty of lamp placement, whereas direct install programs can refine operating hours by room type. Similarly, the same C&I technology can possess different savings characteristics under a Prescriptive and Custom delivery mechanism. While the fourteen measure categories in this section did not include much program delineation, any standardization of savings methods/assumptions ought to capture the influence of program delivery.

Recommended Guidelines (Part C)

The guidelines themselves were designed to be concise characterizations of the recommended savings methods and assumptions for each of the fourteen measures, supplemented by guidelines for specific cross-cutting issues. The guidelines were based on the part A and part B research as well as on KEMA's professional judgment. For each measure, these summary guidelines include:

- The prevailing algorithm for energy and demand savings;
- Commentary on the algorithm and a description of inputs;
- Opportunities for improved consistency or where differences are warranted;
- Recommended methods for:
    - Estimating preliminary "tracking" savings;
    - Verification of installations*;
    - Determining baseline conditions*;
    - Determining measure life and persistence*;
    - Calculating gross Energy and Demand "evaluated" savings
        - Basic evaluation M&V approach

- Alternative M&V approaches to enhance the accuracy or rigor of savings;
- Savings Uncertainty and Validity - considerations on savings rigor, including statistical sampling and validity of savings estimates*.

**Cross cutting recommendations*

The final guideline publication will be a Forum product titled *Regional EM&V Methods and Savings Assumptions Guidelines*, which includes a preface prepared by NEEP (in consultation with Forum participants), followed by the guidelines presented in Section 4 of this report that cover pertinent cross-cutting EM&V issues and the fourteen measure-specific guideline summaries. Detailed research results such as interview responses (Part A results) and savings assumption *values* used by Forum states (Part B results e.g. hours of use equals 350 full-load equivalent hours) are not captured in the guidelines but are available in the full KEMA report.

1. Introduction

In mid-2009, Northeast Energy Efficiency Partnerships, Inc. (NEEP) engaged KEMA to execute this Common EM&V Methods and Savings Assumptions Project ("the Project") on behalf of the Regional Evaluation, Measurement and Verification Forum ("the Forum"). The Forum is a regional consortium that is facilitated and managed by NEEP and represents states in New England, New York, and the mid-Atlantic.

This project is comprised of three fundamental tasks or "Parts":

A. Review and document common evaluation, measurement and verification (EM&V) methods;
B. Review and compare energy and demand savings assumptions; and
C. Develop related guidelines and recommendations.

In a broad sense, this project is intended to help improve and ensure the understanding, transparency, and credibility of both electric and gas energy efficiency resources implemented in the Northeast and mid-Atlantic region as well as the processes used to determine their savings. Currently, program administrators throughout the Forum region employ a diverse range of EM&V methods and savings assumptions. It is hoped that this study will promote greater consistency and collaboration by highlighting existing commonalities and areas with potential for more compatible savings approaches.

The recommendations from this project are intended to serve as guidelines for conducting EM&V in the Forum region. Guidelines are particularly important in this region given the large number of program administrators and the diverse range of EM&V experience and rigor. Methodological consistency helps to facilitate the region's ability to work together, share, compare and aggregate data, and leverage its collective EM&V experience.

This Common EM&V Methods and Savings Assumptions Project is a study of current practice that culminates in advisory guideline EM&V methods for the Forum region. The recommended method is intended to be a basic level of EM&V rigor: the level at which one would achieve parity with prevailing, accepted practice. Alternative methods offer the means of achieving higher levels of rigor and/or acquiring information necessary for specific measures, programs, or regulatory environments. These alternative methods may be particularly well suited for more complex or uncertain applications. Program administrators may benefit from selecting a combination of approaches to meet a range of regulatory, wholesale market, and environmental objectives/requirements.

1.1 Objectives

The core objective of this project was to develop the aforementioned related guidelines and recommendations which address EM&V methods and savings assumptions that can be applied to energy efficiency programs and/or projects across the region. These Part C guidelines were to be the culmination of research, interviews, and documentation reviews performed in the Part A and B tasks.

The early stages of this project included a scoping task to define a "priority set of electric and gas efficiency measures" on which to focus the research of this study. Table 2 below presents the final list of fourteen (14) program types/measures selected by the Project Committee.

Table 2: Priority Set of Program Types/Measures

Program Types/Measures	
Residential	
Central A/C	Gas Boilers/Furnaces
Comprehensive Multi-Measure (R)	Lighting (R)
Commercial/Industrial	
Comprehensive Multi-Measure (NC)	Lighting (R)
Custom Measures (R/NC)	Motors (NC/TR)
Gas Boilers/Furnaces	Prescriptive Chillers (NC/TR)
HVAC (NC/TR)	Unitary/Split HVAC (NC/TR)
Lighting (NC)	VSDs (R/NC)

While this effort indeed included some crosscutting recommendations, the core objective of this project was to produce guidelines for these specific fourteen measures.

1.2 Study Approach

For Part A: Common EM&V Methods, KEMA performed research and interviews with Forum program administrators to identify and define the range of EM&V methods that are applied in the industry and can serve as guidelines for Forum participants' programs. This effort strived to identify and define common and consistent methods for preliminary (ex-ante) savings, gross and net evaluated (ex-post) savings, measure baseline, life, and persistence, and strategies for dealing with uncertainty/rigor.

In Part B: Savings Assumptions, KEMA performed a technical review of existing documentation on gross energy and demand savings determination methods, assumptions, and algorithms across the region for the priority set of fourteen electric and gas efficiency measures. This effort culminated in comparative tables of commonalities and differences in savings assumptions and algorithms and specific methods recommendations for improving consistency.

Finally, Part C: Guidelines employed the results of Parts A and B activities to develop a recommended set of guidelines for fourteen priority measures. These broad guidelines were intended to establish the basis for common EM&V methods and levels of rigor to be implemented consistently in the Region.

1.3 Guideline Description

The guidelines themselves were designed to be concise characterizations of the recommended savings methods, assumptions, and precision/rigor levels for each of the fourteen measures. For each measure, these summary guidelines include:

- The prevailing algorithm for energy and demand savings;
- Commentary on the algorithm and a description of inputs;
- Opportunities for improved consistency or where differences are warranted;
- Recommended methods for:
    - Estimating preliminary “tracking” savings
    - Verification of installations
    - Calculating gross Energy and Demand “evaluated” savings
    - Developing net Energy and Demand savings
    - Basic evaluation M&V approach
- Alternative M&V approaches to enhance the accuracy or rigor of savings; and
- Any measure-specific considerations on sampling or savings rigor.

The final guideline publication will be comprised of an Executive Summary followed by these fourteen measure-specific guideline summaries of approximately two pages each. Detailed research results such as interview responses and savings assumption *values* (e.g. 350 full-load equivalent hours) are not captured in the summary guideline but are detailed in the report body and reflected in the ultimate recommendations.

2. Part A: Common EM&V Methods

Part A involved research (including surveys) to identify and define the range of EM&V methods that are applied in the industry and can serve as the basis for best practices guidelines for EM&V Forum participants' programs. Such methods covered those used in the calculation of both electric and gas efficiency, gross and net energy and demand savings for different policy goals and uses of EM&V results (as found in Northeast and mid-Atlantic programs). With respect to the policy goals, the research included a review of public policies that 'drive' the selection of EM&V methods and rigor.

This report presents KEMA's methods and findings from "Part A" of the Common EM&V Methods and Savings Assumption Project for the NEEP Regional Evaluation, Measurement & Verification (EM&V) Forum ("the Forum"). Part A of this project was research into the range of current EM&V practices in the Northeast and a review of established, broad-based, and documented EM&V practices from other jurisdictions. This research is the basis for our recommendations regarding the development of consistent region-wide EM&V guidelines for the Forum's consideration.

2.1 Data Collection Approach

Part A entailed three distinct data collection efforts to characterize the range of EM&V methods employed in the Region and elsewhere in the energy industry: 1) interviews of program administrators and experts in the field, 2) a review of other guideline documents, and 3) a review of relevant impact evaluations.

2.1.1 Program Administrator Interviews

KEMA designed and implemented an interview with program administrators and other decision makers in the Northeast and Mid Atlantic regions. The survey covered the following fourteen (14) measures and programs:

1. Residential Central Air Conditioning
2. Residential Comprehensive Multi-Measure Retrofit
3. Residential Gas Boilers and Furnaces
4. Residential Lighting Retrofits
5. C&I Comprehensive Multi-Measure New Construction
6. C&I Custom Measures
7. C&I Gas Boilers and Furnaces

8. C&I “Other” HVAC
9. C&I Lighting – New Construction
10. C&I Lighting – Retrofit
11. C&I Motors
12. C&I Prescriptive Chillers
13. C&I Unitary/Split HVAC
14. C&I Variable Speed Drives

The program types/measures were selected in collaboration with the Forum with emphasis on measures common to many programs. The interview itself consisted of eleven research areas that spanned all areas of energy-efficiency program tracking from planning to evaluation. The research pursued data at the resolution of each program type/measure. For example, each question in the eleven research areas was asked multiple times - once for each priority program type/measure. The key topics covered included:

- Tracking of programs
- Use of stipulated values
- Verification of installations
- Type of evaluations
- Baselines, measure lives, and persistence
- Rigor levels
- Sampling precision

A key component of the survey was the matrix of measures and questions which is presented in Appendix A. This matrix consisted of eleven primary questions and 27 secondary questions, each of which was asked for all of the 14 priority measures. Not all respondents responded to all questions. Some of the national experts and implementation contractors responded only at an aggregated level, in other words they did not provide unique responses to each question for each measure, but rather provided one response to each question that covered all measures. Newer program administrators did not necessarily have programs in all categories and / or had not done much program evaluation yet. The questions are presented for the first three question areas below as an example.

Figure 1: Survey Instrument Excerpt

For each program type/measure, describe your methods for:

a. Estimating initial gross energy savings

b. Estimating initial gross demand savings

- *Assign a stipulated value*
- *Compute via worksheet w/ site specific and deemed inputs*
- *Site-specific calculations; no deemed inputs*
- *Other* ______________________________

c. Estimating initial net energy savings

d. Estimating initial net demand savings

- *Assign a stipulated net-to-gross ratio*
- *Assume ad hoc net-to-gross ratio*
- *Apply prior net evaluation results*
- *Other* ______________________________

2) For program type/measures with stipulated values, describe your methods for:

a. Calculating stipulated gross savings values

b. Calculating stipulated net savings values (including NTG ratios)

- *In-house engineering*
- *Independent study*
- *Technical Reference Manual or similar*
- *Other* ______________________________

3) For each program type/measure, describe your EM&V procedures for:

a. Verifying installation of measures

- *Not verified: customer-reported*
- *Not verified: vendor-reported*
- *In-house post installation inspection (% verified?)*
- *Third party post installation inspection (% verified?)*
- *Other* ______________________________

b. Calculating gross evaluated energy savings

c. Calculating gross evaluated demand savings

- *Gross not evaluated*
- *Verification only (e.g. phone survey or visit with no measurement)*
- *Measurement and Verification*
- *Billing Analysis*
- *Building Simulation*
- *Other* ______________________________

d. Calculating net evaluated energy savings

e. Calculating net evaluated demand savings

- *Net not evaluated*
- *Combined net-to-gross study*
- *Discrete free ridership and spillover study*
- *Other* ______________________________

This survey took anywhere from thirty minutes to ninety minutes to complete. Respondents were provided with a copy of the survey instrument, which contained both the questions and a list of potential response options. Although respondents were free to provide as much detail as they wished for each question, most respondents chose to respond using the response options provided in the survey instrument. This did not provide us with a high level of detail regarding specifically what types of procedures were used for certain EM&V methods, such as billing analysis or M&V, for example. The length of the survey was also a barrier in collecting additional detail in some cases. However, many respondents provided useful examples and comments, particularly in response to the open-ended questions. The responses, especially for the commercial and industrial programs, were very similar across measures and may seem repetitive.

In total, KEMA completed seventeen interviews with a diverse range of respondents, including: program administrators with varying degrees of implementation and evaluation experience, experts involved in national and international processes, and implementation firms that provide program delivery services. Some respondents were unable to respond to questions at the measure level given their role, experience, or subject areas.

2.1.2 EM&V Guideline Review

In addition to interviews with program administrators and energy-efficiency organization representatives, KEMA reviewed additional evaluation, measurement, and verification publications. This secondary research effort included an examination of relevant regional, national, and international documents such as:

- International Performance Measurement and Verification Protocol (IPMVP), Efficiency Valuation Organization (EVO), April 2007. Available at: http://www.evo-world.org/index.php?option=com_content&task=view&id=272&Itemid=279&lang=en
- Model Energy Efficiency Program Impact Evaluation Guide, The National Action Plan for Energy Efficiency (NAPEE), November 2007. Available at: http://www.epa.gov/RDEE/documents/evaluation_guide.pdf
- The California Evaluation Framework, California Public Utilities Commission, Revised January 24, 2006. Available at: http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V
- California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals, California Public Utilities Commission, April 2006. Available at: http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V
- Guideline 14-2002: Measurement of Energy and Demand Savings, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), 2002. Available at: http://www.ashrae.org/publications/
- ISO New England Manual for Measurement and Verification of Demand Reduction Value from Demand Resources (Manual M-MVDR), ISO New England Inc., Revision 1,

October 1, 2007. Available at: http://www.iso-ne.com/rules_proceds/isone_mnls/index.html

- PJM Manual 18B: Energy Efficiency Measurement & Verification, PJM Forward Market Operations, Revision 0, April 23, 2009. Available at: http://www.pjm.com/~/media/documents/manuals/m18b.ashx

2.1.3 Review of Recent Evaluations

KEMA experts reviewed the reports from 11 evaluation studies performed in the region within the last 4 years. We explored the relationship between guidelines and practice in the field. The findings of this review offer the Forum additional input to their decision making process and help refine KEMA's recommendations.

2.2 Analysis of Interview data

Each of the questions with multiple sub questions was done for as many measures as the respondent could answer. KEMA processed the survey in Excel first at an overall response level to each question and secondly by measure. The results were analyzed in a series of pivot tables and cross tabulations of the pivot tables. Results are presented at an overall level here and in additional detail in Appendices C and D.

2.3 Interview Findings

In this section results at the aggregate level[6] by question area are presented. Specifically the question areas were:

1. Methods for Determining Savings Values
2. Use of Stipulated Values
3. Verification of Installations
4. Type of Evaluations
5. Baselines, Measure Lives and Persistence
6. Rigor Levels
7. Sampling Precision

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[6] Respondents were asked to provide responses for all program types/measures, for each question. These measure-level results are provided in detail in Appendix D. The results in this section represent the aggregated, or overall, responses for each question, and thus include all of the measure-level responses.

8. Alignment with IPMVP and ISO procedures
9. Importance of Rigor
10. Challenges and Concerns
11. Changes to EM&V Practices
12. Important and Emerging Issues

Results in this section are presented for all measures for all respondents by question area. Results are tabulated in more detail at the aggregate level in Appendix C and at the measure level in Appendix D.

2.3.1 Determining Savings Values

Questions 1a-1d assessed the methods used to derive the underlying data and equations for determining initial gross and net energy and demand savings[7]. To ensure consistency in the interpretation of this question, definitions of "gross" and "net" savings were provided in the survey instrument. Survey questions 1a-d are shown below:

1) For each program type/measure, describe your methods for:

a) Estimating initial gross energy savings

b) Estimating initial gross demand savings

c) Estimating initial net energy savings

d) Estimating initial net demand savings

Key findings include:

Interviewees reported a mix of methods for determining gross energy savings, including: worksheets with site-specific and deemed inputs (29%); custom methods with site-specific data (30%); and deemed (or stipulated) values (36%).

A mix of methods were also reported for determining net energy savings, including; applying prior evaluation results (60%) and assigning a stipulated net-to-gross ratio (31%).

2.3.2 Calculating Stipulated Values

Questions 2a and 2b assessed the methods used for calculating gross and net stipulated values. Stipulated values, also referred to as deemed values, are an estimate of energy or demand savings for a single unit of an installed energy efficiency measure that (a) has been

[7] See definition of terms in Appendix A.

developed from data sources and analytical methods that are widely considered acceptable for the measure and purpose and (b) is applicable to the situation being evaluated[8]. Survey questions 2a and 2b are shown below:

2) For program types/measures with stipulated values, describe your methods for:

a) Calculating stipulated gross savings values

b) Calculating stipulated net savings values (including net-to-gross ratios)

Methods vary for determining gross stipulated values across respondents, including in-house engineering (39%), using a Technical Resource Manual or similar document (30%), or independent study (1%). To determine net stipulated values (and net-to-gross ratios), 26% use a TRM or similar documentation, 15% use independent studies, and 32% use in-house engineering.

Strictly speaking, a technical reference manual is a resource, not a methodology. However, this class of resource, including a wide range of program savings documentation, is increasingly used. There are projects at various levels of completion in many jurisdictions in the studied region to develop comprehensive TRMs, for example in Connecticut, Massachusetts, New York, and Vermont. The Part B report covers this topic in detail.

2.3.3 Verification of Measures

Survey participants were asked to describe their verification procedure(s) with Question 3a: *"For each program type/measure, describe your EM&V procedures for verifying installation of measures"* Five response options were presented, two "unverified" (customer or vendor reported), two "verified" (by in-house or third-party staff) and "other." One of the two verification options included in the response set was reported for 60% of the measures. One of the two "not verified" options was reported for 31% of the measures and the verification methodology was not known for 1% of measures.

2.3.4 Evaluating Saving Calculation Inputs

Questions 3b-3e explored the methods used to evaluate inputs into net and gross energy and demand savings calculations. The question for this sequence is quoted below:

3) For each program type/measure, describe your EM&V procedures for:

b) Calculating gross evaluated energy savings

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[8] Northeast Energy Efficiency Partnership's <u>Glossary of Terms</u>, Version 1.0, March 2009.

c) Calculating gross evaluated demand savings
d) Calculating net evaluated energy savings
e) Calculating net evaluated demand savings

The survey response options provided for questions 3b and 3c relating to gross evaluated energy and demand savings were:

- Gross not evaluated
- Verification only (e.g. phone survey or visit with no measurement)
- Measurement and Verification
- Billing Analysis
- Building Simulation
- Other

The response options provided for questions 3d and 3e relating to net evaluated energy and demand savings were:

- Net not evaluated
- Combined net-to-gross study
- Discrete free ridership and spillover study
- Other

The underlying question in this series is “do you check your inputs, and if so, how?” Survey respondents reported that they check inputs to both gross energy and demand calculations for 82% of measures by at least one evaluation methodology. For only 8% of measures (gross energy) and 9% of measure (gross demand) respondents did not know if there was an evaluation procedure. Respondents reported that there was no evaluation of gross energy or demand calculation inputs in 10% of cases. The dominant methodology was M&V, reported in over 52% and 66% of cases for energy and demand respectively.

For net calculation inputs, respondents report evaluation methodologies are used to confirm 73% of inputs for energy and 70% of inputs for demand. For both energy and demand, 22% were reported as not evaluated. Respondents did not know in 6% of cases (net energy) and 8% of cases (net demand). From the study, it appears that combined net-to-gross studies are relatively rare, used for 5% of measure inputs in both energy and demand. Discrete free rider and spillover studies were more frequent, accounting for measure input evaluation in 24% (net energy) and 23% (net demand) of cases.

Additional detail on measure-level responses is provided in Appendix D.

Respondents were generally not asked to differentiate between "other" types of evaluation methodologies, in part because of the length of the survey. This represents a limitation to the level of detail collected in this question, so we have provided a complimentary discussion on types of impact evaluation in detail in Appendix B, and a review of relevant impact evaluations in Section 2.4.

2.3.5 Baselines, Measure Lives and Persistence

Questions 4a-4d explored the EM&V procedures used to determine estimates of baseline conditions, remaining life of replaced equipment, measure lives, and measure persistence. Survey questions 4a-d are shown below:

4) For each program type/measure, describe your EM&V procedures for:

a) Determining baseline conditions
b) Determining remaining life of replaced equipment
c) Determining measure life
d) Determining measure persistence

Participants were offered four pre-defined options and "other" as responses to Question 4a about determinants of baseline conditions. Baseline conditions represent equipment or practices that would have been used in the absence of program intervention. Building codes (35%), pre-existing equipment (26%), and baseline studies (17%) were reported as the method for determining baselines for a total of 77% of measures. Other in-house standards and the generic "other" category both garnered 11% of responses.

The remaining life of existing equipment (Question 4b) has an influence in several calculations, for example, project economics. Replacing equipment that is relatively new has a higher cost than replacing older equipment in term of foregone value from the old equipment. The instrument offered customer and vendor reporting, and a basic calculation option. The responses in these categories were 6%, 15%, and 45% respectively. A technical reference manual (TRM) was listed as the method for determining remaining life for 32% of measures. TRMs provide either a stipulated or evaluated value for this input, but based on the responses, we could not determine the actual methodology. Respondents used methods with a relatively high rigor (TRM or calculation) for approximately 77% of measures.

The measure life is necessary to determining the duration of the savings stream, since most efficiency measures provide savings for many years. The instrument (question 4c) offered vendor estimates (reported for 10% of measures), independent study (23%), and stipulated in

TRM/PSD (52%) and other (13%)[9]. Only one percent respondents did not know. Three-quarters of measure life determinations (independent studies and TRMs) underwent some degree of analysis and review.

Measure persistence is the duration of an energy consuming measure, taking into account business turnover, early retirement of installed equipment, and other reasons measures might be removed or discontinued[10]. The survey (Question 4d) offered "stipulated in TRM/PSD," "assume ad hoc estimate," "independent study – in-service rate," "independent study; measure persistence," and "other" as response options. Respondents offered their own option: that measure life includes persistence, for 31% of measures, more than any other. Stipulated by documentation was the method applied to 26% of measures, 11% underwent persistence studies, 3% had in-service studies, and 20% were reported as "other".

2.3.6 Rigor level

Question 5 assessed whether different levels of rigor, defined for the purposes of this survey as "the level of effort expended to minimize uncertainty due to factors such as sampling error and bias," are required for different program features. The wording for question five was:

5) Do you have different rigor level requirements for…

a) Gross and net evaluated estimates?

b) Different program types/measures?

Respondent choices in the instrument for both set of questions were "Yes," "No," and "Don't know." "NA" was offered as the answer for 30% of cases regarding gross and net and 37% of cases regarding a difference between program types or measures, even in cases where the respondent offered some or all of the measures covered by this question.

With regard to gross and net savings estimates, 31% of those responding state that the rigor level differs, 28% stated that it did not, and 11% did not know.[11] For programs and measures, 30% had different rigor levels, 27% had the same, and 6% did not know.

2.3.7 Sampling Confidence/Precision

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[9] "PSD" is an acronym for "Program Saving(s) Document," often a functional equivalent to a TRM.

[10] Northeast Energy Efficiency Partnerships Glossary of Terms, Version 1.0, March, 2009.

[11] One respondent stated that they "use ISO-NE" methods. Since the ISO M-MVDR does not differentiate requirements for confidence and precision between net and gross or across measures, these responses were added to the "no difference" category. This was 6% of total responses for both Questions 5a and 5b.

Question 6a assessed the sampling confidence and precision sought in evaluation efforts. The survey question wording is shown below:

6a) For each program type/measure, what sampling confidence/precision is sought for surveyed/evaluated parameters?

Specific results for this question are shown in Table 3:

Table 3: Question 6a Results, Sampling Confidence/Precision

Response	Frequency	%
90/10 for Energy and Demand	68	33%
90/10 Energy	41	20%
80/10 Demand	38	18%
90/30 Demand	13	6%
Other	20	10%
Don't Know	28	13%
Total	208	100%

In summary, while there are some differences, there are many commonalities including:

- For Energy, 90/10 (53%) is the most common sampling precision requirement reported by the respondents
- Requirements for demand are more varied, including 80/20, 90/30, as well as 90/10
- There also was the recognition that although a study may be designed to meet a certain standard, you get what you get for precision in the end.

Note that all responses provided in Table 2-1 are presented exactly they were provided by the respondent. For example, respondents who answered “90/10” provided only one level of rigor, and did not differentiate between rigor levels for energy and demand savings. KEMA provides a more detailed discussion of sampling precision requirements across the Forum region in Section 2.6.

2.3.8 Policy Drivers for Statistical Rigor

Question 6b asked respondents to identify the key drivers for the confidence and precision levels identified in Question 6a. The survey question wording is shown below:

6b) For each program type/measure, what are the policy drivers for this level of statistical rigor?

This open-ended question elicited a range of responses, which we allocated to the four categories shown in Table 4 below.

Table 4: Policy Drivers

Response	Frequency	%
Forward Capacity Market Requirements	66	36%
Regulatory Authority	67	37%
Utility Objectives	34	19%
Don't Know	14	8%
Total	181	100%

2.3.9 Alignment with IPMVP and ISO procedures

Questions 7a and 7b examined the alignment of evaluation practices with IPMVP and ISO requirements. The question text was as follows:

7) For each program type/measure, to what extent does your current practice align with:

a) The International Performance Measurement and Verification Protocol (IPMVP)?

b) ISO New England or PJM Interconnection M&V Manuals?

Participants reported their current practices are consistent to some degree with IPMVP for over three quarters of surveyed measures (46% fully consistent and 30% somewhat consistent). For the balance of measures, they were not able to state a degree of consistency. In no cases did they state that their practices were not consistent with IPMVP.

They reported a slightly lower degree of consistency with ISO M&V manual, 51% reported as fully consistent and 16% reported as somewhat consistent. For this question, they reported 8% of measure M&V practices that were not consistent with ISO guidelines, and a lack of knowledge for 24% of measures.

2.3.10 Importance of Rigor

Questions 8 sought to determine the most important drivers of statistical rigor and precision with the text below. The mean response across all measures and all respondents is show after the application description.

8) For each of the following applications, how important is it to have a high level of rigor? (Rate on a scale of 1-5, where 5 is very important and 1 is not important at all):

- *State savings goals 4.3*
- *Procurement policies... 3.4*
- *Conducting cost effectiveness analysis.. 3.8*
- *Meeting performance metrics.. 4.0*
- *Shareholder incentives... 3.2*
- *Reducing carbon and other emissions.. 3.2*
- *Participating in wholesale capacity markets.. 3.9*

State savings goals scored the highest at 4.3. The range of mean responses was between 3.2 and 4.3. There were some differences across types of respondents; for example, utilities were more likely to give a higher score for incentives than non-utilities. New England respondents were more likely to give a higher score for capacity markets.

2.3.11 Challenges and Concerns

Through an open-ended set of questions (question 9 a – b) respondents were asked to define challenges or weaknesses in current or past EM&V practices, if they are taking any actions to adjust their procedures, and what is driving their choices. The series is quoted below:

9) With regard to your current or past EM&V practices…

a. Are there any specific challenges or weaknesses that should be addressed in developing recommended EM&V guidelines for the region?

b. Are you taking or do you expect to take action to change any EM&V practices?

- *Yes*
- *No*
- *Don't know*

c. If yes, how and in relation to what influences – e.g. new policies, cost and program conditions, etc?

This question series came late in the lengthy instrument and received only a limited set of responses; six for question 9a, seven for question 9b, and six for question 9c. This limited response set is not sufficient for a statistically valid set of findings.

The instrument was designed to identify themes for additional study or discussion. We distilled the total set of responses into a few themes, not listed in priority or frequency order. One was a call for clarity and consistency. Respondents noted that there were "too many piecemeal studies" and that "more large, statewide studies" are in order. Second was the desire for more empirical data. This included comments such as "access to non-regulated fuel" data, “introducing ‘8,760s’ to all measures,” “excessive reliance on ex-ante calculations,” and the expressed “need for more evaluation.” Third was a concern that uncertainty regarding some factors, such as net-to-gross ratios and persistence factors, were inappropriately driving program design and implementation decisions and may act to “discourage program participation.” Fourth, it appears that all respondents are engaged to some degree in modification of the EM&V procedures, driven by external audiences (e.g “ECMB [in] driver’s seat”) , regulatory authorities, or the benefits of participating in forward capacity markets (“improve documentation for ISO-NE”).

2.3.12 Closing Questions

At the end of the survey, two questions gave respondents the opportunity to raise any issues related to EM&V they chose. The questions were as follows:

10) Are there any emerging EM&V issues that you think should be considered in developing recommended common EM&V methods, either currently or in the near future?
Example issues include:

- *The intersection of M&V for efficiency and smart metering*
- *The timeframe for conducting EM&V studies, and need for faster turn-around*
- *Other* ________________________________

11) Are there any parting opinions or concerns you would like to share with regard to the development of common EM&V methods and rigor for the Northeast/Mid-Atlantic regions?

Eleven out of eighteen participants offered responses to one or both of these questions. As was the case for Question 9, the responses are a guide to inform the next steps, not the basis for a statistical analysis.

Attribution of savings to program activities was mentioned by more than one respondent. This includes issues with the treatment of free riders and free drivers. With rapidly advancing technologies, and an increasing number of consumers purchasing energy efficient technologies without incentives, it is becoming more challenging to attribute energy savings to program activities. For example, some large retailers, such as Wal-Mart, now carry CFLs exclusively, leaving many consumers without the option to choose less efficient lighting. The issue of attribution will be the subject of an upcoming Forum scoping paper on Net Savings.

The pace, frequency and incorporation of evaluation results into program implementation was another class of issues raised by some respondents. These respondents were raising issues of optimal investment strategies and the usefulness and timeliness of results from the perspective of program implementation. They also reflected a long standing tension between the needs of program implementation and the requirements of program evaluation.

Finally, several respondents advised caution (the “Forum biting off more than it can chew.”) with regards to the Forum’s perceived objective of a regional EM&V standard. They noted that some state regulatory requirements may run contrary to this objective and that specific demographic and program design features may require differing EM&V approaches.

2.4 Review of Recent Evaluation Reports

As discussed in Section 2.3, the PA interviews only provided us with a high level view of the impact evaluations techniques used in the region. We reviewed a number of recent evaluation reports to provide us additional information with which to make informed recommendations. Table 5 below presents a summary of the studies reviewed:

Table 5: Recent Evaluation Studies Reviewed

Sponsor(s)	Title	Program/ measure	Description of Analysis Used	Statistical Precision
NYSERDA	Small Commercial Lighting Program Final Report; Prepared for NYSERDA by Nexant; May 2007	Small Commercial Lighting	This review focused on verifying the accuracy of applicant reported operating hours by measuring actual hours of use for a sample using loggers. This was used to create realization rates.	Realization Rate is ±14% at 80%
New England State Working Group	Coincidence Factor Study Residential and Commercial Industrial Lighting Measures; Prepared by RLW Analytics (now KEMA); Spring 2007	Lighting in all sectors	This study was developed to support reference documents for the ISO forward capacity market. Loggers were used for measurement and diversity factors for summer and winter on-peak hours and seasonal peak by class were developed.	Varies by measurement and time period. Relative Precision at Summer on peak hours in June ±11.6 % at 80%
NYSERDA	Home Performance with Energy Star Final Report Prepared for NYSERDA; prepared by Nexant, June 2007.	Home Performance with Energy star Electric and Gas Includes shell improvement, thermostats; furnace fans	Analysis included billing analysis and surveys	Realization rate at 80 % confidence interval = ±3%

Sponsor(s)	Title	Program/ measure	Description of Analysis Used	Statistical Precision
National Grid	Impact Study of 2006 Custom Lighting Installations Prepared for National Grid USA Service Company; Prepared by RLW Analytics, July 2007	Commercial/ Industrial Lighting for both Replacement and New Construction	Site visits including physical inspection, interviews with facility managers; observation of site operating conditions and equipment; complete walk though; and metering of usage. Instrumentation included: lighting loggers, current loggers, and power recorders. Reasons for discrepancies between tracking system and evaluation estimates were reported.	Not presented in Exec Summary Small number of sites (10)
New Jersey BPU	New Jersey's Clean Energy Program Impact Evaluation and Protocol Review; Summary Report Prepared for New Jersey Board of Public Utilities; Prepared by KEMA; September 2009.	This report covers multiple programs and measures. The summary presented here will present findings from selected programs.	Residential Electric and Gas HVAC program- billing analysis CFLs- measurement based on primary and secondary data including: telephone surveys; sales data; program data and proxy metering data from another study. Start Smart (C/I) various measures – measurement based on surveys, on-site visits and program data.	Not reported in this Summary report; Reported in Program specific reports Overall data quality of tracking system data was very mixed.
National Grid	Final Report for National Grid USA Service Company; Evaluation of 2005 Custom Process Evaluations. Prepared by UTS Energy Engineering, July 2008.	This report presents data collected on site at both replacement and new construction.	Site visits included: Collection of nameplate data; interviews to obtain scheduling and operational data; spot metering of amperage, voltage, power factor and kw; data loggers, Key results include relationship between evaluation estimates and tracking estimates along with reasons for discrepancies in savings.	
NEEP and New England Administrators	Final Report; Coincidence Factor Study Residential Room Air Conditioners Prepared for NEEP's New England Evaluation and State Program Working Group.; Prepared by RLW Analytics; June 2008.	Residential Room Air Conditioners	Used Metered interval data in nested phone survey. Outputs include peak and seasonal coincidence factor	Precision of coincidence factor varied by month. Average for Summer ±10.4%
NYSERDA	EmPower New York Program Final Report Prepared for NYSERDA; Prepared by Nexant. April 2007	This program is a low income multi measure program	The analysis here included: Site visits to verify operation and installation of measures Development of electric and non – electric measures through engineering calculations and calculated realization rate	
New England Residential Lighting Program Sponsors	Residential Lighting Measure Life Study; Prepared by Nexus Market Research and RLW Analytics,	Residential Lighting	Audits of program participants to collect socket data; Survival analysis used to estimate measure life. Estimate of spillover were also part of this study.	Measure life Data was presented at an 80% confidence level

Sponsor(s)	Title	Program/ measure	Description of Analysis Used	Statistical Precision
National Grid	Impact Evaluations of Custom HVAC Installations – Part II; Prepared for National Grid USA Service Company; Prepared by SAIC, July 2008.	Commercial/ Industrial HVAC measures	Analysis included: site inspections of measures; staff interviews; spot power measurements; field monitoring and data analysis. In some of the projects metering was used to calculate the baseline. Evaluated to tracking calculated for energy and demand.	
National Grid	Large Commercial and Industrial Retrofit Impact Evaluation 2007. Prepared by Summit Blue.	Prescriptive Lighting measures	Billing Analysis using the Statistically adjusted engineering approach.	Precision at the 90% confidence level ±19%

The review of these studies was influential in developing recommendations by measure. The table presents the sponsor, report title, program/measure covered, a description of the analysis, and also a representation of the statistical validity, when provided.

The evaluation reports suggest the following about billing analysis:

- Both billing analysis and a form of measurement and verification are used to estimate gross savings.
- Billing analysis has most typically been done for Commercial and Industrial lighting and residential retrofit measures.

With regard to M&V studies, the actual format varies greatly by program. The M&V techniques observed include:

- Calculation of coincident factors for residential lighting
- Calculation of hours of use for residential lighting
- Using surveys to develop parameters for net savings
- On site visits to estimate measure life for residential lighting
- Detailed site visits for custom HVAC including customer interviews, power measurement of production variables, flow rates and operating speed.
- Using lighting loggers to calculate coincidence factors for commercial and industrial lighting
- Detailed on site visits for custom lighting including: inventory; physical inspection, site observation and short term metering.
- Detailed on site visits of custom applications including: collection of nameplate data, customer interviews, getting schedule data, data loggers, spot metering of amperage, voltage and power factors

The on-sites discussed above typically have these components:

- **Measure Inventory** to confirm quantity and type of installed measure,
- **Measure Operation** to confirm that measure and or controls are operational,
- **Measure Operating Schedule** to confirm operating schedule and or control settings and assumptions,
- **Power Measurements** to confirm full load power consumption for the measure,
- **Power Monitoring** to confirm the operating profile for the measure using either direct interval power measurement or time of use event loggers and spot power measurement where appropriate, and
- **Interactive Effects** that evaluate the impact of the measure on the operation of other electrical equipment at the facility.

Other observations from this review included:

- Separate net-to-gross or free rider/spillover studies are used to adjust gross savings
- Multiple approaches are used in some cases both in a given year and across years
- Some of the studies conducted are joint (namely sponsored by multiple program administrators)
- Where it was calculated, most studies showed a precision of 80/10 or better
- Some studies effectively leverage previous years evaluations to lower costs
- Some evaluators may have chosen one or two variables to measure in a given program in a given year rather than measuring all variables all years
- There is recent focus on measuring demand
- Information on statistical validity, rigor, precision etc is not presented in a similar manner across studies

2.5 EM&V Guideline Review Findings

This section presents the findings from KEMA's review of selected evaluation, measurement, and verification guidelines. These guidelines are widely applied and/or generally accepted reference documents among EM&V practitioners. The KEMA professionals who performed this secondary research were well-versed in the intent and application of documents. This section contains summary results of an examination of these documents focused on developing a resource that the Forum can use to characterize and assess current EM&V practice within the Forum region. This section is intended to be used a reference document and a benchmark during the development of Forum recommendations. It does not contain a detailed comparison between the wide variety of EM&V methods in use by Forum members and any or all of these documents which would have been beyond the scope of work for this project.

2.5.1 International Performance Measurement and Verification Protocol

The IPMVP is a guidance document, not a standard with compliance requirements. It defines a set of practices for measuring, assessing, and reporting savings from energy efficiency at the measure and project level. It provides an objective framework and four measurement and verification (M&V) options for reporting savings. The IPMVP is referenced often in regional M&V manuals and is probably the most widely recognized guidebook of its type. It is a quality document with a thirteen-year pedigree of refinement by respected scholars, technical advisors, and energy organizations.

The IPMVP protocols are clearly defined and if fully implemented can achieve a high level of statistical confidence and precision. In some cases, the costs of rigor level, when balanced with budgetary constraints and the requirements of the regulatory environment, may exceed the benefits. For this reason, it is not applied uniformly and fully across all measures, projects, and programs.

For the Forum's reference, a summary of the IPMVP four M&V options, A through D, is provided below:

A. Retrofit Isolation: Key Parameter Measurement – "Option A" is the most commonly employed method for impact evaluation. It uses a combination of measured and estimated parameters to measure and verify savings. Option A requires measurement of the key parameter(s) for *both* the baseline (pre-installation) and reporting period (post-installation) conditions. The IPMVP is clear on this matter (IPMVP 2007, pp. 25-26), and it follows that any ex-post evaluation work without "pre/post" metering technically is not compliant with IPMVP Option A.
B. Retrofit Isolation: All Parameter Measurement – Option B, in comparison, "requires measurement of all … energy quantities, or all parameters needed to compute energy."
C. Whole Facility - Option C involves measuring energy use at the whole facility through "continuous measurements of the entire facility's energy use (IPMVP 2007, p 22)," and encompasses what the evaluation industry terms "billing analysis."
D. Calibrated Simulation - Option D is the primary M&V approach for assessing energy efficiency inclusions in new facility designs" (IPMVP 2007, p. 33). It is unclear whether the spreadsheet modeling performed by M&V contractors to evaluate new construction measures would be considered compliant with IPMVP Option D.

The typology, and terms, of Option A through D have been adopted by several other guideline documents. These documents have included their own interpretations, exceptions, or application-specific contexts to these terms. As a consequence, these terms have entered the energy-efficiency vernacular with occasionally inconsistent application, as noted in the Northeast.

Current M&V practice in the Northeast aligns reasonably well with the IPMVP in many respects. In general, evaluators use retrofit isolation techniques consistent with Options A and B that measure key parameters, respect the “measurement boundary”,[12] and capture interactive effects beyond this boundary. However, complete and literal compliance with IPMVP Options A and B typically is not achieved in ex-post impact evaluation due to lack of metering in the baseline scenario. The general exception to this practice is for custom retrofit projects where the interactions of multiple measures and complex analytic requirements support the cost of ex-ante measurements that fulfill IPMVP baseline metering requirements.

In another divergence from the IPMVP methodology, evaluators also tend to apply Option A/B-style methods to small-to-moderate sized new construction projects. In these cases where “baseline energy data do not exist or are unavailable” the IPMVP calls for calibrated simulation modeling (Option D).

2.5.2 California Evaluation Framework and Protocols

The 2004 California Evaluation Framework (the Framework) provided detailed guidance on evaluation methodologies. It extensively referenced IPMVP Options A through D. California’s landmark evaluation framework helped consolidate the IPMVP position as the reference standard for measurement and verification of energy-efficiency measures and projects.

In 2006 the California Public Utilities Commission (CPUC) issued the *California Energy Efficiency Evaluation Protocols: Technical, Methodological and Reporting Requirements for Evaluation Professionals* (Protocols) which superseded the Framework as the primary resource for evaluation requirements in California. The Protocols offer comprehensive, consistent, and detailed requirements for all aspects of evaluation, measurement and verification that have been adopted by the regulatory authority in the most populous state in this country. Considering the scope of the analytic effort devoted to its creation, the degree of stakeholder review, and its

[12] The measurement boundary is defined by the IPMVP as “a notional boundary drawn around equipment and/or systems to segregate those which are relevant to *savings* determination from those which are not.” (IPMVP, Concepts and Options for Determining Energy and Water Savings, Volume 1, 2007, p.57)

impact in terms of population, dollars, and units of energy, we offer the following summary as reference for the Forum.

The Protocols outline the evaluation requirements for several different types of evaluation efforts, including:

- Direct and Indirect Impact Evaluations
- Measurement & Verification
- Market Effects Evaluations
- Emerging Technology
- Codes and Standards
- Process Evaluation
- Effective Useful Life (EUL)

These individual protocols are designed be used together, for example, the M&V Protocol is intended to support the Impact Evaluation Protocol. In addition, all of above-mentioned protocols are supported by two additional protocols, the Sampling and Uncertainty Protocol and the Reporting Protocol. The purpose of the Protocols is to provide a consistent approach for conducting evaluations, documenting program effects, supporting the performance bases for judging program and portfolio achievements, and providing data to support cost-effectiveness assessments.

According to the Protocols, each evaluation study is assigned a minimum rigor level and budget by the CPUC, based on a number of factors, including:

- The amount of savings expected from each program in the group;
- Whether the programs are expected to grow or shrink in the future;
- The uncertainty about expected savings and the risk programs pose to achieving portfolio savings goals; and
- How long it has been since the last evaluation and how much the program has changed in the interim.

The term "rigor" is synonymous with "reliability" in the Protocols, encompassing both accuracy and precision. Each type of evaluation has a unique set of rigor levels, which may include "basic," "standard," and/or "enhanced" rigor. Each level of rigor represents a collection of allowable methods for that particular evaluation type, from which evaluators can choose the most appropriate and cost-effective methods for their particular project. For example, the basic rigor level for evaluating gross energy and demand impacts includes two methodological options:

1. Simple Engineering Model (SEM) with M&V equal to IPMVP Option A OR
2. Normalized Annual Consumption (NAC) using pre- and post-program participation consumption from utility bills, normalized for weather.

By contrast, the "enhanced" rigor level for evaluating gross impacts consists of four methodological options:

1. A fully specified regression analysis of consumption information from utility bills
2. Building energy simulation models that are calibrated as described in IPMVP Option D
3. Retrofit Isolation engineering models as described in IPMVP Option B
4. Experimental design established within the program implementation process, designed to obtain reliable net energy savings based upon differences between energy consumption between treatment and non-treatment groups from consumption data.

Regardless of the rigor level or methods chosen, all evaluation studies must also adhere to the sampling requirements laid out in the Sampling and Uncertainty Protocol.

The M&V Protocol is a subset of the Impact Evaluation, Process Evaluation and Market Effects Protocols. The purpose of M&V is to support impact studies by providing measured quantitative data from the field. The M&V Protocol uses the four IPMVP "Options" as a framework, so M&V studies must adhere to the IPMVP and to the additional requirements of the Protocols, including the sampling requirements of the Sampling and Uncertainty and Reporting Protocol. The M&V Protocol addresses the following issues:

- Requirements for installation verification
- M&V requirements
- M&V approach examples
- Project reporting and documentation requirements
- Sampling strategies
- Skills required for conducting M&V activities

In accordance with the IPMVP, the M&V Protocol also requires a site-specific M&V plan that documents the project procedures and rationale for each field measurement project. A site-specific M&V report is also required for each project, as an addendum to the M&V plan. In addition, an overall M&V report is required for programs with M&V activities.

Like the other types of evaluation, the CPUC assigns an appropriate rigor level for each M&V study. The Protocols require that verification of installation take place at all sites that conduct M&V and claim energy or peak demand savings. Verification of measure installation must include verification of measure existence and installation quality. It may also include verification of correct operation and potential to generate savings, depending upon the required level of rigor. The methods used to accomplish this verification also vary according to the level of rigor. The following tables provide a summary of the M&V Protocol requirements for both the "basic" and "enhanced" rigor levels:

Table 6: Summary of California M&V Protocol at the Basic Rigor Level[13]

Provision	Requirement
Verification	Physical inspection of installation to verify correct measure installation and installation quality
IPMVP Option	Option A - Partially Measured Retrofit Isolation. (except comprehensive, new construction, commissioning, or retro-commissioning measures; These must use IMPVP Option D)
Source of Stipulated Data	DEER assumptions, program work papers, engineering references, manufacturers catalog data, on-site survey data
Baseline Definition	Consistent with program baseline definition. May include federal or Title 20 appliance standards effective at date of equipment manufacture, Title 24 building standards in effect at time of building permit; existing equipment conditions or common replacement or design practices as defined by the program
Monitoring Strategy and Duration	Spot or short-term measurements depending on measure type
Weather Adjustments	Weather dependent measures: normalize to long-term average weather data as directed by the Impact Evaluation Protocol
Calibration Criteria	Not applicable
Additional Provisions	None

[13] From the *California Energy Efficiency Evaluation Protocols: Technical, Methodological and Reporting Requirements for Evaluation Professionals* (2006).

Table 7: Summary of California M&V Protocol at the Enhanced Rigor Level[14]

Provision	Requirement
Verification	Physical inspection of installation to verify correct measure installation and installation quality. Review of commissioning reports or functional performance testing to verify correct operation
IPMVP Option	Option B or Option D
Source of Stipulated Data	DEER assumptions, program work papers, engineering references, manufacturers catalog data, on-site survey data
Baseline Definition	Consistent with program baseline definition. May include federal or Title 20 appliance standards effective at date of equipment manufacture, Title 24 building standards in effect at time of building permit; existing equipment conditions or common replacement or design practices as defined by the program
Monitoring Duration	Sufficient to capture all operational modes and seasons
Weather Adjustments	Weather dependent measures: normalize to long-term average weather data as directed by the Impact Evaluation Protocol
Calibration Criteria	Option D building energy simulation models calibrated to monthly billing or interval demand data. Optional calibration to end-use metered data
Additional Provisions	Hourly building energy simulation program compliant with ASHRAE Standard 140-2001

The M&V Protocols also provide examples of the IPMVP options that may be used for various measures:

[14] From the *California Energy Efficiency Evaluation Protocols: Technical, Methodological and Reporting Requirements for Evaluation Professionals* (2006).

Table 8: Example IPMVP Options for Various Measures

Measure Type	Basic Rigor Level	Enhanced Rigor Level
Appliances	A	B
Commissioning and O&M programs	D	D
Comprehensive	D	D
Envelope	D	D
Food Service	A	B
HVAC Controls	D	D
HVAC Equipment Efficiency	A	D
Lighting Controls	A	B
Lighting Efficiency	A	B
New Construction	D	D
Non-HVAC Motor Controls	A	B
Non-HVAC Motor Efficiency	A	B
Process	A	B
Refrigeration	A	D
Water Heating	A	B
Water Pumping/Treatment	A	B

For measures that claim energy or demand savings, the Protocols also provide guidance on how to determine the period of time over which energy savings will be counted, in the Effective Useful Life (EUL) Protocol. This guidance consists of three sub-protocols, each providing the minimum requirements for retention studies, degradation studies, and EUL analysis studies. Retention studies determine the proportion of measures that are in place and operational; degradation studies measure the relative difference between high efficiency equipment/behavior and non-high efficiency equipment/behavior over time; and EUL analysis studies determine the median number of years that a measure installed under a program is still in place, operable, and generating savings. Each of these three sub-protocols has two possible levels of rigor ("basic" and "enhanced"), which are assigned to the study by the CPUC.

All evaluation studies must adhere to the requirements set forth in the Sampling and Uncertainty Protocol, in conjunction with the other protocol(s) relevant to the study (i.e. Impact Evaluation, M&V, Process, or Market Effects). The Sampling and Uncertainty Protocol provides *precision targets* for a variety of different parameters at each rigor level, including gross impacts, net impacts, measure-level M&V, sampling within a site, and verification studies in support of non-impact evaluation gross and net estimates. For example, the precision target for measure level M&V at the basic rigor level using simplified engineering models is 90/30, while the precision target at the enhanced rigor level using direct measurement and energy simulation models is 90/10. These precision targets are goals established at the start of an evaluation, based largely on initial estimates of uncertainty. If an evaluator does not achieve the targeted level of precision, they are not penalized, because the assumptions underlying the sample sizes proposed in the evaluation plan were already “clearly presented and carefully documented,” as required by the Protocols. If a precision target is not met, an adjustment of the input assumptions is required prior to the next evaluation cycle and, if necessary, evaluation dollars must be reallocated to support larger sample sizes. As outlined in the Impact Evaluation, M&V Protocols, and EUL Protocols, the level of rigor assigned to each program by the CPUC will vary depending on the evaluation priorities and budget.

2.5.3 Regional Wholesale Market M&V Manuals

Energy efficiency project savings, if they meet certain requirements, may be bid into wholesale capacity markets (ISO-NE in the northeast and PJM in the mid Atlantic region). As noted in the summary of survey findings above, these requirements are significant drivers for the design of M&V activities.

In April 2007, the ISO New England published its Manual for Measurement and Verification of Demand Reduction Value from Demand Resources (Manual M-MVDR). In Section 5: Measurement and Verification Approach, the M-MVDR follows the nomenclature of IPMVP Options A through D. Regardless of the nomenclature, the M-MVDR does not reference the IPMVP or imply that the IPMVP represents any additional or overriding M&V criteria. In fact, ISO New England’s M-MVDR makes some substantial allowances for methods that are not consistent with the IPMVP. The most notable Option A allowance is “The factors, parameters and/or variables not measures can be stipulated based on assumptions, analysis of historical data, or manufacturer’s data” (ISO-NE M-MVDR, p. 5-2). Finally, the M-MVDR offers considerable flexibility by allowing project sponsors to “propose alternative methodologies”.

In April 2009, the PJM Interconnection published its Manual 18B: Energy Efficiency Measurement & Verification, a document which drew heavily from the ISO New England M-MVDR. In light of the financial opportunity offered by capacity markets, and the influence that PJM and ISO-NE have on utility operations, any regional or statewide evaluation protocol would best serve its users through consistency with, or at least ready translation to, the M&V requirements of these organizations.

2.5.4 American Recovery and Reinvestment Act (ARRA) Reporting Guidelines

The American Recovery and Reinvestment Act provided a short term influx of funds to energy efficiency activities. The primary objective of these funds is to stimulate the economy, not the development of capacity for, or acquisition of, energy efficiency resources. Nonetheless, substantial evaluation guidelines have been promulgated by the U.S. Department of Energy (DOE) in the recently issued Recovery Act Reporting Guidelines Program Notice. [15], This document covers evaluation of State Energy Programs (SEP), the conduit for ARRA efficiency funding. For this reason, if only for the approximately three year duration of program funding, these guidelines must be considered in utility evaluation program design to avoid multiple, duplicative, and wasteful evaluation activities.

The DOE guidelines provide recommendations for the successful management and administration of evaluation activities, and recommended technical standards for the methods and research approaches used in evaluation studies. It recommends that state evaluations focus on the same four metrics that will be used in the national evaluation of ARRA activities. These are energy and demand savings, renewable energy capacity and generation, carbon emission reductions, and job creation.

The document also offers guidance on some of the technical aspects of evaluation, but does not provide any detail on the technical methods that should be used to evaluate specific energy efficiency measures. Instead, the document refers readers to a number of relevant guidelines, including each of the guidelines reviewed by KEMA in this report. Notably, the DOE specifically recommends that field data be collected using the methods outlined in the four IPMVP M&V options. In addition, the DOE specifies that the statistical rigor of sampling should be no less than a 90% level of confidence with a precision limit of plus or minus 10% (90/10), and that state-of-the-art technical approaches should be used in evaluations. Projects must also calculate the SEP Recovery Act Cost Effectiveness Test, which requires projects to "seek to achieve annual energy savings of at least 10 million source BTUs for each $1,000 of total investment."

2.5.5 NAPEE Model Energy Efficiency Program Impact Evaluation Guide

The National Action Plan for Energy Efficiency (NAPEE) Model Energy Efficiency Program Impact Evaluation Guide defines a standard evaluation planning and implementation process,

[15] http://apps1.eere.energy.gov/wip/pdfs/sep_recovery_act_reporting_program_guidance.pdf

describes standard options that can be used for calculating savings, and provides guidance on key evaluation issues. While each jurisdiction defines its own policy requirements, the Guide provides a structure for applying consistent approaches and definitions. It can also be used as a reference document, defining terms and listing efficiency evaluation resources. The Guide remains more consistent with the 2007 IPMVP than other guidelines, yet like the ISO manuals introduces an allowance for stipulated parameters in place of measured values.

This NAPEE guide goes beyond the IPMVP by accommodating additional factors such as interactive factors and deemed savings approaches. Its terminology and methodology are in line with those used by program administrators. As a document developed by wide ranging consensus at the national level, it is a solid foundation for making decisions at the state and regional level.

2.5.6 EU Directive on Evaluation and Monitoring

To assure that the Forum received a broad perspective on energy efficiency EM&V, KEMA reviewed two papers developed under the auspices of the Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services (EMEEES). Efficiency and energy market activities in the European Union often lead those in the USA, and as such often provide valuable insights and lessons learned. A brief summary of these relevant papers is presented below.

Measuring and Reporting Energy Savings for the Energy Services Directive – How It Can Be Done **by Wuppertal Institute on behalf of EMEEES Consortium** [16]

This report was developed to address monitoring and evaluation practices in response to the Energy Services Directive (ESD) (2006/32/EC), through which member states have adopted an energy savings target of 9%[17] by 2016. A consortium of 21 partners worked on development of concrete evaluation methods including methods for evaluation of single programs and services as well as methods for evaluating the overall impact of numbers of measures implemented in member states. The partners made recommendations on how to calculate energy savings per the ESD, delineating top down and bottom up approaches and when to use them. An overview of the recommended applications for using the bottom up approaches is presented in Table 9.

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[16] Measuring and Reporting Energy Savings for the Energy Services Directive – How It Can Be Done by Wuppertal Institute on behalf of EMEEES Consortium.

[17] The 9% savings target is a cumulative reduction of 9% by 2016 from the national annual average amount of energy consumption over the most recent five-year period prior to the adoption of the directive.

The report also offers advice on levels of rigor, or in EU parlance, levels of harmonization. These three levels of harmonization are as follows:

- Level 1: European Default Values: existing/available regulations, studies, statistics
- Level 2: National Representative Values: up-to-date national statistics, surveys, samples, registries
- Level 3: Program or Participant Specific: specific monitoring systems, surveys, measurements

Finally, the report concludes that further study and adjustments will be required once member states begin to report their energy savings data.

Table 9: Overview of EMEES Bottom-up Applications[18]

End-use/Measure	Sector	Level 1 Possible?	Default Value for savings by EMEEES	Method(s) proposed for Level 2 or 3 calculations
New building regulations	Residential	No	No	Mixed deemed and ex-post
Residential building envelope	Residential	No	No	Mixed deemed and ex-post
Biomass boilers	Residential	No	No	Mixed deemed and ex-post
Residential condensing boilers in space heating	Residential	Yes	Yes	Deemed savings
Energy efficient cold appliances and washing machines	Residential	Yes	Yes	Deemed savings
Domestic hot water - solar water heaters	Residential	No	No	Mixed deemed and ex-post
Domestic hot water - heat pumps	Residential	No	No	Mixed deemed and ex-post
Non-residential space heating improvement in case of heating distribution by a water loop	Tertiary	Yes	Yes	Deemed savings (enhanced engineering)
Lighting	Tertiary (industry)	Yes	Yes	Deemed savings
Central A/C	Tertiary	Yes	Yes	Deemed savings
Office equipment	Tertiary	Yes	Yes	Deemed savings
Motors	Industry	Yes	No	Deemed savings (direct measurement)
VFDs	Industry	Yes	Yes	Deemed savings (direct measurement)
Vehicle energy efficiency	Transport	Yes	No	Deemed savings
Modal shifts in passenger transport	Transport	Yes	No	Mixed deemed and ex-post
Ecodriving	Transport	Yes	Yes	Deemed savings
Energy performance contracting	Tertiary and industry	No	No	Mixed deemed and ex-post
Energy audits	Tertiary and industry	Yes	Yes	Enhanced engineering
Voluntary agreements - billing analysis method	Tertiary and industry	No	No	Billing analysis
Voluntary agreements with individual companies - engineering method	Tertiary and industry	Yes	Yes	Enhanced engineering

[18] Adapted from Measuring and Reporting Energy Savings for the Energy Services Directive – How It Can Be Done by Wuppertal Institute on behalf of EMEEES Consortium.

General Bottom-Up Data Collection, Monitoring, and Calculation Methods **by Harry Vreuls, Stefan Thomas, and Jean-Sébastien Broc for the Wuppertal Institute on behalf of EMEEES Consortium** [19]

This paper was created as part of an effort to develop concrete methods for “bottom up” calculations to support harmonized reporting of energy savings by European Union member states (MS). In Europe, bottom-up methods start with data collected on a specific energy efficiency measure and comprise savings per participant and number of participants. Results are then aggregated for all measures. (By contrast, top down methods start with national statistics on energy consumption or equipment sales, and data is disaggregated from these sources.) The paper provides direction on calculating unitary gross energy savings and on calculating savings in relation to the data collection methods employed. Where applicable, the savings calculations are correlated to IPMVP Options, including Options B, C, and D. Methodologies are then discussed for establishment of energy consumption baselines, and the paper describes approaches for accounting for double-counting and technical interactions, multiplier effects, and free-rider effects.

2.5.7 Other Notable U.S. M&V Guidance Documents

The American Society of Heating, Refrigerating, and Air Conditioning Engineer’s (ASHRAE) *Guideline 14: Measurement of Energy and Demand Savings* and the Federal Energy Management Program’s (FEMP) *M&V Guidelines: Measurement and Verification for Federal Energy Projects* have been developed to serve specific constituencies. The ASHRAE guidelines primary use is in the context of energy service company (ESCO) performance contracts. The FEMP guidelines define the requirements for projects implemented for or by Federal agencies. Both documents undergo a regular review and update, with work in process on ASHRAE’s Guideline 14 and a revised FEMP M&V guideline published in April 2008. Both documents have constructs, definitions, and methods that in many cases are functionally equivalent, or identical to the IPMVP.

[19] *General Bottom-Up Data Collection, Monitoring, and Calculation Methods* by Harry Vreuls, Stefan Thomas, and Jean-Sébastien Broc for the Wuppertal Institute on behalf of EMEEES Consortium. 30 April 2009.

2.6 Statistical Confidence and Precision

This section provides a high-level overview of statistical precision requirements, implications, and related issues.

Complexity of Different Requirements: Understanding – let alone achieving – the statistical precision requirements across the Northeast today is a real challenge. For many years, the standard precision target for evaluated annual energy savings was two-tailed 90/10 confidence/precision. This standard was based upon requirements for accuracy of estimated demand at peak hours expressed in the 1978 Public Utility Regulatory Policies Act (PURPA). Two-tailed 90/10 remains the prevailing precision target for estimation of peak demand via class load research studies, and is also frequently set as the standard for the accuracy of program-level energy savings estimates. However, many jurisdictions recognize that the sample size required to measure a *difference* (savings) at a particular confidence/precision level can be substantially greater than the sample size required to estimate a usage or demand level alone. For this reason, some jurisdictions have moved to less stringent requirements for reporting of savings.

For example, for demand-side resources bid into regional capacity markets, ISO-NE requires ±10% relative precision at 80% confidence (a 2-tailed confidence interval), while PJM requires 10% relative precision for a 90% confidence *lower bound* (a 1-tailed confidence interval). These two requirements actually imply the same relative error for the lower side of the confidence interval. However, the 2-tailed 80/10 corresponds to a finite upper bound, while the 1-tailed 90/10 corresponds to an infinite upper bound. That is, for a given confidence interval half-width *w*, one would be 80% confident that the true value is *between* the lower bound *x-w* and the upper bound *x+w*; for this same analysis, one would be 90% confident the true value is *greater than* the lower bound *x-w*, including the possibility that the true value may be arbitrarily high.

Understanding the Domains: In addition to the statistical precision requirements, one must also understand the domain to which the precision applies. For example, the key domain for the ISO New England is that of the Project Sponsor's demand reduction value for the collection of efficiency projects that the Sponsor has bid into the capacity market. While the composition of said DRV varies by market participant, *in practice* most sponsors have elected to bid in their entire portfolio of energy-efficiency programs. Regardless, each Project Sponsor must assess and document the statistical precision across the domain of their unique DRV compilation.

Domain Implications: The matter of quantifying the statistical precision of a composite domain such as an energy-efficiency portfolio is a complex one, and analytical consultants can assist with this process. One of the practical implications is that the statistical precision for dominant measures/sectors can 'carry' ones portfolio, i.e. ensure the portfolio achieves precision targets regardless of the precision in other program areas. In a strictly statistical sense, the level of precision for dominant program areas such as Large C&I Retrofit or Residential Lighting tends to be far more important than the precision of lesser areas such as HVAC tune-ups or ENERGY STAR Appliances. In fact, the statistical precision of 'minor' portfolio components can remain immaterial even with assumed ±100% precision.

Validity and Cost: Program administrators must also consider that statistical precision in impact evaluation is not solely a matter of regulatory and capacity market rules compliance. Statistical precision is an important means of expressing the validity of estimated tracking and evaluation impacts. Further, one must remember that statistical precision often positively correlates with evaluation cost. This is true because sample size increases with statistical precision, and for each sample point that improves statistical precision there is an added burden of evaluation cost (i.e. added travel costs, monitoring equipment, interviews etc.) Despite increased rigor from capacity market rules, sample designs must remain efficient and optimized to achieve appropriate precision at a reasonable cost.

Table 10 below provides a basic illustration of how sample size varies with confidence interval, number of tails, and precision requirements. For site-specific impact evaluation methods such as phone surveys or site visits, evaluation costs are fairly proportional to sample size. Accordingly, the table below suggests that a 5% improvement in precision translates to around a 100% increase in sample size and hence cost.

Table 10: Illustration of Sample Size Requirements by Confidence/Precision

Confidence	Tails	z-Value	Precision	Sample Size
90%	2	1.645	±10%	271
90%	2	1.645	±15%	120
90%	2	1.645	±20%	68
90%	1	1.282	±10%	164
90%	1	1.282	±15%	73
90%	1	1.282	±20%	41
80%	2	1.282	±10%	164
80%	2	1.282	±15%	73
80%	2	1.282	±20%	41

Assumed CV = 1.0

Other Sources of Error: The aforementioned confidence/precision requirements are for statistical sampling alone and do not reflect other sources of error such as measurement error, equipment accuracy, and parameter bias. Most M&V manuals (ISO-NE, PJM, FEMP, ASHRAE) include guidelines for controlling these other sources of error.

Recommendations: In order to establish and achieve statistical precision objectives in all required/sought dimensions, the following process should be considered:

1. Identify statistical confidence/precision requirements. These should include key requirements (e.g. capacity market specifications) and legacy objectives (e.g. 90/10 for annual energy savings). Also, establish the domain for each requirement, be it the portfolio, program, state, load-zone, etc.
2. Establish your unique precision targets and dimensions. Regulatory and market requirements may offer program administrators either a threshold or a range of confidence intervals and precision. In either case, program administrators may make an independent assessment of the precision targets that are necessary for their particular needs relative to the domain of the evaluation (i.e. sector, program, end use,), their intended use and audience for the evaluation results, and considerations of expected variability and the financial or system impact of varying degrees of uncertainty.
3. Pursue the most challenging target. In most cases, statistical objectives will be multi-pronged, e.g. 80/10 for summer kW, 80/10 for winter kW, and 90/10 for energy kWh. Designing a single sample to meet all objectives can be difficult and is dependent upon the unique population characteristics and expected variability for each parameter. In practice, one often can achieve all objectives by pursuing the element with the greatest variability; for New England large C&I programs, this tends to be the winter coincident demand impact. For example, a recent KEMA large C&I impact evaluation achieved ±10.6% precision for winter kW and ±8.2% precision for summer kW (both at 80% confidence as per ISO New England requirements) and ±4.7% energy precision at the 90% confidence level.

Statistical methods provide the opportunity to characterize the whole from observations of a part. As energy efficiency's role in system operations, and the amount of money involved, increases so does the importance of accurately and appropriately characterizing its impacts. The discussion and recommendations above are offered as a starting point for what is likely to be an iterative decision making process.

2.7 Part A: Conclusions

Part A: EM&V Methods presented the findings of KEMA's research into EM&V methods among Forum participants and as memorialized by guidelines promulgated by other organizations.

This preliminary research is an essential first step towards achieving the Forum's expressed objective of a regional guideline for evaluation, measurement and verification. It determined the state of practice in the region from the perspective of participants and through review of actual efforts. It described some of the precedent and benchmark resources that will be used to develop the recommendations in the closing section of this report. It explored the reasons for, and requirements of, current and anticipated future EM&V activities. It also began the process of discovering attitudes and barriers that must be accommodated to reach the Forum's objective.

In the next section, Part B: Savings Assumptions, we present the findings of our review of a technical review of program documentation, including algorithms used for calculating savings and the inputs for those calculations.

Part C: Guidelines presents KEMA's recommendations for set of guidelines for regional consideration. These recommendations are based on the findings from the Part A and Part B research.

3. Part B: Review and Compare Savings Assumptions

Part B of the project involved reviewing and comparing, for a priority set of both electric and gas efficiency measures, existing gross energy and demand savings determination methods, assumptions (e.g. deemed values, effective useful life, and savings calculation input assumptions) and algorithms across the region (and across the U.S. as appropriate).

The following sections are measure-specific and include comparative tables that identify commonalities and explain differences in assumptions and algorithms for gross savings determination. Each section includes recommendations for how to improve consistency in determining savings for the priority set of measures (and by inference, other measures); for example: which methods, assumptions, algorithms and rigor/applicability criteria should be used for different program types.

3.1 Priority List of Program Types/Measures

Both Part A and Part B began with EM&V Forum subcommittee participants suggesting a list of priority end-use measures (for electric and natural gas efficiency). The Consultant reviewed the list and recommended any changes for final review by the subcommittee and Forum. The final priority list of 14 program types/measures is presented in Table 11.

Table 11: Priority List of Program Types/Measures

Program Types/Measures	
Residential	
Central A/C	Gas Boilers/Furnaces
Comprehensive Multi-Measure (R)	Lighting (R)
Commercial/Industrial	
Comprehensive Multi-Measure (NC)	Lighting (R)
Custom Measures (R/NC)	Motors (NC/TR)
Gas Boilers/Furnaces	Prescriptive Chillers (NC/TR)
HVAC (NC/TR)	Unitary/Split HVAC (NC/TR)
Lighting (NC)	VSDs (R/NC)

In hindsight, this effort may have benefited from more specificity with regard to technology and program delivery mechanism within the fourteen measures above. In the case of both residential and C&I lighting, the breadth of technologies (fluorescents, CFLs, HIDs, exterior, etc.) made for lengthy comparative tables which did not always facilitate meaningful comparisons. And some technologies such as residential compact fluorescent lamps (CFLs) can have different savings assumptions under a retail program than under a direct install program. These issues complicate some of the individual program type/measure write-ups and should be considered when interpreting or employing the comparative data.

With the few exceptions noted parenthetically in Table 11, most of the fourteen measure categories carry little distinction of program market, i.e. new construction, retrofit, or market opportunity equipment replacement. According to one program administrator, the latter term encompasses equipment purchases driven by non-energy factors such as equipment failure, renovation, etc.; not all TRMs distinguish retrofit from "replacement" measures consistently or clearly. In the following sections, each measure's introduction states the reviewed scope, and again in retrospect more meaningful comparisons may have been attained via more specific priority measure categories.

3.2 Review of Technical Reference Manuals and Other Program Documents Used for Savings Assumptions

Table 12 presents the technical program/measure documentation by state that KEMA reviewed for common savings algorithms and assumptions.

Table 12: Reviewed Documentation Sources

State	Program/Measure Documentation	Version/Date
CT	UI and CL&P Program Savings Documentation for 2009 Program Year	October 1, 2008
MA	MA NGRID MADREEM2009.pdf	ISO Year 2009 QP
MA	MA NSTAR C&I Field Definitions.xls	October 9, 2009
MA	MA NSTAR Electric C&I Table Values.xls	October 9, 2009
MA	MA NSTAR TRM - C&I Algorithms.doc	June 1, 2009
ME	Efficiency Maine Commercial Technical Reference Manual No. 2007-1	March 5, 2007
ME	Efficiency Maine Residential Technical Reference Manual No. 2006-1	February 20, 2007
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings	December 2007
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs - Selected Residential & Small Commercial Measures (Gas)	March 25, 2009
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs	September 1, 2009
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Multifamily Programs	July 9, 2009
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Selected Residential & Small Commercial Measures (Electric)	December 28, 2008
VT	Efficiency Vermont Technical Reference User Manual (TRM)	December 30, 2008

At this particular time, the State of Massachusetts poses a unique situation. The Massachusetts Department of Energy Resources is in the process of developing a Statewide Technical Reference Manual. As of December 2009, the Massachusetts TRM is in an early draft form and some utilities are still submitting technical documentation of their programs and measures to the DOER and its TRM development contractor. For this report, KEMA examined information made available by the three largest Massachusetts utilities (National Grid, NSTAR, and WMECo[20]). The final Massachusetts TRM is expected in the fall of 2010.

3.3 Measure-Specific Reviews

The following sections present each of the fourteen priority program types/measures as depicted in Table 13. The individual measure write-ups adhere to a consistent format and provide a measure overview, summary of research sources, the prevailing savings algorithm(s) with commentary, a comparative table of savings assumptions with commentary, and recommendations to improve consistency.

[20] The Western Massachusetts Electric Company (WMECo) is a subsidiary of the Connecticut-based Northeast Utilities System and generally follows the CL&P Program Savings Documentation.

Table 13: Individual Measure Write-Ups

Section	Program Type/Measure
3.3.1	Residential Central Air Conditioning
3.3.2	Residential Comprehensive Multi-Measure Retrofit
3.3.3	Residential Natural Gas Boilers and Furnaces
3.3.4	Residential Lighting
3.3.5	C&I Comprehensive Multi-Measure New Construction
3.3.6	C&I Custom Measures
3.3.7	C&I Natural Gas Boilers and Furnaces
3.3.8	C&I HVAC: Prescriptive Chillers
3.3.9	C&I HVAC: Unitary/Split
3.3.10	C&I HVAC: Other Measures
3.3.11	C&I Lighting (New Construction)
3.3.12	C&I Lighting (Retrofit)
3.3.13	C&I Motors
3.3.14	C&I Prescriptive Variable Speed Drives

3.3.1 Residential Central Air Conditioning

For the purposes of this research study, this category is limited to single-family central air conditioning (CAC). Accordingly, the research did not include heat pumps or measures specific to low-income or multi-family programs. This category also does not include ENERGY STAR room air conditioners or "space cooling" measures.

Also, this section addresses stand-alone central air conditioning measures and excludes CAC installed through comprehensive new construction programs. In New Jersey and Vermont, new construction CAC is not a single measure but a component of performance-based new construction programs that address central cooling efficiency in a comprehensive manner.

Research Sources

Table 14 presents the technical program/measure documentation by state that KEMA reviewed for residential central air conditioning savings algorithms and assumptions.

Table 14: Residential Central Air Conditioning Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year Residential: 5.2.1 ENERGY STAR Central AC: New Construction Residential: 5.2.1 ENERGY STAR Central AC: Early Retirement
MA	National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP Energy Star Air Conditioning: CoolSmart AC QIV ES & NES Energy Star Air Conditioning: CoolSmart AC SEER 14 (Equip) - EER 11.5-11.99 Energy Star Air Conditioning: CoolSmart AC SEER 14 => (Equip) - EER>=12 Energy Star Air Conditioning: CoolSmart AC SEER 15.0 => (Equip) - EER>=12.5 Cool Smart Central Air Conditioning Program (www.mycoolsmart.com) 2009 Cool Smart program brochure and form UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) Residential: 5.2.1 ENERGY STAR Central AC: New Construction Residential: 5.2.1 ENERGY STAR Central AC: Early Retirement
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 Residential Electric HVAC: Central Air Conditioner (A/C) Residential New Construction Program: Efficient HVAC Equipment
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Selected Residential & Small Commercial Measures (Electric) Residential Central Air Conditioning
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Residential New Construction: Space Cooling: Central Air Conditioner Residential Emerging Markets: Space Cooling: ENERGY STAR Central Air Conditioner

The Efficiency Maine Residential Technical Reference Manual No. 2006-1 does not include any central air conditioning measures.

Prevailing Savings Algorithm

Review of the aforementioned documentation shows that the prevailing algorithms for energy and demand savings are as follows:

kWh Saved = (Size in Btu/hr) x (1/$SEER_{baseline}$ – 1/$SEER_{installed}$) / 1000 x (Full Load Cooling Hours)

kW Saved = (Size in Btu/hr) x (1/$EER_{baseline}$ – 1/$EER_{installed}$) / 1000 x (Coincidence Factor)

It should be noted that the prevailing algorithms use the Energy Efficiency Ratio (EER) for kW impacts and the Seasonal Energy Efficiency Ratio (SEER) for kWh impacts. The SEER rating is the total cooling output divided by the total electric input across a typical cooling season, while the EER rating is the ratio of cooling output to electric input at a prescribed set of interior and exterior conditions that reflect peak operation.

Commentary on the Algorithm

There are three primary yet mathematically insignificant variants of this residential central air conditioning savings algorithm.

1. Some entities express unit size or cooling capacity in terms of “tons” of cooling, a unit of power equivalent to 12,000 Btu/hr. A simple conversion factor handles this difference in the algorithms.

2. Others algorithm (e.g. New York) use discrete estimates of load factor, diversity factor, and coincidence factor in place of a combined “coincidence” factor to account for all these effects. The product of the three discrete factors is equivalent to the single combined loading/diversity/coincidence factor.

3. Most TRMs cite “full load hours” or “equivalent full load hours” in their algorithm, but New York introduces an expression “cooling load hours” which separates the influence of electrical efficiency from the time term in the equation.

Comparative Tables of Savings Assumptions

Table 15 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for residential air conditioning energy and demand savings. Italicized values are stated in the program documentation but not substantiated with sources for the values themselves.

Table 15: Residential Central AC Savings Assumptions

State	Utility	Application	Savings Estimation Method	Efficiency		Units of Cooling Capacity	Eligible Capacity Range	Full Load Hours	Demand Factors			
				Baseline	Minimum Installed				Loading	Diversity	Summer Coinc.	Winter Coinc.
CT	CL&P and UI	New Construction	Calculated	13 SEER/ 11.1 EER	Energy Star or higher	Btu/hr	Not specified	500	N/A	N/A	*75%*	0%
CT	CL&P and UI	Early Retirement (first 5 years)	Calculated	Existing Equipment	Energy Star or higher	Btu/hr	Not specified	500	N/A	N/A	*75%*	0%
CT	CL&P and UI	Early Retirement (remaining 18 yrs)	Calculated	13 SEER/ 11.1 EER	Energy Star or higher	Btu/hr	Not specified	500	N/A	N/A	*75%*	0%
MA	NGRID	CoolSmart AC	Calculated	13 SEER/ 11 EER	14.5 SEER/ 12 EER	Tons	Not specified	*250*	N/A	N/A	85%	0%
MA	NGRID	Early Replacement	Calculated	9 SEER	14.5 SEER/ 12 EER	Tons	Not specified	*250*	N/A	None	85%	0%
MA	NSTAR	CoolSmart AC	Calculated	13 SEER/ 11 EER	14.5 SEER/ 12 EER	Tons	Not specified	*500*	N/A	None	85%	0%
MA	NSTAR	Early Replacement	Calculated	9 SEER	14.5 SEER/ 12 EER	Tons	Not specified	*500*	N/A	None	85%	0%
MA	WMECo	New Construction	Calculated	13 SEER/ 11.1 EER	Energy Star or higher	Btu/hr	Not specified	500	N/A	N/A	*75%*	0%

State	Utility	Application	Savings Estimation Method	Efficiency		Units of Cooling Capacity	Eligible Capacity Range	Full Load Hours	Demand Factors			
				Baseline	Minimum Installed				Loading	Diversity	Summer Coinc.	Winter Coinc.
MA	WMECo	Early Retirement (first 5 years)	Calculated	Existing Equipment	Energy Star or higher	Btu/hr	Not specified	500	N/A	N/A	*75%*	0%
MA	WMECo	Early Retirement (remaining 18 yrs)	Calculated	13 SEER/ 11.1 EER	Energy Star or higher	Btu/hr	Not specified	500	N/A	N/A	*75%*	0%
NJ	All	Time of Replacement	Calculated	13 SEER/ 11.3 EER	Not specified	Btu/hr	Not specified	600	N/A	N/A	70%	0%
NY	All	Early Replacement	Calculated	10 SEER	14 SEER	Tons	Not specified	312-837*	80%	80%	100%	0%
NY	All	New Construction	Calculated	13 SEER	14 SEER	Tons	Not specified	263-811*	80%	80%	100%	0%
NY	All	Replace on Failure	Calculated	13 SEER	14 SEER	Tons	Not specified	312-837*	80%	80%	100%	0%
VT	All	Existing Homes	Calculated	13 SEER/ 11 EER	14 SEER/ 12 EER	Btu/hr	<65,000 Btu/hr	375	N/A	N/A	82.9%	0%

* Cooling hours for New York State are a lookup by vintage (old, average, new) and city (Albany, Buffalo, Massena, NYC, and Syracuse).

With relatively few exceptions, this presentation elucidates the compatibility of the residential central air conditioning savings assumptions across the Forum states with formal TRMs or program savings documentation.

Commentary on Savings Assumptions

In general, the residential central air conditioning savings equations and assumptions are compatible and fairly consistent.

Only New York and Vermont specifically acknowledge the influence of home vintage on cooling hours. In New York, the assumptions for cooling hours vary for old, average, and new homes. Vermont assumes 200 cooling hours for new homes and 375 cooling hours for existing homes. Presumably, other programs incorporate the distribution of home vintages in their market into the cooling hour research to develop a single representative estimate.

New York's approach is the most complex and rigorous, and the aforementioned lookup tables for cooling hours based upon vintage and city is valid approach given its size, varying climate zones, and diverse housing demographics. New York does a few other things differently as well. As seen in Table 15, New York is the only state with discrete demand factors for loading, diversity, and coincidence. It is unclear if this is an artifact of traditional load research or if there is something unique about the New York market that warrants the disaggregation. National Grid only recently dropped discrete diversity and coincidence factors in Massachusetts in favor of a combined factor.

New York also uses Cooling Load Hours (CLH) instead of cooling Equivalent Full-Load Hours (EFLH). The former is the ratio of building annual cooling load (Btu) to the building peak[21] cooling load (Btu/hr), while the latter is the ratio of annual energy to peak demand. As such, the CLH term is independent of the electrical performance characteristics of a given air conditioner, creating a less biased estimate of cooling hours.

Vermont is also the only state which explicitly limits the cooling unit capacity (maximum of 65,000 Btu/hr or about 5.4 tons) for residential CAC measures.

[21] Non-coincident; the maximum hourly cooling load.

Recommendations

Standardize on Btu/hr for Cooling Capacity. With regard to the algorithm itself, inputs of unit size in Btu/hr are more accurate than tons because it is less susceptible to error introduced by numerical rounding. For example, two entries in the AHRI (Air-Conditioning, Heating, and Refrigeration Institute) directory of certified product performance for similar central AC systems have cooling capacities of 35,600 Btu/hr and 37,600 Btu/hr, yet both are considered 3 ton (nominal 36,000 Btu/hr) units. Also, this approach reflects the reality that cooling capacity of a central air conditioning system is the function of the specific indoor/outdoor unit pairing, not the nominal rating of the outdoor unit. KEMA recommends algorithms with unit sizing in Btu/hr in order to 1) eliminate error from nominal tonnage rounding, 2) ensure that compliant indoor/outdoor unit combinations are being installed, and 3) base the EER and SEER ratings on AHRI performance of the specific indoor/outdoor unit installation.

Include both SEER and EER in Algorithms. Since SEER reflects typical seasonal performance and EER is a better expression of performance under peak conditions, KEMA recommends separate computations for energy and peak demand as per the "prevailing savings algorithm". This appears to be the case for all TRM's reviewed above.

Consolidate Demand Factors. A potentially controversial issue, some program administrators and evaluators would see practical benefit to consolidating load, diversity, and coincidence factors into a single factor which combines all of these peak coincidence drivers. The three discrete factors are entirely real and valid, but the energy-efficiency industry seems to be settling upon the single-factor approach. One of the primary problems with the discrete-factor model is that each input must be exclusive of the others, e.g. the coincidence factor must not include any loading or diversity effects. Unless a compelling reason exists for discrete factors, KEMA recommends that the Forum region move towards the use of combined factors that reflect local loading, diversity, and coincidence effects. Where existing algorithms and databases are already coded for multiple factors, the solution would be to employ 100% for all but one and a single combined factor for the remaining input.

Develop Localized Assumptions. Standardizing on a single algorithm for residential central air conditioning should be achievable, since the savings methods are largely consistent. But given the differences in climate across the Forum region, it is appropriate for specific states or utilities to continue to develop localized assumptions for cooling hours and peak coincidence, for these inputs carry local characteristics of climate, demographics, and behavior.

Consider Location and Vintage of Home. New York takes an interesting approach by factoring building location and vintage into the estimated cooling hours. With regard to location, a state the size of New York has vast differences in climate, but one also might expect a state with similar coastal/inland distance or range of altitude (e.g. Massachusetts or New Hampshire) to have similar effects. The use of building vintage is an effective means of adjusting cooling hours for construction techniques and infiltration levels. Other states may find it more appropriate to use existing methods rather than incorporating the added complexity of this approach. Their reasoning is likely to include that the technical studies which develop cooling hours express the average building vintage and climate across the program area and that the homogeneity of the state climate characteristics means that the expense is out of line with the benefits.

Document the Source of Savings Assumptions. Not all of the savings assumptions presented in Table 15 have well-documented data sources in the respective technical documentation. Many measures in the TRMs include footnotes or other references which specify the source of a particular savings parameter such as full-load cooling hours. For example, New York indicates that its cooling load hours come from "a DOE-2.2 simulation of prototypical residential buildings" while Connecticut cites that its estimate "is conservatively lower than 600 hours estimated by ARI." Whether based on empirical data or a conservative estimate, TRMs ought to document credible sources for all savings assumptions to improve methodological transparency.

3.3.2 Residential Comprehensive Multi-Measure Retrofit

This category encompasses comprehensive multi-measure retrofit installations in residential homes. Sometimes called “deep retrofits” or “home energy services”, these measures are characterized by a whole-home approach which typically involves an audit followed by efficiency recommendations for multiple end uses and technologies. The comprehensive residential approach tends to be electric-centric but also may span fuel measures such as water heating, boilers, or furnaces.

Research Sources

Table 16 presents the technical program/measure documentation by state that KEMA reviewed for residential comprehensive multi-measure retrofit approach and methodology. As a collective efficiency offering, an umbrella comprehensive measure is not documented specifically in technical reference manuals. However, the following individual measures are thought to be involved in residential comprehensive multi-measure retrofits.

Table 16: Residential Comprehensive Multi-Measure Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year 5.1.1 CFL Light Bulb (Direct Install – New Homes, HES & Low Income) 5.3.7 Clothes Washer (Retail Products, HES & Low Income) 5.3.8 Dishwasher (Retail Products, HES & Low Income) 5.3.11 Refrigerator Retirement (HES & Low Income) 5.3.12 Freezer (HES & Low Income) 5.3.13 Dehumidifier Retirement (HES & Low Income) 5.4.4 Blower Door Test (New Homes, HES & Low Income) 5.5.1 Water Heater Thermostat Setting (HES & Low Income) 5.5.1 Water Heater Wrap (HES & Low Income) 5.5.3 Low Flow Showerhead (HES & Low Income) 5.5.4 Faucet Aerator (HES & Low Income) 5.5.5 Install Ceiling Insulation (HES & Low Income) 5.5.6 Install Wall Insulation (HES & Low Income)

State	Program/Measure Documentation
MA	National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP Appliance Management Program: AC or POOL Timer, Appliance Removal, CFLs, DHWater Measure (elec), DHWater Measure (gas&other), DHWater Measure (OIL), Electric Weatherization, Fixtures, Heat System Replacement, Oil Weatherization, Replacement Freezer, Replacement Refrigerator, Torchieres, Tstats, Waterbed replacement, Window AC Replacements, Energy Wise: AC Timers, CFLs, DHW, Fixtures, Heat Pumps, Refrigerators, Insulation, Torchieres – (Electric and Non-Electric) Low Income Energy Wise: AC Timers, CFLs, DHW, Fixtures, Heat Pumps, Refrigerators, Insulation, Torchieres – (Electric and Non-Electric) Residential Conservation Services: Air Sealing, CFLs, DHW, Duct Insulation, Duct Sealing, Heat System Replacement, Indirect DHW, Insulation, Refrigerators, Thermostats, Windows, Insulation (Electric, Gas, Oil, Other Fuels) MassSAVE Home Energy Solutions Program (www.masssave.com) MassSAVE program online documentation UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) 5.1.1 CFL Light Bulb (Direct Install – New Homes, HES & Low Income) 5.3,7 Clothes Washer (Retail Products, HES & Low Income) 5.3.8 Dishwasher (Retail Products, HES & Low Income) 5.3.11 Refrigerator Retirement (HES & Low Income) 5.3.12 Freezer (HES & Low Income) 5.3.13 Dehumidifier Retirement (HES & Low Income) 5.4.4 Blower Door Test (New Homes, HES & Low Income) 5.5.1 Water Heater Thermostat Setting (HES & Low Income) 5.5.1 Water Heater Wrap (HES & Low Income) 5.5.3 Low Flow Showerhead (HES & Low Income) 5.5.4 Faucet Aerator (HES & Low Income) 5.5.5 Install Ceiling Insulation (HES & Low Income) 5.5.6 Install Wall Insulation (HES & Low Income)
ME	Efficiency Maine Residential Technical Reference Manual No. 2006-1 Compact Fluorescent Lamp, Interior Fluorescent Fixture, Interior Fluorescent Fixture, Exterior Fluorescent Fixture, Torchiere, Ceiling Fan with ENERGY STAR Light Fixture, LED Holiday Lights
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 Residential Electric HVAC: Central Air Conditioner (A/C) & Air Source Heat Pump (ASHP), Ground Source Heat Pump (GSHP), GSHP Desuperheater, Furnace High Efficiency Fan Residential Gas HVAC: Space Heaters, Water Heaters Residential Low Income Program: Efficient Lighting, Hot Water Conservation Measures, Efficient Refrigerators, Air Sealing, Duct Sealing and Repair, Insulation Up-Grades, Thermostat Replacement, Heating and Cooling Equipment Maintenance Repair/Replacement, Other “Custom” Measures ENERGY STAR Products Program: ENERGY STAR Refrigerators, Clothes Washers, Dishwashers, Dehumidifiers, Room Air Conditioners, Lighting, Windows, Audit, Refrigerator/Freezer Retirement

State	Program/Measure Documentation
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Selected Residential & Small Commercial Measures (Electric) Residential Measures: CFL Light Bulb, CFL Light Fixture, Electric Heat Pump Water Heater, Central Air Conditioning, Central Heat Pumps, Refrigerant Charge Correction
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Efficient Products Program: ENERGY STAR Clothes Washer, Refrigerators, Dish Washer, Room Air Conditioner, Dehumidifiers, CFL, Torchiere, Dedicated CF Table and Floor Lamps, Interior/Exterior Fluorescent Fixture, Solid State (LED) Recessed Downlight, Ceiling Fan with ENERGY STAR Light Fixture, Internal Power Supplies Low Income Single-Family Program: Hot Water Tank Wrap, Pipe Wrap, Tank Temperature Turn-Down, Low Flow Showerhead, Low Flow Faucet Aerator , Waterbed Insulating Pad, CFL, Fluorescent Fixture, Torchiere, Interior/Exterior CFL Direct Install, Energy Star Refrigerators Residential Emerging Markets Program: Hot Water Tank Wrap, Pipe Wrap, Tank Temperature Turn-Down, Low Flow Showerhead, Low Flow Faucet Aerator , Electric Domestic Hot Water System Fuel Switch, Electric Clothes Dryer Fuel Switch, CFL, Interior/Exterior CFL Direct Install, Solid State (LED) Recessed Downlight, Efficient Furnace Fan Motor, Duct Sealing, Air Sealing, Insulation Upgrade, Efficient Space Heating System, ENERGY STAR Central Air Conditioner

Prevailing Savings Algorithms

As they are comprised of a wide variety of measures and technologies, residential comprehensive multi-measure retrofits do not subscribe to a prevailing savings algorithm, although the component measures themselves may. This report examines discrete residential central air conditioning, natural gas boilers and furnaces, and lighting measures in sections 3.3.1, 0, and 3.3.4, respectively.

In recent impact evaluations of the MassSAVE Home Energy Solutions program, KEMA has reported on the disparities in the savings methods and assumptions in this residential program area. The various energy-efficiency vendors that deliver MassSAVE tend to employ in-house software for developing/reporting savings. While the vendors and software methods are approved by the program, the savings methods are not necessarily unified or consistent. Accordingly, a detailed review of the algorithms and savings assumptions for the remaining component measures such as appliances, insulation, weatherization, and water heating would necessitate an examination of each vendor's methods in Massachusetts.

Commentary

Technical reference manuals tend not to document residential comprehensive multi-measure retrofits as an umbrella offering. While a comparative table of the component measures by utility or state would be useful, the TRMs do not provide sufficient data to facilitate such a comparison. While Table 16 lists a broad spectrum of residential measures, it is not clear whether all measures are offered in residential comprehensive multi-measure retrofit programs.

As described above, KEMA is aware of savings inconsistencies in the MassSAVE program, but there are indications that such residential program offerings may be more standardized in other jurisdictions such as New Jersey and Vermont.

Recommendations

Employ Stipulated Savings Values Where Appropriate. The nature of residential comprehensive retrofit programs lends itself well to a stipulated savings approach for simpler measures. Residential audit programs generally pursue modest savings across a large number of customers with relatively low rigor and time-investment. A measure such as domestic hot water is a good candidate for stipulated savings estimates.

Calculate Residential Lighting Savings. Residential lighting measures pose a good opportunity for streamlining the implementation and tracking process with stipulated parameters, e.g. wattage reduction and hours-of-use. A calculated approach using 1) stipulated demand reductions by lighting technology (e.g., CFLs versus interior fixtures) and 2) stipulated hours-of-use by space type offers consistency for connected demand impact and localized tuning for energy and coincident peak demand savings.

Acknowledge Local Savings Influences. Standardizing on algorithms for certain residential measures such as lighting and central air conditioning should be achievable, since the savings methods already are largely consistent. But given the differences in climate across the Forum region, it is appropriate for specific states or utilities to continue to develop certain localized assumptions that reflect local characteristics of climate, demographics, and behavior.

Standardize Vendor Savings Methods. At minimum, administrators should require consistent savings methodologies across all vendors delivering residential comprehensive retrofits in a given program or state.

3.3.3 Residential Natural Gas Boilers and Furnaces

For the purposes of this research study, this category is limited to residential natural gas boilers and furnaces. Accordingly, the research did not include space heating equipment such as portable or room space heaters, electric or oil space heating equipment, or associated controls such as boiler reset controls. This section addresses stand-alone heating equipment and excludes natural gas boilers/furnaces installed through comprehensive new construction programs such as in New Jersey and Vermont.

Research Sources

Table 17 presents the technical program/measure documentation by state that KEMA reviewed for residential natural gas boiler and furnace algorithms and assumptions.

Table 17: Residential Gas Heating Equipment Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year Residential: 5.4.1 REM Savings Low Income 6.2.6: HVAC System Custom
MA	GasNetworks Residential High Efficiency Heating Equipment Residential High Efficiency Heating Equipment: Furnaces and Boilers UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) Residential: 5.4.1 REM Savings Low Income 6.2.6: HVAC System Custom
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 Residential Gas HVAC: Space Heaters Residential New Construction Program: Efficient HVAC Equipment
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Selected Residential & Small Commercial Measures (Gas, 2009) Single Family Residential Measures: Boilers Single Family Residential Measures: High Efficiency Gas Furnaces
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Low Income Multifamily Program (REEP): Space Heating End Use: Heating System Residential New Construction Program: Space Heating End Use: Heating Savings Residential Emerging Markets: Space Heating End Use: Efficient Space Heating System

The Efficiency Maine Residential Technical Reference Manual No. 2006-1 does not include any gas boiler or furnace measures.

Prevailing Savings Algorithm

Review of the aforementioned documentation shows that the prevailing algorithm for annual natural gas savings for residential boiler and furnace measures is as follows:

Therms saved = (Size in Btu/hr) x ($1/AFUE_{baseline}$ – $1/AFUE_{installed}$) x (Full Load Heating Hours) / 100,000

The prevailing algorithm uses the Annual Fuel Utilization Efficiency (AFUE) of the furnace or boiler. The AFUE represents the average seasonal thermal efficiency of a furnace or boiler, taking into account the unit's response to changes in load due to weather and occupant controls, and is expressed as a percentage. AFUE does not measure the steady state efficiency of a unit, but rather is intended to measure the overall efficiency of a furnace or boiler in a typical application over the course of a year.

An Alternative algorithm that is increasingly being used or considered is as follows:

Therms savings = (Size in Btu/hr INPUT) x $ELFH_{eff}$ x ($AFUE_{eff}$ / $AFUE_{base}$ - 1)/100,000
Where the x $ELFH_{eff}$ of the installed high eff unit.

Commentary on the Algorithm

There are several variants of this natural gas boiler and furnace algorithm:

1. Most TRMs cite "full load hours" or "equivalent full load hours" in their algorithm, but New York introduces an expression called "heating load hours," which separates the influence of thermal efficiency from the time term in the equation.

2. New York also uses a heating load factor to adjust for over-sizing of the heating unit.

3. The New Jersey algorithm accounts for the size of the installed and baseline units separately. A fixed baseline capacity of 91,000 Btu/hr is used to represent the "typical heating unit" based on a New Jersey Residential Baseline Study.

Comparative Tables of Savings Assumptions

Table 18 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for natural gas furnace and boiler energy savings.

Table 18: Residential Gas Heating Equipment Savings Assumptions

State	Utility	Application	Type	Savings Estimation Method	Baseline Efficiency	Minimum Installed Efficiency	Eligible Capacity Range	Operating Hours	Summer Coinc.	Winter Coinc.
CT	CL&P and UI	Low Income Early Replacement	Boilers & Furnaces	Stipulated	Existing equipment	Sufficiently > baseline to pass benefit cost test	Not specified	1500	N/A	N/A
CT	CL&P and UI	New Construction	Boilers & Furnaces	REMrate software	Average "baseline" home in CT	Energy Star	Not specified	Not specified	N/A	N/A
MA	NGRID	Time of Replacement	Boilers (FHW)	Stipulated	80% AFUE	>85% non-condensing >90% condensing	Not specified	Not specified	N/A	N/A
MA	NGRID	Time of Replacement	Boilers (Steam)	Stipulated	75% AFUE	>82% with electronic ignition	Not specified	Not specified	N/A	N/A
MA	NGRID	Time of Replacement	Furnaces	Stipulated	78% AFUE	>92% AFUE	Not specified	Not specified	N/A	N/A
NJ	All	Time of Replacement	Boilers	Calculated	83% AFUE	Not specified	Not specified	965	N/A	N/A
NJ	All	Time of Replacement	Furnaces	Calculated	80% AFUE	Not specified	Not specified	965	N/A	N/A
NY	All	Single Family	Furnaces	Calculated	78% AFUE	>90% AFUE condensing	Not specified	1076-1982	N/A	N/A
NY	All	Single Family	Boilers (Hot Water)	Calculated	80% AFUE	>85% non-condensing >90% condensing	<300,000 Btu/hr	1076-1982	N/A	N/A
NY	All	Single Family	Boilers (Steam)	Calculated	75% AFUE	>82% with electronic ignition	<300,000 Btu/hr	1076-1982	N/A	N/A

State	Utility	Application	Type	Savings Estimation Method	Baseline Efficiency	Minimum Installed Efficiency	Eligible Capacity Range	Operating Hours	Summer Coinc.	Winter Coinc.
VT	All	Low Income Multi-family	Boilers	Calculated	Mid-efficiency boiler (not specified)	High-efficiency boiler w/smart controls (not specified)	Not specified	N/A	N/A	N/A
VT	All	Existing Homes	Boilers	Stipulated lookups	Oil boiler ≤65% LP boiler ≤70%	85% AFUE (all fuels)	Not specified	Not specified	0%	45%
VT	All	Existing Homes	Furnaces	Stipulated lookups	Nat gas ≤75% Oil furnace ≤75%	Nat gas 92% AFUE (ENERGY STAR) + efficient fan motor	≤200,000 Btu/hr	Not specified	0%	45%

With relatively few exceptions, this presentation elucidates the compatibility of the natural gas furnace and boiler savings assumptions across the Forum states with formal TRMs or program savings documentation.

Commentary on Savings Assumptions

In general, the residential natural gas boiler and furnace equations and assumptions are compatible and fairly consistent.

New Jersey and Connecticut use home energy rating software to compute energy savings due to residential new construction measures. New Jersey includes not only heating system replacement but also insulation upgrades, efficient windows, air sealing, and duct sealing in this measure. Connecticut estimates energy savings for Energy Star Certified Homes relative to a base or "user-defined reference home." Heating, cooling, and water heating savings are computed separately by the REMrate software in this case, however, savings due to heating system replacement alone are not provided. Both the New Jersey and Connecticut approaches are more akin to a comprehensive multi-measure program offering than a single heating measure.

As with residential central air conditioning, only New York specifically acknowledges the influence of home vintage on heating hours. In New York, the assumptions for heating hours vary for old, average, and new homes according to geographical location for residential measures. Presumably, other programs incorporate the distribution of home vintages in their market into the heating hour research to develop a single representative estimate.

New York's approach is the most complex and rigorous, and the aforementioned lookup tables for heating hours based upon vintage and city provide a valid approach given its size, varying climate zones, and diverse housing demographics. New York does a few other things differently as well. New York also uses Heating Load Hours (HLH) instead of heating Equivalent Full-Load Hours (EFLH). The former is the ratio of annual to peak heating load in thermal units while the latter is the ratio of annual energy to peak demand. As such, the HLH term is independent of the thermal performance characteristics of a given furnace or boiler, creating a less biased estimate of heating hours. New York is also the only state that uses a discrete factor to adjust for oversizing of the heating unit. This is expressed as the Rated Load Factor (RLF), which is the ratio of the peak heating load imposed on the system to the total rated heating capacity of the system.

New York and New Jersey also incorporate estimates of distribution system efficiency into their algorithms. New York provides lookup tables for furnace duct system efficiency according to city for residential measures. These values are based on average heating season distribution efficiency data for duct systems located in unconditioned spaces across several New York cities. Distribution efficiency for hydronic distribution systems associated with boilers is assumed to be negligible. New Jersey uses a prescriptive approach, with a fixed distribution system efficiency factor of 13% in a separate algorithm for gas savings due to duct sealing.

For existing homes, Vermont requires that furnaces have an efficient furnace fan motor with a ratio of annual electricity use to total energy use of less than or equal to 2 percent. Electricity and demand savings are stipulated to account for the savings associated with the efficient furnace fan.

Only two states explicitly limit eligible heating unit capacity. Vermont limits residential furnace capacity to ≤200,000 Btu/hr, while New York limits residential boiler capacity to ≤300,000 Btu/hr.

Recommendations

Consider Electric Fan Impacts. Vermont and New Jersey are the only states that include estimates of electric impacts associated with efficient furnace fans within the natural gas furnace measure. New York acknowledges that EC motors may be included in residential gas furnace measures, but indicates that these savings may be reduced or eliminated by a shift in operating practices towards continuous fan operation. The remaining states do not provide specific guidance on efficient furnace fans. While tracking systems designed for a single fuel may pose a barrier, programs should take credit for electric and gas impacts.

Standardize "Point of Sale" Residential Gas Heating as Prescriptive. This is another measure that elucidates how program design can affect savings. Connecticut treats low-income gas HVAC as a custom measure; low-income programs tend to promote early retirement and warrant custom assumptions. For "point of sale" heating equipment, there is reasonable consensus on savings calculation methodologies and baseline assumptions for residential natural gas furnaces and boilers. KEMA recommends that those states currently using a custom approach for "point of sale" residential gas furnace and boiler measures adopt a prescriptive approach using the prevailing savings algorithm described above to calculate heating energy savings.

Develop Localized Assumptions. Given the differences in climate across the Forum region, it is appropriate for specific states or utilities to continue to develop localized assumptions for heating hours because these inputs carry local characteristics of climate, demographics, and behavior.

Consider Location and Vintage. New York takes an interesting approach by factoring building location and vintage into the estimated heating hours in residential measures. With regard to location, a state the size of New York has vast differences in climate, but one also might expect a state with similar coastal/inland distance or range of altitude (e.g. Massachusetts or New Hampshire) to have similar effects. The use of building vintage is a recommended and effective means of adjusting heating hours for construction techniques and infiltration levels.

Accept Home Rating Approaches. The Home Energy Rating software approach of New Jersey, Vermont, and Connecticut may pose the greatest challenge to regional consistency for residential natural gas furnace and boiler measures. While such methods do not conform to the prescriptive approach used by neighboring utilities, the technical Home Energy Rating methods are effective and need not change.

KEMA

3.3.4 Residential Lighting

For the purposes of this research study, this category is limited to single-family residential lighting exclusive of specialty low-income and multi-family programs. These measures span new construction, retrofit, direct install, and retail lighting programs.

Research Sources

Table 19 presents the technical program/measure documentation by state that KEMA reviewed for residential lighting savings algorithms and assumptions.

Table 19: Residential Lighting Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year Residential: 5.1.1 CFL Light Bulb (Direct Install – New Homes, HES & Low Income) Residential: 5.1.2 CFL Fixtures (New Homes & Low Income) Residential: 5.3.1 CFL Bulbs (Retail Products) Residential: 5.3.2 Portable Lamps (Retail Products & Low Income) Residential: 5.3.3 Torchiere (Retail Products & Low Income) Residential: 5.3.4 Fixture (Hard Wired) Residential: 5.3.5 Ceiling Fan & Lights (Hard Wired)
MA	National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP Residential Energy Star Lighting Retail Program: CFL, Fixtures, Torchieres Appliance Management Program: CFLs, Fixtures, Torchieres Energy Star New Construction: CFLs, Fixtures Energy Wise: CFLs, Fixtures, Torchieres Residential Conservation Svcs, CFLs, CFLs Piggyback, CFL Torchieres, Indoor Fixture, Outdoor Fixture, Screw Base CFL UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) Residential: [Same measures as CT above]
ME	Efficiency Maine Residential Technical Reference Manual No. 2006-1 Compact Fluorescent Lamp Interior Fluorescent Fixture Exterior Fluorescent Fixture Torchiere Ceiling Fan with ENERGY STAR Light Fixture LED Holiday Lights
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 Residential New Construction Program: Lighting and Appliances ENERGY STAR Products Program: Residential ENERGY STAR Lighting Home Performance with ENERGY STAR Program: Lighting
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Selected Residential & Small Commercial Measures (Electric) CFL Light Bulb - Residential (Single Family) CFL Light Fixture - Residential (Single Family)

State	Program/Measure Documentation
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Efficient Products Program: Lighting End Use (9 measures) Efficient Products Program: Ceiling Fan with ENERGY STAR Light Fixture Residential New Construction Program: Lighting End Use (11 measures) Residential Emerging Markets Program: Lighting End Use (5 measures)

Prevailing Savings Algorithm

Review of the aforementioned documentation shows that the prevailing algorithms for energy and demand savings are as follows:

$$\text{kWh Saved} = (\text{Quantity}_{baseline} \times \text{Watts}_{baseline}) - (\text{Quantity}_{installed} \times \text{Watts}_{installed}) / 1000 \times (\text{Annual Hours})$$

$$\text{kW Saved} = (\text{Quantity}_{baseline} \times \text{Watts}_{baseline}) - (\text{Quantity}_{installed} \times \text{Watts}_{installed}) / 1000 \times (\text{Coincidence Factor})$$

The prevailing algorithms do not employ in-service rates or HVAC interaction, although several entities include such factors. Such variants of the prevailing algorithm are discussed below.

Commentary on the Algorithm

Approximately half of the measures stipulate the wattage reduction, utilizing a common Quantity term and substituting a ∆Watts or kW/unit term for ($\text{Watts}_{baseline} - \text{Watts}_{installed}$) in the equation above. In those instances where the ∆Watts is stipulated, the unit quantity term remains to scale the demand reduction for the number of fixtures. Program administrators have expressed a need to maintain discrete baseline and installed quantity terms for installations that are not one-to-one replacements.

Some algorithms employ an in-service rate (ISR) in the gross savings algorithm to represent the percentage of rebated units that actually get used, while others either presume 100% installation rate or account for ISR in a net savings adjustment. The ISR term is somewhat unique to – or at least particularly significant for – residential lighting measures given 1) the ease by which CFLs can be installed and removed by the end user and 2) the tendency for consumers to purchase spare bulbs, and 3) situations where consumers remove CFLs due to aesthetic or operational dissatisfaction.

Comparative Tables of Savings Assumptions

Table 20 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for residential lighting energy and demand savings.

Table 20: Residential Lighting Savings Assumptions

State	Utility	Program Type	Technology	Baseline Fixture	Gross kW Savings	Operating Hours	Gross kWh Savings	In-Service Rate	HVAC Interact.	Summer Coinc.	Winter Coinc.
CT	CL&P and UI	Direct Install	CFL Bulbs	3.4 x CFL W	Calculated	0.65 to 6.25 hrs/day by Room Type	Calculated	70-80% (Net)	No	9%	26%
CT	CL&P and UI	New Construction	CFL Fixtures (hard-wired)	3.4 x CFL W	Calculated	0.32 to 5.57 hrs/day by Room Type	Calculated	70-80% (Net)	No	9%	26%
CT	CL&P and UI	Retail	CFL Bulbs, Lamps, Fixtures, Fan Lights	3.4 x CFL W	Calculated	1.98-2.6 hrs/day	Calculated	70-80% (Net)	No	9%	26%
CT	CL&P and UI	Retail	Torchiere	Lesser of 3.4 x CFL W or 190 W	Calculated	1.98 hrs/day	Calculated	70-80% (Net)	No	9%	26%
MA	NGRID	Appliance Mgmt.	CFLs, Fixtures, Torchieres	N/A	Stipulated	N/A	Stipulated	100%	No	35%	100%
MA	NGRID	New Construction	CFLs, Fixtures	N/A	Stipulated	Unclear	Calculated	84-95%	No	11%	22%
MA	NGRID	Energy Wise	CFLs, Fixtures, Torchieres	Site-specific	Calculated	Unclear	Calculated	100-104%	No	35%	100%
MA	NGRID	RCS	CFLs, Torchieres, Fixtures	N/A	Stipulated	Unclear	Calculated	84-95%	No	8%	26%

State	Utility	Program Type	Technology	Baseline Fixture	Gross kW Savings	Operating Hours	Gross kWh Savings	In-Service Rate	HVAC Interact.	Summer Coinc.	Winter Coinc.
MA	NGRID	Retail	CFLs, Interior Fixtures, Exterior Fixtures, Torchieres	kW derived from impact study, set by technology	Calculated	CFl = 2.8 markdown CFL coupon = 3.2 IFix = 2.5 Efix = 4.5 Torchieres = 3.3	Calculated	CFL = 97% markdown CFL coupon = 84% IFix = 95% Efix = 87% Torchiere = 83%	No	11%	22%
MA	WMECo	Direct Install	CFL Bulbs	3.4 x CFL W	Calculated	0.65 to 6.25 hrs/day by Room Type	Calculated	70-80% (Net)	No	9%	26%
MA	WMECo	New Construction	CFL Fixtures (hard-wired)	3.4 x CFL W	Calculated	0.32 to 5.57 hrs/day by Room Type	Calculated	70-80% (Net)	No	9%	26%
MA	WMECo	Retail	CFL Bulbs, Lamps, Fixtures, Fan Lights	3.4 x CFL W	Calculated	1.98-2.6 hrs/day	Calculated	70-80% (Net)	No	9%	26%
MA	WMECo	Retail	Torchiere	Lesser of 3.4 x CFL W or 190 W	Calculated	1.98 hrs/day	Calculated	70-80% (Net)	No	9%	26%
ME	All	All	CFL, Int/Ext Fixtures, Torchiere, Fan Light	Lookup Table	Calculated	912.5-1460 hrs/yr	Calculated	100%	No	17%	100%
ME	All	All	LED Holiday Lights	Lookup Table	Calculated	150 hrs/yr	Calculated	100%	No	17%	100%
NJ	All	New Construction	CFLs, Torchieres, Int/ext Fixtures	N/A	Stipulated	2.6-4.5 hrs/day	Calculated	84%	No	5%	5%
NJ	All	ENERGY STAR Products	CFLs, Torchieres, Int/ext Fixtures	N/A	Stipulated	2.6-4.5 hrs/day	Calculated	84%	No	5%	5%
NJ	All	Home Performance	CFLs, Torchieres, Int/ext Fixtures	N/A	Stipulated	2.6-4.5 hrs/day	Calculated	84%	No	5%	5%

State	Utility	Program Type	Technology	Baseline Fixture	Gross kW Savings	Operating Hours	Gross kWh Savings	In-Service Rate	HVAC Interact.	Summer Coinc.	Winter Coinc.
NY	All	All	CFL Light Bulb	3.4 x CFL W	Calculated	3.2 hrs/day	Calculated	N/A	No	8%	30%
NY	All	All	CFL Light Fixture	3.4 x CFL W	Calculated	2.5 hrs/day	Calculated	N/A	No	8%	30%
VT	All	Efficient Products	CFL, Torchiere, Dedicated Lamps, Interior Fixtures, LED Downlights	N/A	Stipulated	949-1241 hrs/yr	Calculated	73-95%	Yes	8.2%	29.8%
VT	All	Efficient Products	Ceiling Fan with Energy Star Light Fixture	N/A	Stipulated	N/A	Stipulated	100%	Yes	8.2%	29.8%
VT	All	Efficient Products	Exterior Fixtures	N/A	Stipulated	1642.5 hrs/yr	Calculated	87%	No	1.8%	34.6%
VT	All	New Construction	Exterior CF/LF Fixture	N/A	Stipulated	1102-1423.5 hrs/yr	Calculated	100%	No	1.8%	34.6%
VT	All	New Construction	Exterior HID fixture	N/A	Stipulated	2920 hrs/yr	Calculated	100%	No	3.2%	61.4%
VT	All	New Construction	LED Exit Sign	N/A	Stipulated	8760 hrs/yr	Calculated	100%	No	100%	100%
VT	All	New Construction	Interior CF/LF Direct Install	N/A	Stipulated	1102-1168 hrs/yr	Calculated	100%	No	8.2%	29.8%
VT	All	New Construction	Solid State (LED) Recessed Downlight	N/A	Stipulated	1241 hrs/yr	Calculated	73%	Yes	8.2%	29.8%
VT	All	Emerging Markets	Interior CFL Direct Install	Site-specific	Calculated	1168 hrs/yr	Stipulated	100%	No	8.2%	29.8%
VT	All	Emerging Markets	Exterior CFL Direct Install	Site-specific	Calculated	1423.5 hrs/yr	Calculated	100%	No	1.8%	34.6%
VT	All	Emerging Markets	Solid State (LED) Recessed Downlight	Site-specific	Calculated	1241 hrs/yr	Calculated	73%	No	8.2%	29.8%

While fairly consistent with regard to the measures that are offered, this presentation elucidates some of the disparities amongst the residential lighting assumptions and savings methods across the Forum states with formal TRMs or program savings documentation.

Commentary on Savings Assumptions

With regard to the programs and measures offered for residential lighting, the savings equations and assumptions are reasonably compatible. The primary distinctions involve stipulated versus calculated demand impacts, hours of use assumptions, and the inclusion of in-service rates in the gross savings algorithms. Only in a few instances are HVAC interactive effects considered, and seasonal coincidence factors sometimes vary considerably.

In Connecticut and New York, baseline fixture wattage is 3.4 times the installed fixture (with one special condition for a torchiere). For other programs, lookup tables prescribe the baseline fixture for a given energy-efficient lighting fixture. In general, such tables are developed either via a wattage multiplier or on the basis of equivalent lumen output.

As a point of clarification, the Connecticut and New York TRMs compute CFL savings on a ∆Watts basis where ∆Watts = 2.4 x CFL. This is derived from the incandescent-to-CFL ratio of 3.4, or:

$$\Delta Watts = Watts_{baseline} - Watts_{installed} = (3.4 \times CFL) - CFL = 2.4 \times CFL$$

The large majority of residential lighting measures have prescribed operating hours, but some are assigned by measure type (e.g. CFL bulb, torchiere, interior hard-wired fixture) and others reflect the room type (e.g. bedroom, hallway, kitchen).

Some utilities prescribe an average hours/day and include a 365 days/year factor in the calculation, while other utilities publish an hours/year estimate. Table 20 presents the estimates in their native form, but these estimates are easily unified on either time basis (hours/day or hours/year).

Recommendations

Stipulated versus Calculated. Only a few of the residential lighting measures in Table 20 employ fully stipulated values for gross kW and kWh savings. For the most part, residential lighting measures pose a good opportunity for streamlining the implementation and tracking process with stipulated parameters, e.g. wattage reduction and hours-of-use. A calculated approach using 1) stipulated demand reductions by lighting technology (e.g., CFLs versus interior fixtures) and 2) stipulated hours-of-use by space type offers consistency for connected demand impact and localized tuning for energy and coincident peak demand savings.

Standardize Hours of Use Dimensions. For residential lighting hours, there are two distinct approaches in the region: whole-home and room-specific. Since retail lighting programs cannot know where CFLs are installed until after evaluation, it makes sense for such programs to employ average, whole-home estimates of lighting hours of use. Direct install programs have the ability to use room type to assign hours of use. The selection or perhaps blending of these two methods will be a key consideration in the pursuit of common savings assumptions for residential lighting measures in the Forum region. In the same manner that "exterior fixtures" effectively is a blend of fixture type and location, methods exist to consolidate homogenous dimensions without overcomplicating the approach.

A recent regional CFL markdown impact study presented residential interior lighting hours in terms of "high use" living spaces (e.g. kitchen, family room) and "low use" spaces such as bedrooms, bathrooms, and basements. This may be a reasonable compromise between the room and whole-home approach. To achieve common savings assumptions for residential lighting measures in the Forum region, program administrators may need to settle on common dimensions. The estimates themselves may remain localized (see below).

Incorporate the In-Service Rate. The majority of residential lighting programs reviewed incorporate an in-service rate into estimates of gross savings, but a few do not. While it is not entirely clear, it appears that these programs elect to apply the in-service rate as a net savings adjustment. KEMA does not assert that in-service rate should be gross or net; valid arguments exist for both. But since the majority of residential lighting programs factor the ISR into gross savings, a recommendation for regional consistency suggests inclusion as a gross effect.

Combine Coincidence and Diversity. A potentially controversial issue, some program administrators and evaluators would see practical benefit to consolidating diversity and coincidence factors into a single combined factor. Unless a compelling reason exists for discrete factors, KEMA recommends that the Forum region move towards the use of combined factors that reflect diversity and coincidence effects.

Review Coincidence Factors. The summer and winter coincidence values in Table 20 suggest that different definitions may be in use across the region. For example, measures with 100% winter coincidence (except exit signs) are distinct outliers against the predominant ~30% winter peak coincidence factor. These factors ought to converge once diversity and coincidence are consistently combined (or separated).

Develop Localized Assumptions. Standardizing on a single algorithm for residential lighting should be achievable, even if some entities choose to stipulate or assign baseline wattage differently. But given demographic, geographic (longitude and latitude affect lighting hours of use), program maturity, and possibly behavioral differences in lighting usage across the Forum region, it is reasonable for specific states or utilities to pursue localized assumptions for lighting hours and peak coincidence. This likely would apply to HVAC interaction factors should the region choose to incorporate it into the standard residential lighting algorithm. Program design (e.g. retail vs. direct install vs. new construction) is also an important factor which may warrant distinct assumptions.

3.3.5 C&I Comprehensive Multi-Measure New Construction

This category is limited to the installation of commercial and industrial comprehensive multi-measure new construction projects. The comprehensive and multi-measure category is not clearly defined or specifically mentioned in many of the TRM's. References to multiple measures are included in custom measure discussions. The Vermont and Maine TRM's include multiple measures in discussions of interactive effects.

Research Sources

In the other components of this report this section includes a table of applicable measures obtained from each TRM's table of contents. None of the documents contained specific measures labeled as "Comprehensive" or "Multi-Measure". These terms are discussed intermittently through the TRM's, or not mentioned at all. The exclusion of specific text or discussions does not mean that comprehensive paths are not included in the programs or that no criteria exists that define acceptable comprehensive projects. Measures not directly covered in prescriptive text fall into an implied comprehensive track.

Prevailing Savings Algorithms

Technical reference manuals do not provide calculations or algorithms for commercial and industrial comprehensive multi-measures. Comprehensive projects are often directed towards large facilities with multiple interactive measures. These projects cover wide ranges of equipment, schedules, approaches, and measure interactions. Each comprehensive project is unique and calculations and assumptions used to generate the energy and demand savings must be obtained and approved on a site-by-site basis.

Commentary

When comprehensive measures are mentioned in the TRM's, they are discussed in conjunction with custom measures. The comprehensive approach is a project that contains multiple custom measures. A custom measure has standalone savings. The calculations may be complex, weather related, or load related, but the savings are not dependent upon other factors outside the parameters of the custom measure.

Table 21 shows the most detailed discussion of comprehensive measures. The text is taken from the New Jersey TRM. The table shows the bundling of the custom and comprehensive approaches. Custom and complex comprehensive jobs are listed as examples of projects. The

CHP example refers to combined heat and power projects. The TRM also includes a combined heat and power measure. No specific algorithms are provided in the text. The measure states that gas savings "should be reported on a consistent basis by all applicants as the reduction in fuel related to the recapture of thermal energy." Electrical savings "should be reported only in cases where the recapture of thermal energy from the CHP system is used to drive an absorption chiller that would displace electricity previously consumed for cooling."

Table 21: Comprehensive Measure Approach and Examples

Type of Measure	Type of Protocol	General Approach	Examples
Custom or site-specific measures, or measures in complex comprehensive jobs	Site-specific analysis	Greater degree of site specific analysis, either in the number of site-specific input values, or in the use of special engineering algorithms	Custom Industrial process Complex comprehensive jobs CHP

Comprehensive multi-measures consist of a series of measures that impact one another and often involve central plant cooling. An example of a comprehensive project would consist of the installation of two new chillers, ventilation modifications at the air handlers, and controls upgrades to provide optimum chiller staging and schedule changes. For some programs, a comprehensive measure is required to include more than one end use (e.g. cooling and lighting).

Calculating the energy savings on a standalone basis for each of the three measure components would yield different total savings when the interactive effects of the measures are addressed. Reductions in scheduled operation and ventilation each impact the total cooling load at the chillers. Each measure employs custom algorithms. The hierarchy of interaction, that is the order in which the measures are calculated, is crucial in estimating the savings for multiple measures. In the example above identifying the actual load after scheduling and ventilation changes are made are required before calculating performance at the chillers.

The Vermont TRM provides examples of the inclusion of interactive effects on "multiple custom measures." Again, "custom" and "comprehensive" are treated as one discussion. Multiple custom measures are modeled with interactions between measures and the final energy savings is reported as a single measure. The TRM acknowledges that modeling and reporting as a “single measure” may not always occur. Individual custom measures can be presented separately even though measure interactions are present. The protocol for this scenario is to determine custom savings based upon measure life. “The procedure 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.” The TRM stated that this measure life hierarchy typically applies to lighting measures. This protocol offsets the impact of short term measures reducing the savings linked to long term measures.

Recommendations

Define the Comprehensive Track. It is not possible to anticipate all possible factors and assumptions that comprise comprehensive multiple measures. However, criteria when comprehensive measures are required should be established and stated clearly in technical program documentation.

Define Measure Interactions Custom. Calculations using site-specific baselines, installed equipment, and savings assumptions provide the most appropriate and rigorous path to savings impacts. Establishing interactive requirements for custom multiple measures is essential in obtaining true energy and demand savings.

Define Interactions with Prescriptive Measure. Comprehensive projects can be comprised of both custom and prescriptive measures. For example, refrigeration projects can include efficient compressors as well as efficient freezer doors, night curtains, and other measures that are prescriptive. Interactive hierarchies should be developed to provide a uniform track to calculate and report savings.

3.3.6 C&I Custom Measures

This category is limited to the installation of commercial and industrial custom measures in both retrofit and new construction situations. The custom category includes measures that either do not comply with or benefit from examination beyond a prescriptive calculation approach. In general, these are more complex measures that necessitate site-specific information and detailed calculations to estimate energy and demand savings. In this context, custom measures may entail any end use or technology.

Research Sources

Table 22 presents the technical program/measure documentation by state that KEMA reviewed for custom measure approach and methodology. The table contains the specific measures identified as "Custom" in the TRM's Table of Contents.

Table 22: C&I Custom Measures Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year C&I Lost Opportunity: Custom C&I Retrofit: Custom Measure
MA	UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) C&I Lost Opportunity: Custom C&I Retrofit: Custom Measure
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs Commercial & Industrial Measures: Custom Measures

The exclusion of states from the table above does not mean that custom measures are not included in their respective TRM's. The table above simply shows measures specifically labeled as "Custom". Custom measures are discussed indirectly in other TRM's and in additional measures in the states listed above.

Prevailing Savings Algorithms

Technical reference manuals do not provide calculations or algorithms for custom calculations since the category covers a wide range of equipment, approaches, and measures. Where custom measures are discussed, the TRMs require site specific equipment, operating schedules, baseline and installed efficiencies, and calculation methodologies in the development of energy and demand savings.

Comparative Table of Custom Measure Technologies

Table 23 presents a comparative matrix of the custom measures that are mentioned in the technical manuals, although none of these were listed in the table of contents. For National Grid, the measures were specifically labeled as a "Custom" while most other measures were identified in the text of similar prescriptive measures.

Table 23: C&I Custom Measures Matrix

EQUIPMENT	CT	MA NGRID	MA WMECo	ME	NJ	NY	VT
Compressed Air		Y			Y		Y
EMS/HVAC Controls	Y	Y	Y			Y	Y
Commercial Equipment Control		Y				Y	
Process Cooling		Y					
HVAC Equipment		Y					Y
Building Shell		Y					Y
Industrial Refrigeration	Y	Y	Y				
Lighting Systems		Y					Y
Lighting Controls		Y					Y
Process Equipment		Y					
HVAC VSDs		Y		Y	Y	Y	Y
Comprehensive Design		Y					
Chillers	Y	Y	Y	Y	Y	Y	Y
DHW Heaters					Y		
Boilers					Y		
Gas-Driven Chillers	Y		Y				
Non-HVAC Motors	Y	Y	Y				

Commentary

Table 23 suggests that chillers and VSDs are the most common custom measures. Variable speed drive savings require detailed calculations and are a prime example for custom calculations. The weather sensitive nature of chiller measures also makes these savings conducive to the custom approach. References to custom chiller measures also include staging of multiple chillers and total system operation that includes pumping and tower operation. HVAC controls and energy management systems (EMS) require complicated calculation with extensive potential interactive impacts.

Three TRMs include "Custom Measures" in discussions of interactive savings effects from multiple measures installed in a single project. Custom components are also discussed in measure protocols, load shapes, peak demand calculations, measure lives, and realization rates. Most these "Custom" references are non-specific. No firm calculations are provided for demand savings. Measure life tables have specific values for Custom Measures.

Most discussions of custom measures equipment types refer back to Prescriptive Measure Text. These measures establish what equipment is treated as prescriptive. All remaining pertinent equipment that falls outside of these parameters is eligible for inclusion in custom programs.

There are no caps of equipment types or sizes, limitations on annual operation, or other major restrictions. This conforms to the wide range of measure types and retrofit scenarios.

Recommendations

Provide a Custom Track. The custom approach is indispensable for delivering energy efficiency to customers, markets, or building/process systems that are not conducive to a standardized, prescriptive approach. However, custom measures are more costly and require technical in-house resources to examine and qualify non-prescriptive applications. Where program funding and technical resources permit, include a custom measure offering to capture more complex efficiency opportunities.

Limit Scope of Custom TRM Entries. It is not possible to anticipate all possible factors and assumptions that comprise custom measures. Custom calculations using site-specific baselines, installed equipment, and savings assumptions provide the most appropriate and rigorous path to savings impacts. Accordingly, there are no specific recommendations for the standardization of custom measure algorithms or approach.

3.3.7 C&I Natural Gas Boilers and Furnaces

For the purposes of this research study, this category is limited to commercial natural gas boilers and furnaces. Accordingly, the research did not include other types of space heating equipment, such as individual or room space heaters, electric or oil space heating equipment, or associated controls such as boiler reset controls.

Research Sources

Table 24 presents the technical program/measure documentation by state that KEMA reviewed for C&I natural gas boiler and furnace algorithms and assumptions.

Table 24: Commercial Gas Heating Equipment Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year C&I Lost Opportunity: 2.7.4 C&I Lo Custom C&I Retrofit: 3.3.1 C&I R Custom Measure Small Business: 4.2.1 SMB Custom
MA	GasNetworks Savings Documentation
	High Efficiency Heating Equipment: Furnaces and Boilers
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 Commercial and Industrial Energy Efficient Construction: Furnaces and Boilers
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Selected Residential & Small Commercial Measures (Gas, 2009) Small Commercial Measures: Boilers Commercial and Industrial Measures: High Efficiency Furnaces
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Commercial Energy Opportunities: Space Heating End Use: Efficient Space Heating Equipment

The Efficiency Maine Residential Technical Reference Manual No. 2006-1 does not include any gas furnace or gas boiler measures. The New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs (2009) does not include any gas boiler measures. The National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP does not include any commercial or industrial gas boiler or furnace measures.

Prevailing Savings Algorithm

Review of the aforementioned documentation shows that the prevailing algorithm for annual natural gas savings for C&I boiler and furnace measures is as follows:

Therms saved = (Size in Btu/hr) x ($1/AFUE_{baseline} - 1/AFUE_{installed}$) x (Full Load Heating Hours) / 100,000

The prevailing algorithm uses the Annual Fuel Utilization Efficiency (AFUE) of the furnace or boiler. The AFUE represents the average seasonal thermal efficiency of a furnace or boiler, taking into account the unit's response to changes in load due to weather and occupant controls, and is expressed as a percentage. AFUE does not measure the steady state efficiency of a unit, but rather is intended to measure the overall efficiency of a furnace or boiler in a typical application over the course of a year.

Recommended Savings Algorithm

It has been brought to our attention that AHRI[22] establishes limits the use of AFUE to furnaces under 225 MBH and boilers less than 300 MBH. Units above these sizes have efficiency ratings in thermal efficiency and combustion efficiency. It is our recommendation that these standards be followed and savings calculations reflect the size of the systems and appropriate efficiency ratings.

Furnaces < 225 MBH and boilers < 300 MBH

Therms saved = (Size in Btu/hr) x ($1/AFUE_{baseline} - 1/AFUE_{installed}$) x (Full Load Heating Hours) / 100,000

Furnaces > 225 MBH and boilers > 300 MBH

Therms saved = (Size in Btu/hr) x ($1/Efficiency_{baseline} - 1/Efficiency_{installed}$) x (Full Load Heating Hours) / 100,000

Commentary on the Algorithm

There are several variants of this natural gas boiler and furnace algorithm:

[22] The Gas Appliance Manufacturers Association (GAMA) merged with the Air-Conditioning and Refrigeration Institute (ARI) in 2008 to become the Air-Conditioning, Heating and Refrigeration Institute (AHRI).

1. Most TRMs cite “full load hours” or “equivalent full load hours” in their algorithm, but New York introduces an expression called “heating load hours,” which separates the influence of thermal efficiency from the time term in the equation.

2. The Vermont algorithm does not specify that baseline and qualifying equipment efficiency ratings must be expressed as AFUE. Instead, the qualifying equipment efficiency rating may be expressed as combustion efficiency, thermal efficiency, or AFUE, but in any case, this qualifying equipment rating must be consistent with the baseline equipment efficiency rating. The 2005 Vermont Guidelines for Energy Efficient Commercial Construction serve as the baseline for new construction measures.

KEMA

Comparative Tables of Savings Assumptions

Table 25 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for commercial natural gas boiler and furnace energy savings.

Table 25: Commercial Gas Heating Equipment Savings Assumptions

State	Utility	Application	Type	Savings Estimation Method	Baseline Efficiency	Minimum Installed Efficiency	Eligible Capacity Range	Operating Hours	Summer Coinc.	Winter Coinc.
MA	NGRID	Commercial Replacement	Furnaces	Stipulated	78% AFUE	92% AFUE	Not specified	Not specified	N/A	N/A
MA	NGRID	Commercial Replacement	Boilers (Hot Water)	Stipulated	80% AFUE	>85% non-condensing >90% condensing	≤2,000,000 Btu/hr	Not specified	N/A	N/A
MA	NGRID	Commercial Replacement	Boilers (Steam)	Stipulated	75% AFUE	>82% with electronic ignition	Not specified	Not specified	N/A	N/A
NJ	All	Large C&I New Construction	Boilers	Calculated	80% AFUE	Not specified	≤1,500,000 Btu/hr	900	12%	88%
NJ	All	Large C&I New Construction	Furnaces	Calculated	78% AFUE	Not specified	Not specified	900	12%	88%
NY	All	Small Commercial	Furnaces	Calculated	78% AFUE	Tier 1: >92% AFUE Tier 2: >95% AFUE	Not specified	707-2200	N/A	N/A
NY	All	Small Commercial	Boilers (Hot Water)	Calculated	80% AFUE	>85% non-condensing >90% condensing	<300,000 Btu/hr	707-2200	N/A	N/A
NY	All	Small Commercial	Boilers (Steam)	Calculated	75% AFUE	>82% with electronic ignition	<300,000 Btu/hr	707-2200	N/A	N/A
NY	All	Large C&I	Furnaces	Calculated	78% AFUE	Tier 1: >92% AFUE Tier 2: >95% AFUE	Not specified	239-2182	N/A	N/A
VT	All	Commercial New Construction	Boilers & Furnaces	Calculated	Equipment type based upon 2005 Guidelines	Exceeding VT EE guidelines	All capacities	N/A	N/A	N/A

With relatively few exceptions, this presentation elucidates the compatibility of the natural gas furnace and boiler savings assumptions across the Forum states with formal TRMs or program savings documentation.

Commentary on Savings Assumptions

In general, the commercial natural gas boiler and furnace equations and assumptions are compatible and fairly consistent.

New York's approach is the most complex and rigorous, including lookup tables for heating hours according to building type (e.g. small retail, fast food restaurant, assembly, small office) and geographical location, and discrete factors for loading and distribution system efficiency. Providing lookup tables for heating hours based on location is a valid approach given New York's size and varying climate zones. Different types of commercial buildings may also have different operating patterns, and thus different heating hours. Presumably, other programs incorporate the distribution of building types and locations in their market into heating hour research to develop a single representative estimate.

New York also uses Heating Load Hours (HLH) instead of heating Equivalent Full-Load Hours (EFLH). The former is the ratio of annual to peak heating load in thermal units while the latter is the ratio of annual energy to peak demand. As such, the HLH term is independent of the thermal performance characteristics of a given furnace or boiler, creating a less biased estimate of heating hours. New York is also the only state that uses a discrete factor to adjust for oversizing of the heating unit. This is expressed as the Rated Load Factor (RLF), which is the ratio of the peak heating load imposed on the system to the total rated heating capacity of the system.

New York and New Jersey both incorporate estimates of distribution system efficiency into their algorithms. New York provides lookup tables for furnace duct system efficiency according to building type and city for commercial and industrial measures. These values are based on average heating season distribution efficiency data for duct systems located in unconditioned spaces across several New York cities. Distribution efficiency for hydronic distribution systems associated with boilers is assumed to be negligible. New Jersey uses a prescriptive approach, with a fixed distribution system efficiency factor of 13% in a separate algorithm for gas savings due to duct sealing.

Vermont's approach to calculating savings for commercial furnaces and boilers is unique in the region. Vermont introduces a factor called "$MMBTU_{sfhload}$" in their algorithm, to represent the average annual building space heating energy use in MMBTU per square foot for buildings in Vermont. This factor is fixed at 0.072, and derived from NYSERDA data for office and retail buildings in upstate New York. This factor accounts for heating load hours, and thus eliminates the need to input heating load hours in the algorithm. However, this factor also requires that square footage be used as a proxy for the capacity of the installed system.

New Jersey and New York explicitly limit eligible heating unit capacity. However, the capacity limits in each state are different. New Jersey limits C&I boilers to 1,500,000 Btu/hr and New York limits small commercial boilers to 300,000 Btu/hr, but neither state limits furnace capacity. Industrial boilers are not included in the New York program savings documentation.

Recommendations

Consider Custom Approach for Large Commercial. While there is reasonable consensus on savings calculation methodologies and assumptions for small commercial natural gas heating equipment, it may be appropriate to treat large commercial boilers as custom measures. States currently using or considering a custom approach for small commercial gas heating equipment might consider a prescriptive approach using the prevailing savings algorithm to calculate heating energy savings.

Develop Localized Assumptions. Given the differences in climate across the Forum region, it is appropriate for specific states or utilities to continue to develop localized assumptions for heating hours because these inputs carry local characteristics of climate, demographics, and behavior.

Consider Location and Vintage. New York takes an interesting approach by factoring both building location and type into the estimated heating hours for C&I measures. With regard to location, a state the size of New York has vast differences in climate, but one also might expect a state with similar coastal/inland distance or range of altitude (e.g. Massachusetts or New Hampshire) to have similar effects. Different types of commercial buildings may also have different operating patterns, and thus different heating hours. When shown to be relevant, savings parameters by location, vintage, or other dimensions should be employed. Other states may not be receptive to the added complexity of this approach, despite its improved rigor for individual savings estimates, on the basis that technical studies which develop heating hours express the average building vintage and climate across the program area.

Standardize on Capacity Limits. Differing limits placed on eligible capacities throughout the region may also pose a barrier to greater consistency for commercial natural gas boiler and furnace measures. For example, New Jersey's limit for eligible commercial boilers is more than four times greater than the limit on commercial boilers in New York. In these two states, boiler capacity is used to determine whether a measure is treated as a custom measure, so capacity limits will also impact how savings are calculated.

3.3.8 C&I HVAC: Prescriptive Chillers

This category is limited to air-cooled and water-cooled chiller installations in commercial and industrial facilities as a prescriptive measure. Custom chiller installations are covered under C&I Custom Measures in Section 3.3.6 of this report.

Research Sources

Table 26 presents the technical program/measure documentation by state that KEMA reviewed for the chiller savings algorithms and assumptions. Any notable issues or exceptions are described below the table.

Table 26: C&I Chiller Sources

State	Program/Measure Documentation
MA	National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP Design 2000: HVAC Equipment - Chillers NSTAR eTRAC Savings Calculations Documentation by Technology Business Solutions and Construction Solutions: Chillers
ME	Efficiency Maine Commercial Technical Reference Manual No. 2007-1 HVAC: High Efficiency Electric HVAC Systems.
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 C&I Energy Efficient Construction: Electric Chillers
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs Chillers
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Commercial Energy Opportunities: Electric HVAC [Chiller sub section]

There are no prescriptive chiller measures in Connecticut or Western Massachusetts. For these utilities, chiller replacements are treated as custom measures. While the Vermont TRM lists a prescriptive chiller measure, most chiller applications are analyzed on a custom basis. The prescriptive algorithm is applied to occasional small chiller applications.

Prevailing Savings Algorithms

Savings calculations for chillers are very similar across all state TRMs. The simple, but effective, formula can be summarized as:

kWh savings = Tons x ∆efficiency x annual operating hours

kW savings = Tons x ∆efficiency x Demand factors

Delta efficiency ("∆efficiency") refers to the difference in efficiency between the base and installed equipment. This value provides the per/unit-hour improved efficiency for the savings calculation. "Annual operating hours" are referred to as either equivalent full load hours (EFLH), cooling load hours (CLH), or are stated simply as annual hours without a cooling reference.

The demand savings algorithm excludes operating hours and incorporates demand factors. These multipliers are called coincidence factors or load factors that modify the chillers peak kW consumption.

Commentary on the Algorithm

The savings factors used in the algorithm vary across the TRMs. kW per ton is the most prevalent source of base and installed efficiencies. The coefficient of performance (COP) is used in one TRM and Integrated Part Load Value (IPLV) is referred to in two other TRMs. The COP is defined at the ratio of heat removed compared to the energy input of the chiller. IPLV is the average power input (kW/ton) at 100%, 75%, 50%, and 25% loads. One TRM permits the option of using kW/ton, IPLV calculations for water cooled chillers and uses EER in air-cooled chiller calculations.

Demand savings are calculated using the same formula without the annual operating hours and the inclusion of summer demand coincidence factors as required. Subscripts of s (summer) or c (cooling) are used to identify seasonal savings values. One TRM includes a default 80% load factor (LF) in the equation. A second utility uses a fixed load factor for air-cooled chillers and analyzes water cooled units using according to a range of load factors. This de-rates the total cooling load by 20%. All other TRMs use 100% of chiller capacity to achieve savings.

Two states use single fixed annual operating hours for all systems and two states require site specific annual operating hours. A fifth utility utilizes a fixed EFLH based upon size, type, and efficiency of the unit. The remaining TRMs use annual operating hours obtained from lookup tables that provide operating diversity by facility type or weather region.

The algorithm is simple and provides a concise and accurate estimation of prescriptive savings. Savings factors in the equation vary across the TRMs. States with fixed annual operating hours provide little diversity in operation. The delta efficiency calculations all provide a difference between base and installed equipment.

Comparative Tables of Savings Assumptions

Table 27 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for chiller energy and demand savings. Italicized values are stated in the program documentation but not substantiated with sources for the estimates themselves.

Table 27: C&I Chiller Savings Assumptions

State	Utility	Application	Applicable Technologies	Eligible Unit Size	Savings Estimation Method	Base Efficiency	Minimum Installed Efficiency	Annual Energy Savings	Load Factor	Diversity Factor	Summer Demand Impact	Winter Demand Impact	Annual Hours
MA	NGRID	Design 2000+	Air-cooled chillers	≥ 20 tons and ≤300 tons	Calculated	9.56 to 9.8 EER	*10.2 EER*	tons x ΔkW/ton x EFLH	72.0%	N/A	*100.0%*	*0.0%*	698 EFLH
MA	NGRID	Design 2000+	Water-cooled, reciprocating, screw Chillers	≥ 70 tons and <150 tons	Calculated	0.813 kW/ton	*0.74 kW/ton*	tons x ΔkW/ton x EFLH	88.0%	N/A	*100.0%*	*0.0%*	1086 EFLH
MA	NGRID	Design 2000+	Water-cooled chillers - centrifugal	≥ 30 tons and <150 tons	Calculated	0.651 to 0.79 kW/ton	*0.65 to 0.75 kW/ton*	tons x ΔkW/ton x EFLH	88.0%	N/A	*100.0%*	*0.0%*	1086 EFLH
MA	NGRID	Design 2000+	Water-cooled chillers - centrifugal	≥ 150 tons and <300 tons	Calculated	0.633 kW/ton 0.57 kW/ton IPLV	*0.61 kW/ton 0.51 kW/ton IPLV*	tons x ΔkW/ton x EFLH	88.2% kW/ton 82.3% IPLV	N/A	*100.0%*	*0.0%*	1086 EFLH kW/ton 1038 EFLH IPLV
MA	NGRID	Design 2000+	Water-cooled chillers	≥ 300 tons and <1000 tons	Calculated	0.576 kW/ton 0.52 kW/ton IPLV	*0.56 kW/ton 0.51 kW/ton IPLV*	tons x ΔkW/ton x EFLH	76.2% kW/ton 76.5% IPLV	N/A	*100.0%*	*0.0%*	1620 EFLH kW/ton 2066 EFLH IPLV

State	Utility	Application	Applicable Technologies	Eligible Unit Size	Savings Estimation Method	Base Efficiency	Minimum Installed Efficiency	Annual Energy Savings	Load Factor	Diversity Factor	Summer Demand Impact	Winter Demand Impact	Annual Hours
MA	NGRID	Design 2000+	Water-cooled screw chiller	≥ 150 tons and <300 tons	Calculated	0.718 kW/ton 0.646 kW/ton IPLV	*0.61 kW/ton 0.51 kW/ton IPLV*	tons x ΔkW/ton x EFLH	88.2% kW/ton 82.3% IPLV	N/A	*100.0%*	*0.0%*	1086 EFLH kW/ton 1038 EFLH IPLV
MA	NSTAR	Construction Solutions	Air-cooled chillers	≥ 30 tons and <300 tons	Prescriptive	1.26 kW/ton	10.2 IPLV	tons x ΔkW/ton x FLH	N/A	N/A	Variable by facility type	Variable by facility type	*495 to 3653 FLH*
MA	NSTAR	Construction Solutions	Water-cooled centrifugal chillers	≥ 30 tons and <1000 tons	Prescriptive	0.58 to 0.79 kW/ton	0.51 to 0.60 IPLV	tons x ΔIPLV x FLH	N/A	N/A	Variable by facility type	Variable by facility type	*496 to 3653 FLH*
MA	NSTAR	Construction Solutions	Water-cooled screw/scroll chillers	≥ 30 tons and <800 tons	Prescriptive	0.64 - 0.65 kW/ton	0.51 to 0.63 IPLV	tons x ΔIPLV x FLH	N/A	N/A	Variable by facility type	Variable by facility type	*497 to 3653 FLH*
ME	All	New Construction or Retrofit	Small chillers	<50 Tons	Calculated	Not specified	Not specified	tons x Δpeak efficiency x EFLH	N/A	N/A	100.0%	0.0%	*800 hours*
NJ	All	New Construction or Retrofit	Air cooled chillers	<150 tons	Calculated with default hours	*1.256 kW/ton*	*ARI Variable*	tons x ΔkW/ton x EFLH	N/A	N/A	*67.0%**	*67.0%**	*1360 hours*
NJ	All	New Construction or Retrofit	Water cooled chillers	All	Calculated with default hours	*0.577 - 0.706 kW/ton*	*ARI Variable*	tons x ΔkW/ton x EFLH	N/A	N/A	*67.0%**	*67.0%**	*1360 hours*
NY	All	New Construction or Retrofit	Air-cooled chillers	All	Calculated with default hours	*3.05 avg COP*	*3.36 avg COP*	tons x LF x ΔCOP x CLH	*80%*	*100%*	*80.0%*	*0.0%*	*630 to 2812 hours*

State	Utility	Application	Applicable Technologies	Eligible Unit Size	Savings Estimation Method	Base Efficiency	Minimum Installed Efficiency	Annual Energy Savings	Load Factor	Diversity Factor	Summer Demand Impact	Winter Demand Impact	Annual Hours
NY	All	New Construction or Retrofit	Water-cooled reciprocating	All	Calculated with default hours	*5.05 avg COP*	*5.56 avg COP*	tons x LF x ΔCOP x CLH	*80%*	*100%*	*80.0%*	*0.0%*	*630 to 2812 hours*
NY	All	New Construction or Retrofit	Water-cooled screw/scroll	All	Calculated with default hours	*5.2 to 6.15 avg COP*	*4.45 to 5.5 avg COP*	tons x LF x ΔCOP x CLH	*80%*	*100%*	*80.0%*	*0.0%*	*630 to 2812 hours*
NY	All	New Construction or Retrofit	Water-cooled centrifugal chillers	All	Calculated with default hours	*5.25 to 6.4 avg COP*	*5.0 to 6.1 avg COP*	tons x LF x ΔCOP x CLH	*80%*	*100%*	*80.0%*	*0.0%*	*630 to 2812 hours*
VT	All	New Construction or Retrofit	Air-cooled chillers with and without condenser	All	Calculated	*2.5 - 3.1 IPLV*	*2.5 - 3.1 IPLV*	tons x ΔIPLV x FLH	N/A	N/A	80.8%	1.7%	Site Specific
VT	All	New Construction or Retrofit	Water-cooled reciprocating	All	Calculated	*3.9 IPLV*	*4.65 IPLV*	tons x ΔIPLV x FLH	N/A	N/A	80.8%	1.7%	Site Specific
VT	All	New Construction or Retrofit	Water-cooled screw and scroll	All	Calculated	*3.9 - 5.3 IPLV*	*4.5 - 5.6 IPLV*	tons x ΔIPLV x FLH	N/A	N/A	80.8%	1.7%	Site Specific
VT	All	New Construction or Retrofit	Water -cooled centrifugal	All	Calculated	*3.9 - 5.3 IPLV*	*5.0 - 6.1 IPLV*	tons x ΔIPLV x FLH	N/A	N/A	80.8%	1.7%	Site Specific

* New Jersey demand calculations do not have seasonal heating/cooling or summer/winter factors or modifiers. The TRM notes a single 67% peak coincidence factor. This was applied to both winter and summer periods.

This presentation outlines the similarities and differences of the commercial and industrial chiller applications across the Forum states with formal TRMs or program savings documentation.

Commentary on Savings Assumptions

There is continuity in calculation methodology and equipment covered in the TRMs. The chiller measure covers a wide range of air and water-cooled equipment. Only one TRM does not differentiate between water and air-cooled chillers. Equipment covered in the remaining TRMs includes reciprocating, centrifugal, screw and scroll compressors.

Equipment size is open ended in two TRMs with no limitations on installed size. One state limits prescriptive measures to units less than 50 tons. The remaining TRMs provide caps on equipment covered in the measure. Two documents cap air-cooled systems at 300 tons and one TRM permits installations up to 150 tons. Two TRMs cap screw equipment at 300 tons and 800 tons respectively. Centrifugal equipment up to 1000 tons is permitted in these TRMs as well.

Equivalent full load hours are used to calculate annual energy savings in all TRMs except one. Calculations in the New York TRM utilize “Cooling Load Hours” (CLH). However, New York will be converting from CLH to equivalent full load hours in a draft TRM that was unavailable at the time of this analysis. Two states calculate savings with fixed annual cooling hours. Two TRMs utilized a range of lookup values for full load cooling hours. One of these states provides equivalent full load hours for eight facility types and six weather regions. The second TRM provides equivalent full load hours for ten building types for a single weather region. Site specific cooling hours are used in the one of the TRMs. The remaining TRM uses fixed equivalent full load hours according to equipment size, type and efficiency to calculate savings

The assumptions reflect a uniform approach to calculations and equipment type across the chiller measures. There is limited discussion and differentiation of efficient chillers and efficient chillers equipped with variable speed drives in the TRMs. Directions for the applicability of VSD equipped units were identified in appendix attachments from program application forms in two documents.

Recommendations

Provide Expanded Diversity. Applicable facility types range from 24 to two with specific air handling criteria. Facility type is unspecified across most TRMs. Default operating hours rely on average operation of multiple facility types across regions. Identifying annual operating hours by selected facility types will provide more accurate estimation of prescriptive savings by capturing the unique operating profiles for each facility.

Capture Loading in Equivalent Full Load Hours. Load factors are included in some calculations to account for average seasonal loading and/or oversized systems. In the case of New York, a load factor was used because average loading is not captured in the Cooling Load Hours as with Equivalent Full Load Hours. By standardizing on EFLH, a load factor term is no longer needed.

Standardize Efficiency. KW/ton is most commonly used to estimate savings. Integrated Part Load Value (IPLV) is a more accurate unit and should be used to calculate savings. KW/ton can refer to peak load of the chiller. Peak load is required to estimate demand savings. The IPLV estimates energy savings according to seasonal performance by accounting for chiller operation at different loads. The load factors described above are essentially used to modify annual operating hours. Using the IPLV estimates savings across the range of modified hours.

3.3.9 C&I HVAC: Unitary/Split

For the purposes of this research study, this category is limited to unitary HVAC installations in commercial and industrial facilities as a prescriptive measure. Unitary equipment covers split system AC, packaged systems, air-source heat pumps, and water source heat pumps. Custom unitary air conditioning applications are covered under C&I Custom Measures in Section 3.3.6 of this report.

Research Sources

Table 28 presents the technical program/measure documentation by state that KEMA reviewed for C&I variable speed drive savings algorithms and assumptions. Any notable issues or exceptions are described below the table.

Table 28: C&I Unitary HVAC Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year C&I Lost Opportunity: Unitary AC & Heat Pumps C&I Lost Opportunity: Water & Ground Source Heat Pumps C&I Retrofit: Cooling HVAC
MA	National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP Design 2000: HVAC Equipment - Packaged A/C, Heat Pump Design 2000: HVAC Equipment - Water Source Heat Pumps, Air C NSTAR eTRAC Savings Calculations Documentation by Technology Construction Solutions: Small HVAC Package Units UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) C&I Lost Opportunity: Unitary AC & Heat Pumps C&I Lost Opportunity: Water & Ground Source Heat Pumps C&I Retrofit: Cooling HVAC
ME	Efficiency Maine Commercial Technical Reference Manual No. 2007-1 Commercial Measures: HVAC Electric Systems
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 C&I Energy Efficient Construction: HVAC Systems
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs C&I Measures: Packaged Air Conditioners C&I Measures: Packaged Air Source Heat Pumps
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Commercial Energy Opportunities: HVAC End Use – Electric HVAC

Prevailing Savings Algorithms

Review of the documentation shows that the prevailing algorithms for energy and demand savings are as follows:

Cooling Calculations:

kWh Saved = (Size in kBtu/hr) x ($1/SEER_{baseline}$ – $1/SEER_{installed}$) x (Full Load Cooling Hours)

kWh Saved = (Size in kBtu/hr) x ($1/EER_{baseline}$ – $1/EER_{installed}$) x (Full Load Cooling Hours)

Heating Calculations:

kWh Saved = (Size in kBtu/hr) x ($1/HSPF_{baseline}$ – $1/HSPF_{installed}$) x (Full Load Heating Hours)

kWh Saved = (Size in kBtu/hr) x ($1/COP_{baseline}$ – $1/COP_{installed}$) x (Full Load Heating Hours)

Demand Calculations:

kW Saved = (Size in kBtu/hr) x ($1/EER_{baseline}$ – $1/EER_{installed}$) x (Coincidence Factor)

Different efficiency units are required for heating and cooling energy savings.

Demand savings are calculated using the same formula without the annual operating hours and the inclusion of summer demand coincidence factors as required. Subscripts of s (summer), c (cooling), or h (heating) are used to identify seasonal savings values.

Commentary on the Algorithm

The approach in calculating energy and demand savings is uniform across the documentation. There are minor differences in some calculation components, but the core approach is consistent and represents an efficient prescriptive savings methodology.

1. One TRM includes an 80% load factor (LF) in the energy savings equation. This de-rates the total cooling load by 20%. Annual savings in the remaining TRM's are based upon 100% of air conditioner and heat pump capacity.

2. Unit "size" varies across the documentation. Two TRM's use tons as the unit size. The remaining calculations use kBtuh as the unit capacity.

3. The consistency in the energy savings algorithm remains consistent as equipment size and type change. Delta efficiency (∆efficiency) refers to the difference in efficiency between the base and installed equipment. The units of efficiency change according to equipment size and type. Seasonal Energy Efficiency Ratio (SEER) is used when calculating savings for heat pumps and AC units that are < 65,000 Btuh in size. Energy Efficiency Ratio (EER) is used to analyze performance of air source all heat pumps and AC units above this size. Water source heat pumps utilize EER to estimate cooling savings and COP (Coefficient of Performance) to determine heating savings. The Heating Seasonal Performance Factor (HSPF) is used in heating savings for air source heat pumps < 65,000 Btuh.

4. Equivalent Full Load Hours (EFLH) and Full Load Hours (FLH) are used to annualize savings. Separate operating hours are identified for heating and cooling modes. The New York TRM calculates savings with "Cooling Load Hours" (CLH). CLH is scheduled to be replaced with equivalent full load hours in the next version of the New York TRM.

The algorithm is simple and provides a concise and accurate estimation of prescriptive savings. Savings factors in the equation vary across the TRMs. States with fixed annual operating hours provide little diversity in operation. The delta efficiency calculations all provide a difference between base and installed equipment.

Comparative Tables of Savings Assumptions

Table 29 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for residential air conditioning energy and demand savings. Italicized values are stated in the program documentation but not substantiated with sources for the values themselves

Table 29: C&I Unitary HVAC Savings Assumptions

State	Utility	Application	Type	Savings Estimation Method	Baseline Efficiency	Minimum Installed Efficiency	Eligible Capacity Range	Operating Hours	Loading Factor	Summer Coinc.	Winter Coinc.
CT	CL&P and UI	New Construction	Unitary & split AC & air source HP	Calculated	9.0 EER- 13 SEER	10 EER- 14 SEER	All	644-1149	N/A	*82%*	N/A
CT	CL&P and UI	Retrofit	Unitary & split AC & air source HP	Calculated	Site specific	10.0 EER- 14 SEER	<360,000 Btuh	644-1149	N/A	*82%*	N/A
CT	CL&P and UI	New Construction	Water source HP	Calculated	11.2-12 EER 4.2 COP	14.0 EER 4.2 COP	All	644-1149	N/A	*82%*	N/A
CT	CL&P and UI	New Construction	Ground water HP	Calculated	16.2 EER 3.6 COP	18.0 EER 3.6 COP	All	644-1149	N/A	*82%*	N/A
CT	CL&P and UI	New Construction	Ground loop HP	Calculated	13.4 EER 3.1 COP	15.0 EER 3.1 COP	All	644-1149	N/A	*82%*	N/A
MA	NGRID	New Construction	Split/Unitary AC	Calculated	10 SEER, 8.6-8.92 EER	14.0 SEER, 9.7-11.5 EER	All	777	N/A	*44%*	*0%*
MA	NGRID	New Construction	Air-To-Air HP	Calculated	10 EER	14.0 SEER, 10.5-11.5 EER 3.2 COP	All	777	N/A	*44%*	*0.0%*
MA	NGRID	New Construction	Water Source Heat Pump	Calculated	11.5 EER	14 EER 4.6 COP	< 135,000 Btuh	1029	0.653	100%	0.0%

State	Utility	Application	Type	Savings Estimation Method	Baseline Efficiency	Minimum Installed Efficiency	Eligible Capacity Range	Operating Hours	Loading Factor	Summer Coinc.	Winter Coinc.
MA	NGRID	New Construction	Ground Water Heat Pump - Closed Loop	Calculated	11.5 EER	15 EER 3.2 COP	< 135,000 Btuh	1029	0.653	100%	0.0%
MA	NGRID	New Construction	Ground Water Heat Pump - Open Loop	Calculated	11.5 EER	18 EER 4.0 COP	< 135,000 Btuh	1029	0.653	100%	0.0%
MA	NSTAR	New Construction	Split/Unitary AC	Calculated	9.2 EER	9.7 EER	≥ 760,000 Btuh	495-3653	N/A	Site specific	Site specific
MA	NSTAR	New Construction	Air-To-Air HP	Calculated	9.0 EER 3.1 COP	10.5 EER 3.2 COP	≥ 240,000 < 360,000 Btuh	495-3653 cool 2250 heat	N/A	Site specific	Site specific
MA	NSTAR	New Construction	Water Source Heat Pump	Calculated	12.0 EER 4.2 COP	14 EER 4.6 COP	< 135,000 Btuh	495-3653 cool 2250 heat	N/A	Site specific	Site specific
MA	NSTAR	New Construction	Ground Water Source Heat Pump - Closed Loop	Calculated	3.1 COP	15 EER 3.2 COP	< 135,000 Btuh	495-3653 cool 2250 heat	N/A	Site specific	Site specific
MA	NSTAR	New Construction	Ground Water Source Heat Pump - Open Loop	Calculated	16.2 EER 3.6 COP	18 EER 4.0 COP	< 135,000 Btuh	495-3653 cool 2250 heat	N/A	Site specific	Site specific
MA	WMECo	New Construction	Unitary & split AC & air source heat pumps	Calculated	9.0 EER-13 SEER	10 EER-14 SEER	All	644-1149	N/A	*82%*	N/A
MA	WMECo	Retrofit	Unitary & split AC & air source heat pumps	Calculated	Site specific	10.0 EER-14 SEER	<360,000 Btuh	644-1149	N/A	*82%*	N/A
MA	WMECo	New Construction	Water source HP	Calculated	11.2-12 EER 4.2 COP	14.0 EER 4.2 COP	All	644-1149	N/A	*82%*	N/A
MA	WMECo	New Construction	Ground water HP	Calculated	16.2 EER 3.6 COP	18.0 EER 3.6 COP	All	644-1149	N/A	*82%*	N/A
MA	WMECo	New Construction	Ground loop HP	Calculated	13.4 EER 3.1 COP	15.0 EER 3.1 COP	All	644-1149	N/A	*82%*	N/A

State	Utility	Application	Type	Savings Estimation Method	Baseline Efficiency	Minimum Installed Efficiency	Eligible Capacity Range	Operating Hours	Loading Factor	Summer Coinc.	Winter Coinc.
ME	All	New Construction & Retrofit	Split & Unitary AC	Calculated	9.5 EER 10.0 SEER	10.0 EER 13.0 SEER	≤ 360,000 Btuh	800	N/A	*100%*	N/A
ME	All	New Construction & Retrofit	Split/Unitary Air-To-Air HP - Cooling	Calculated	9.0 EER 10.0 SEER	10.0 EER 13.0 SEER	≤ 360,000 Btuh	800	N/A	*100%*	N/A
ME	All	New Construction & Retrofit	Unitary Air-To-Air Heat Pump - Heating	Calculated	9.7 - 10.0 SEER	13.0 SEER 11.0 EER	<65,000 Btuh	2200	N/A	N/A	*100%*
ME	All	New Construction & Retrofit	Split & Unitary Air-To-Air Heat Pump - Heating	Calculated	9.0 EER 9.7 SEER	10.0 EER 13.0 SEER	≤ 360,000 Btuh	1600	N/A	N/A	*100%*
ME	All	New Construction & Retrofit	Water Source Heat Pump - Cooling	Calculated	12.0 EER	14.0 EER	≤ 360,000 Btuh	800	N/A	*100%*	N/A
ME	All	New Construction & Retrofit	Water Source Heat Pump - Heating	Calculated	12.0 EER	14.0 EER	≤ 360,000 Btuh	1600 or 2200	N/A	N/A	*100%*
NJ	All	New Construction & Retrofit	Split & Unitary AC	Calculated	9.3 EER 12.0 EER	Site specific	≤ 360,000 Btuh	381	N/A	67%	N/A
NJ	All	New Construction & Retrofit	Air-To-Air Heat Pumps	Calculated	9.0 EER 13.0 SEER	Site specific	≤ 360,000 Btuh	381 cool 800 heat	N/A	67%	N/A
NJ	All	New Construction & Retrofit	Water Source Heat Pumps	Calculated	12.0 EER	Site specific	All	381 cool 800 heat	N/A	67%	N/A
NJ	All	New Construction & Retrofit	Central DX AC	Calculated	11.0 EER	Site specific	All	381	N/A	67%	N/A

State	Utility	Application	Type	Savings Estimation Method	Baseline Efficiency	Minimum Installed Efficiency	Eligible Capacity Range	Operating Hours	Loading Factor	Summer Coinc.	Winter Coinc.
NJ	All	New Construction & Retrofit	Ground Water Source Heat Pumps	Calculated	16.2 EER	Site specific	All	381 cool 800 heat	N/A	67%	N/A
NY	All	New Construction & Retrofit	Unitary AC 1 Phase	Calculated	13.0 SEER	14.0 SEER	<65,000 Btuh	306-1599	Site specific	*80%*	N/A
NY	All	New Construction & Retrofit	Unitary AC 3 Phase	Calculated	8.1 EER-12.0 SEER	8.9 EER-13.0 SEER	All	306-1599	Site specific	*80%*	N/A
NY	All	New Construction & Retrofit	Unitary Heat Pump Cooling 1 Phase	Calculated	13.0 SEER	14.0 SEER	<65,000 Btuh	306-1599	Site specific	*80%*	N/A
NY	All	New Construction & Retrofit	Unitary Heat Pump Cooling 3 Phase	Calculated	8.0 EER 12.0 SEER	8.8 EER 13.0 SEER	All	306-1599	Site specific	*80%*	N/A
NY	All	New Construction & Retrofit	Unitary Heat Pump Heating 1 Phase	Calculated	8.1 HSPF	8.6 HSPF	<65,000 Btuh	239-2182	Site specific	N/A	N/A
NY	All	New Construction & Retrofit	Unitary Heat Pump Heating 3 Phase	Calculated	3.1 COP 3.2 COP	3.3 COP 3.4 COP	All	239-2182	Site specific	N/A	N/A
VT	All	New Construction	Split System AC Air-Cooled	Calculated	13.0 SEER AC 12.1 SEER Evap	12.0 EER 14.0 SEER	< 65,000 Btuh	800	N/A	*80.8%*	*1.7%*
VT	All	New Construction	Single Package AC Air-Cooled	Calculated	13.0 SEER AC 12.1 SEER Evap	11.6 EER 14.0 SEER	< 65,000 Btuh	800	N/A	*80.8%*	*1.7%*
VT	All	New Construction	Split & Single AC Air-Cooled	Calculated	10.3 EER AC 11.5EER Evap	11.5 EER	≥ 65,000 < 135,000 Btuh	800	N/A	*80.8%*	*1.7%*

State	Utility	Application	Type	Savings Estimation Method	Baseline Efficiency	Minimum Installed Efficiency	Eligible Capacity Range	Operating Hours	Loading Factor	Summer Coinc.	Winter Coinc.
VT	All	New Construction	Split & Single AC Air-Cooled	Calculated	9.7 EER AC 11.0 EER Evap	11.5 EER	≥ 135,000 < 240,000 Btuh	800 cool 1600 heat	N/A	*0.03% - heating 80.8% cooling*	*1.7% heating - 57.0% cooling*
VT	All	New Construction	Split & Single AC Air-Cooled	Calculated	9.5 EER AC 11.0 EER Evap	10.0 EER	≥ 240,000 < 760,000 Btuh	800 cool 1600 heat	N/A	*0.03% - heating 80.8% cooling*	*1.7% heating - 57.0% cooling*
VT	All	New Construction	Split & Single AC Air-Cooled	Calculated	9.2 EER AC	9.7 EER	≥ 760,000 Btuh	800 cool 1600 heat	N/A	*0.03% - heating 80.8% cooling*	*1.7% heating - 57.0% cooling*
VT	All	New Construction	Water Source Heat Pumps	Calculated	11.2 EER 4.2 COP	14 EER 4.6 COP	< 17,000 Btuh	2088 cool 2248 heat	N/A	*0.03% - heating 80.8% cooling*	*1.7% heating - 57.0% cooling*
VT	All	New Construction	Water Source Heat Pumps	Calculated	12.0 EER 4.2 COP	14 EER 4.6 COP	≥ 17,000 ≥ 375,000 Btuh	2088 cool 2248 heat	N/A	*0.03% - heating 80.8% cooling*	*1.7% heating - 57.0% cooling*
VT	All	New Construction	Ground Water Source Heat Pumps	Calculated	16.2 EER 3.6 COP	Not specified	< 135,000 Btuh	2088 cool 2248 heat	N/A	*0.03% - heating 80.8% cooling*	*1.7% heating - 57.0% cooling*

This presentation outlines the similarities and differences of the commercial and industrial unitary AC and heat pump applications across the NEEP Forum states with formal TRMs or program savings documentation.

Commentary on Savings Assumptions

The savings assumptions exhibit the same conformity identified in the review of the savings algorithms. The equipment selected for the prescriptive measures include split and unitary air conditioners, air-to-air heat pumps, and water source heat pumps. One TRM extends unit type classifications to include air-cooled, evaporatively-cooled, and water cooled air conditioning units. This equipment is arranged according to type and size and this structure is also common across the TRM's. One state does not include water source heat pumps in their prescriptive measures.

Table 30 presents the minimum efficiency levels for compliance with the Cool Choice program, available in the NSTAR, National Grid, Western Massachusetts Electric, Cape Light Compact, and Unitil service territories. This is typical of equipment and structure across the Prescriptive Programs.

Table 30: Cool Choice Minimum Efficiency Levels

MINIMUM EFFICIENCY LEVELS/INCENTIVE LEVELS						
HVAC UNIT SIZE			LEVEL 1		LEVEL 2	
Tons	Btuh		Minimum SEER/EER for Incentive	Incentive $/Ton	Minimum SEER/EER for Incentive	Incentive $/Ton
Air-Cooled Unitary AC and Split Systems (new condenser and new coil)						
< 5.4	< 65,000	Split	14.0 SEER & 12.0 EER	$125	15.0 SEER & 12.5 EER	$175
< 5.4	< 65,000	Packaged	14.0 SEER & 11.6 EER	$125	15.0 SEER & 12.0 EER	$175
≥ 5.4 to < 11.25	≥ 65,000 to < 135,000		11.5 EER	$80	12.0 EER	$95
≥ 11.25 to < 20	≥ 135,000 to < 240,000		11.5 EER	$80	12.0 EER	$95
≥ 20 to < 63	≥ 240,000 to < 760,000		10.5 EER	$50	10.8 EER	$70
≥ 63	≥ 760,000		9.7 EER	$50	10.2 EER	$70
Air-to-Air Heat Pump Systems						
< 5.4	< 65,000	Split	14.0 SEER & 12.0 EER & 8.5 HSPF	$125	15.0 SEER & 12.5 EER & 9.0 HSPF	$175
< 5.4	< 65,000	Packaged	14.0 SEER & 11.6 EER & 8.0 HSPF	$125	15.0 SEER & 12.0 EER & 8.5 HSPF	$175
≥ 5.4 to < 11.25	≥ 65,000 to < 135,000		11.5 EER & 3.4 COP	$80	12.0 EER & 3.4 COP	$95
≥ 11.25 to < 20	≥ 135,000 to < 240,000		11.5 EER & 3.2 COP	$80	12.0 EER & 3.2 COP	$95
≥ 20	≥ 240,000		10.5 EER & 3.2 COP	$50	10.8 EER & 3.2 COP	$70
Water Source Heat Pumps						
< 11.25	< 135,000		14.0 EER & 4.6 COP	$80	N/A	N/A
Ground Water – Water Source Heat Pump Equipment (Open Loop)						
< 11.25	< 135,000		18.0 EER & 4.0 COP	$150	N/A	N/A
Ground Loop – Water Source Heat Pump Equipment (Closed Loop)						
< 11.25	< 135,000		15.0 EER & 3.2 COP	$150	N/A	N/A

The uniformity in equipment type also extends to the baseline and installed efficiencies. Only minor efficiency variances were noted when comparing similarly sized equipment. All programs have nearly identical base and proposed efficiencies across equipment offerings. Minor differences occur primarily with ground source heat pumps.

Three TRM's cap unitary AC and air source heat pumps to sizes ≤ 360,000 Btuh. Unitary AC and heat pumps for remaining states are either open ended or capped at 760,000 Btuh. Four TRM's do not cap the size of water source heat pumps. Two limit installations to units less than 360,000 Btuh in size. The final TRM lists 135,000 Btuh as the maximum allowed unit.

Equipment can be replaced through any of New Construction, Time-of-Replacement, or Retrofit Programs. Two utilities do not include unitary AC or heat pumps in retrofit programs. One TRM limits retrofit installations to equipment > 360,000 Btuh.

Four TRM's use heating and cooling lookup hours that identifies operation by facility type. New York is unique by providing operating hours for eight facility types and six climate zones. Two utilities provide heating and cooling hours for 60 sites and one TRM utilizes 24 building types to define cooling, but uses a fixed EFLH hour value.

Of the remaining TRM's uses evaluation study information to set operating hours. The remaining three TRM's assign fixed hours to all heating and cooling operation.

In general, the assumptions that support savings algorithms are uniform across all the documents and represent a solid approach to calculating savings. There is significant agreement on what equipment is included in prescriptive measures as well as consensus on base and installed efficiencies.

Recommendations

Expanded Operating Hour Diversity. Operating hours is the most dynamic variable in the savings algorithm. All other variables are closely aligned throughout the TRM's. Two TRM's provide annual operating hours for 60 facility types for use in savings calculations. This provides an excellent range of diversity for unitary AC operation. This operational diversity should be extended to other TRM's with the lookup hours representing average operation across the region. The ability to use site specific operating hours should also be permitted to provide even greater flexibility. The expansion of the default operating hours will provide more accurate prescriptive estimates when site specific values are not available or the values are in doubt. Both equivalent full load heating and cooling hours should be created. The EFLH values should also be expanded to cover equipment type. A ground water source heat pump will have different equivalent full load cooling hours when compared to a unitary AC unit of comparable size. A consistent regional approach can still reflect regional and operational differences: New York should continue using Equivalent Full Load Hours lookup tables by city, but Rhode Island need not.

Include Electric Resistance Savings. Electric resistance elements operate with air-to-air heat pumps. The resistance heating assumes more of the heating load as outside temperatures drop. Two utilities mention the impact of resistance heating and estimate 600 hours of annual operation for the elements. Electric resistance operation is not included in savings estimates. However, these savings should be included when water source heat pumps replace air-to-air systems.

Standardize Cooling Capacity Units. Two TRM's use tons as the capacity unit in savings calculations. Calculations should be standardized and use kBtu as the units capacity. The TRM's use a similar bin structure for handling equipment sizes. However, installed systems can have a wide range of operating capacity. Cooling equipment is nominally reported in half ton increments. Using kBtus estimates savings using the stated system capacity and prevents rounding errors by excluding blanket designations (10 tons) that may cover several different units.

Capture Oversizing in Full Load Hours. Load factors are included in calculations to account for average seasonal loading and/or oversized systems. Common design practice is to identify a cooling or heating load then round up to the next size unit that satisfies the conditioning load. The New York load factor de-rates system capacities by 20% to compensate for this over sizing. KEMA recommends that studies which inform program estimates of equivalent full load hours be leveraged to incorporate over sizing adjustments.

3.3.10 C&I HVAC: Other Measures

The Forum subcommittee for this project elected to limit this Other HVAC category to HVAC control measures such as thermostats, economizers, and dual-enthalpy controls. This category is limited to prescriptive installations in commercial and industrial facilities. Custom HVAC applications are covered under C&I Custom Measures in Section 3.3.6 of this report.

Research Sources

Table 31 presents the technical program/measure documentation by state that KEMA reviewed for C&I HVAC savings algorithms and assumptions. Any notable issues or exceptions are described below the table.

Table 31: C&I Other HVAC Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year C&I Lost Opportunity: Dual Enthalpy Controls
MA	National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP Design 2000: HVAC Building Energy Mgmt Systems - Ventilation Small Building Solutions: Programmable Thermostats UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) C&I Lost Opportunity: Dual Enthalpy Controls
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs Commercial & Industrial Measures: Programmable Setback Thermostat Commercial & Industrial Measures: Air Side Economizer
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Commercial Energy Opportunities: HVAC End Use - Dual Enthalpy Economizer

There were no HVAC controls measures of this nature in the New Jersey TRM or in NSTAR's (Massachusetts) C&I program documentation. The Maine TRM included an agricultural ventilation measure. The New York TRM included one-of-a-kind measures for duct insulation and leakage, close approach cooling tower, and proper refrigerant charge. The Vermont TRM also contained a prescriptive proper HVAC sizing measure. These measures were excluded from analysis per agreed upon definitions and the inability to compare unique measures to other TRM's.

Prevailing Savings Algorithms

Three of the four TRM's utilize a savings factor to estimate prescriptive savings for the dual enthalpy economizer measures. The prevailing algorithm is:

kWh savings = Tons x savings factor

One state further modifies the savings by including a commissioning factor. A factor of 80% is used when no commissioning services are used. 100% of the savings are used when systems are commissioned. The savings are further adjusted by accounting for the efficiency of the cooling system (EER).

No demand savings are calculated in two TRM's. One TRM calculates demand by dividing the prescriptive savings by 4438 default hours. The second document estimates demand savings by applying a kW savings factor to installed tons of cooling.

Programmable thermostats are offered in two TRMs. One covers setback thermostats in the Small Business Solutions Program. The savings are calculated as the difference between base and installed kW/ton times the total tons time site specific annual operating hours. The other offers programmable thermostats to small businesses with unitary AC, heat pumps, boilers, or furnaces. Savings are estimated at 3.6% of annual operation based upon the controlled equipment, annual efficiencies, and default lookup operating hours (239 hours to 2182 hours).

Commentary on the Algorithm

The savings factor annualizes savings. No annual operating hours are required in the formula.

One TRM uses 289 kWh per ton in annualized savings, and a 0.289 kW/ton demand savings calculation, without placing limits on system tonnage. The second estimates annual savings using a 4576 savings factor for units less than 5.4 tons and a 3318 savings factor for units greater than 5.4 tons. The prescriptive dual enthalpy economizer in two TRMs can be installed in conjunction with new CoolChoice approved HVAC units. All other economizers are treated as custom measures.

One utility calculates dual enthalpy savings using a savings factor of 276 kWh/ton. A second TRM estimates savings dual enthalpy economizes when installed on packed units in seven facility types. Savings are estimated at 25 to 202 kWh per ton depending upon facility type. Savings are annualized and no annual operating hours are required.

Comparative Tables of Savings Assumptions

Table 32 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for "Other" HVAC energy and demand savings. Italicized values are stated in the program documentation but not substantiated with sources for the estimates themselves.

Table 32: C&I Other HVAC Savings Assumptions

State	Utility	Application	Applicable Technologies	Eligible Unit Size	Savings Estimation Method	Annual Energy Savings	Demand Savings	Summer Demand Impact	Winter Demand Impact	Annual Hours
CT	All	Lost Opportunity	Dual enthalpy controls	All	kWh/ton savings factor	*276 kWh/ton*	No	N/A	N/A	Annualized in savings factor
MA	NGRID	Design 2000	Dual Enthalpy Economizer	All	kW/ton and kWh/ton savings factors	289 kWh/ton	0.289 kW/ton	*40.0%*	*0.0%*	EFLH Not defined
MA	NGRID	Small business	Programmable thermostats	> 500 FT2 controlled area	kWh/FT2 savings factor	savings factor condition dependent	No	*0.0%*	*0.0%*	N/A
NY	All	Small commercial new construction or retrofit	Programmable thermostats	AC units, HPs, boilers, furnaces in small buildings.	Calculated	*3.6% of annual heat/cool usage*	No	N/A	N/A	*239 hours to 2182 hours lookup values*
NY	All	Small commercial new construction or retrofit	Air-side economizer [7 facility types]	Packaged RTUs	kWh/ton savings factor	*25 to 202 kWh/ton*	No	N/A	N/A	Annualized in savings factor

State	Utility	Application	Applicable Technologies	Eligible Unit Size	Savings Estimation Method	Annual Energy Savings	Demand Savings	Summer Demand Impact	Winter Demand Impact	Annual Hours
VT	All	New Construction or Retrofit	Dual Enthalpy Economizer	<5.4 tons-no economizer >5.4 tons-dry bulb	kWh/ton savings factor	SF x Tons x OTF/EER	No	0.0%	0.0%	*4439 used to calculate demand only*

Commentary on Savings Assumptions

The dual enthalpy economizer measures are presented in four documents. While the savings approach and calculations are similar, the savings factors used to generate the annual savings vary widely and show little uniformity across the TRMs. Savings of 25 kWh/ton are linked with light industrial buildings in one TRM. Another TRM assigns a savings factor of 4576 for fixed damper units that are less than 5.4 tons in size. The magnitude of the difference between the high and low savings factors says that dual enthalpy economizer on a 5-ton unit in one location will yield significantly more savings for the same measure installed in at another location. The remaining savings factors fall between these values or are not defined.

The sources for the savings factors were reviewed. The Connecticut TRM refers to DOE-2 simulations across broad sections of building types and sizes. The New York TRM states that savings factors are derived from DOE-2 simulations of prototypical small commercial buildings using TMY3 long-term average weather data. The Vermont TRM savings factor is derived from Burlington, Vermont building simulations and Burlington bin weather data. In no cases did the TRMs include output from simulation models, so it is not possible to compare or comment on accuracy or relevance.

The review of the programmable thermostat measure found the factors driving the savings as nebulous as the dual enthalpy economizer measure. Savings in New York State are calculated using the tonnage of the AC unit or kBtu capacity of the heating systems, rated heating and cooling load factors, system efficiencies adjusted for distribution efficiency, heating/cooling load hours, and heating and cooling savings factors. The energy savings factor is described as the “the ratio of the energy savings resulting from installation of a programmable setback thermostat to the annual cooling energy”. The other TRM calculates programmable thermostat savings using the site specific area of the conditioned space and a kWh/SQFT savings factor. No supporting documentation or references are provided that explain the relationship between the kW reduction and installation of the programmable thermostat.

Recommendations

Consistent Simulation Modeling. The lack of reliable source documentation makes it difficult to compare savings assumptions and state what variables are the most accurate and reliable. A wide range of savings assumptions were noted when reviewing the dual enthalpy economizer measure. In terms of methods, one study based savings upon DOE-2 modeling while the other program relied upon spreadsheet weather bin modeling. Given the lack of uniformity between the models, assumptions, and savings factors, more measurement-based research is warranted to improve consensus and confidence of economizer savings across the Forum region.

3.3.11 C&I Lighting (New Construction)

This category encompasses commercial and industrial lighting in new construction programs. Commercial and industrial retrofit lighting is discussed in Section 3.3.12.

Research Sources

Table 33 presents the technical program/measure documentation by state that KEMA reviewed for C&I new construction lighting savings algorithms and assumptions.

Table 33: C&I New Construction Lighting Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year 2.1.1 C&I Lost Opportunity Standard Lighting
MA	National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP D2 LIGHT: Interior Lighting (Fluorescent, CF, LED Exits, HID), Controls (Occupancy Sensors, Daylight Dimming) NSTAR eTRAC Savings Calculations Documentation by Technology Lighting – BS & CS Controls Lighting – CS Fixtures UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) 2.1.1 C&I Lost Opportunity Standard Lighting
ME	Efficiency Maine Commercial Technical Reference Manual No. 2007-1 New Fluorescent Fixtures, Fluorescent Fixtures with Reflectors, Compact Fluorescent, High Efficiency Fluorescent Fixtures, Low Glare H.E. Recessed Fixtures, Pendant Mounted Indirect Fluorescent Fixtures, High Intensity Fluorescent (H.I.F.), Controls for H.I.F. Systems, Remote Mounted Occupancy Sensor, LED Exit Sign
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 C&I Energy Efficiency Construction: Baseline and Code Changes, Lighting Equipment, Prescriptive Lighting, Prescriptive Lighting Savings Table, Lighting Controls
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009 Interior and Exterior Lighting, Interior Lighting Controls
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Commercial Energy Opportunities: Lighting End Use: T8 Fixtures with Electronic Ballast, CFL Fixture, Exterior HID, LED Lighting Systems, LED Exit Sign, Lighting Controls, HID Fixture Upgrade – Pulse Start Metal Halide, CFL Screw-in, Metal Halide Track, “High Performance” T8 Fixtures and Lamp/Ballast Systems, T5 Fluorescent High-Bay Fixture, Lighting Power Density, Electronic Ballast HID Fixtures, T5 Fixtures and Lamp/Ballast Systems

Certain specialty lighting measures or fixture types were excluded from this review due to the impracticality of a comparative analysis across regional TRM documents. These include dairy farm vapor-proof fixtures and halogen infra-red bulbs in the Vermont TRM. LED traffic and pedestrian signals also were excluded from several sources in order for this document to focus on predominant and similar lighting fixtures and controls.

Prevailing Savings Algorithm

Review of the aforementioned documentation shows that the prevailing algorithms for energy and demand savings are as follows:

$$\text{kWh Saved} = (\text{Quantity}_{baseline} \times \text{Watts}_{baseline}) - (\text{Quantity}_{installed} \times \text{Watts}_{installed}) / 1000 \times (\text{Annual Hours})$$

$$\text{kW Saved} = (\text{Quantity}_{baseline} \times \text{Watts}_{baseline}) - (\text{Quantity}_{installed} \times \text{Watts}_{installed}) / 1000 \times (\text{Coincidence Factor})$$

The prevailing algorithms do not employ in-service rates or HVAC interaction, although several entities include such factors. Such variants of the prevailing algorithm are discussed below.

Commentary on the Algorithm

Several entities stipulate the wattage reduction of C&I lighting measures in lookup tables of the proposed/installed high-efficiency fixture and use a common Quantity term. In such cases, one would substitute a ∆Watts or kW/unit term for $(\text{Watts}_{baseline} - \text{Watts}_{installed})$ in the equation above. In those instances where the ∆Watts is stipulated, the unit quantity term remains to scale the demand reduction for the number of fixtures. However, program administrators have expressed a need to maintain discrete baseline and installed quantity terms for installations that are not one-to-one replacements.

Some algorithms employ an in-service rate (ISR) in the gross savings algorithm to represent the percentage of rebated units that actually get used, while others either presume 100% installation rate or account for ISR in a net savings adjustment. The ISR term is less prevalent in the commercial/industrial sector than for residential lighting measures, and most utilities in the region either exclude ISR or assume it to be 100%.

Comparative Tables of Savings Assumptions

Table 34 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for C&I new construction lighting energy and demand savings.

Table 34: C&I New Construction Lighting Savings Assumptions

State	Utility	Technology	Baseline Fixture	Gross kW Savings	Operating Hours	Lookup Type	Gross kWh Savings	In-Service Rate	HVAC Interaction	Summer Coinc.	Winter Coinc.
CT	CL&P and UI	Any C&I lighting (w/ LPD 10% below baseline)	Ashrae 90.1-2004 LPD Tables	Calculated	*1949-7674*	By building type	Calculated	N/A	Yes	38-77%	48-90%
CT	CL&P and UI	Controls	Uncontrolled systems	Calculated	*1949-7674*	By building type	Calculated	N/A	Yes	2-28%	7-30%
MA	NGRID	Fluorescent, CFLs, HID, LED Exit	Lookup Table	Stipulated	Site-specific	N/A	Calculated	100%	Yes	88%	58%
MA	NGRID	Controls (OccSens and Dimming)	Uncontrolled systems	Stipulated	Site-specific	N/A	Calculated	100%	Yes	15-30%	0-19%
MA	NSTAR	Fluorescent, CFLs, HID, LED Exit	Lookup Table	Calculated	Site-specific	N/A	Calculated	N/A	Yes	Unclear	Unclear
MA	NSTAR	Controls (OccSens and Dimming)	Uncontrolled systems	Calculated	Site-specific	N/A	Calculated	N/A	Yes	Unclear	Unclear
MA	NSTAR	Performance Lighting	Ashrae 90.1-2004 LPD Tables	Calculated	Site-specific	N/A	Calculated	N/A	Yes	Unclear	Unclear
MA	WMECo	Any C&I lighting (w/ LPD 10% below baseline)	Ashrae 90.1-2004 LPD Tables	Calculated	1949-7674	By building type	Calculated	N/A	Yes	38-77%	48-90%
MA	WMECo	Controls	Uncontrolled systems	Calculated	1949-7674	By building type	Calculated	N/A	Yes	2-28%	7-30%
ME	All	T5s, HPT8s, CFLs	Incandescent (for CFLs), T12s	Calculated	1270-5010	Site-specific or by bldg	Calculated	Unclear	No	17%	100%

State	Utility	Technology	Baseline Fixture	Gross kW Savings	Operating Hours	Lookup Type	Gross kWh Savings	In-Service Rate	HVAC Interaction	Summer Coinc.	Winter Coinc.
			or T8s			type					
ME	All	LED Exit	Incandescent or fluorescent sign	Calculated	1270-5010	Site-specific or by bldg type	Calculated	Unclear	No	100%	100%
ME	All	Controls	Uncontrolled systems	Calculated	1270-5010	Site-specific or by bldg type	Calculated	Unclear	No	Unclear	Unclear
NJ	All	Fluorescents, Exits, LEDs, MH, Controls	Most efficient T-12/MAG equivalent	Calculated	2289-7000	By building type	Calculated	N/A	Yes	35-90%	35-90%
NY	All	Lighting that provides the required illumination at reduced input power	Local energy code	Calculated	1952-7674	By building type	Calculated	N/A	Yes	100%	100%
NY	All	Controls	Uncontrolled systems	Calculated	1952-7674	By building type	Calculated	N/A	Yes	100%	100%
VT	All	T8, HPT8, T5, CFL fixture, MH, Specialty lighting	Lookup	Stipulated	2080-5010	Building type <10,000 FT^2	Calculated	90-98%	Yes	69-93%	36-47%
VT	All	Exterior HID	Lookup Table	Stipulated	3338	Building type <10,000 FT^2	Calculated	98%	No	37%	70%
VT	All	Controls	Uncontrolled systems	Calculated	2080-5010	Building type <10,000 FT^2	Calculated	98%	Yes	69-93%	36-47%

While somewhat consistent with regard to the lighting technologies that are offered, this presentation elucidates some of the inconsistencies amongst the C&I new construction lighting assumptions and savings methods across the Forum states with formal TRMs or program savings documentation.

Commentary on Savings Assumptions

With regard to the programs and measures offered for commercial and industrial new construction lighting, the savings equations and assumptions are reasonably compatible. The primary distinctions involve baseline fixture assignments, hours of use assumptions, and the inclusion of in-service rates in the gross savings algorithms. In perhaps half of the instances are HVAC interactive effects considered for gross savings, and seasonal coincidence factors vary considerably.

While all technical documents take care to clearly define the allowable baseline wattages for C&I new construction lighting, the approach and ultimate source of the baseline source data varies from utility to utility. Connecticut and Western Massachusetts reference ASHRAE Lighting Power Density (LPD) tables explicitly, and NSTAR's performance lighting application seems to source the same ASHRAE LPD data. Other utilities have compiled lookup tables that prescribe the installed and allowable baseline wattage for a given energy-efficient lighting fixture. Such tables are developed either via a wattage multiplier, "standard practice" fixtures, or on the basis of equivalent lumen output.

There are two distinct camps with regard to lighting operating hours. Given that these are new construction lighting installations, most programs prescribe lighting hours-of-use from lookup tables by building type. Such estimates typically are based upon lighting-logger studies or other regional research on lighting hours-of-use. Some programs use site-specific lighting hours, presumably estimated by the lighting design team or others involved in the project. Maine and Vermont take a middle-ground approach, using site-specific hours when available, otherwise defaulting to lighting hour lookup tables by building type.

As stated earlier, documentation suggests that in-service rate is less significant in the C&I market. Amongst TRMs reviewed, only Vermont uses an ISR below 100% for C&I lighting measures. In states such as CT and MA, installation rate ends up being reflected in the gross evaluated realization rate, not an explicit ISR value.

With a few notable exceptions, most utilities/states incorporate HVAC interaction into gross savings for C&I lighting measures. National Grid and NSTAR quantify these effects via impact evaluation, while Maine's treatment of HVAC interaction is unclear.

Finally, coincidence factors for lighting measures – new construction and retrofit alike – vary by considerably. Across regional lighting programs, C&I coincidence factors are prescribed in a plethora of ways: by end use, by building type, by lighting technology, etc.

Recommendations

Stipulated versus Calculated. In reality, most of the lighting measures employ calculated demand impacts that reflect the difference between baseline and installed watts per fixture. Items marked as “stipulated” in Table 34 are a minor distinction, indicating that the lookup tables contain a “wattage reduction” term so that the wattage impact is effectively pre-calculated. All kWh energy impacts are calculated using the prevailing savings equation.

Adopt Flexible Hours-of-Use Strategy. Operating hours are likely to be the most contentious issue for C&I lighting measures. As stated before, there are two distinct approaches in the region: lookups by building type and site-specific hours. Technically speaking, the blended approach employed by Vermont and Maine appears to be a logical and reasonable compromise between these two extremes. Site-specific lighting hours could be employed when available and considered to be accurate, but prescriptive lighting hours would default to lookup tables by building type or other relevant dimension.

Use or Lose the In-Service Rate. The majority of *residential* lighting programs reviewed incorporate an in-service rate into estimates of gross savings, but only Vermont employs discrete ISR estimates for prescriptive fixture-by-fixture commercial/industrial lighting measures. It is a valid effect; the only question remains whether to account for it in preliminary or evaluated savings. KEMA recommends dropping the ISR from the C&I lighting algorithm and capturing its effect in the gross evaluated realization rate.

Develop Localized Assumptions. Standardizing on a single algorithm for C&I lighting should be achievable, even if some entities choose to stipulate of assign baseline wattage differently. But given demographic, geographic (longitude and latitude affect lighting hours of use), program maturity, and possibly behavioral differences in lighting usage across the Forum region, it is reasonable for specific states or utilities to pursue localized assumptions for lighting hours and peak coincidence.

Improve Interactive Consistency. Currently, most TRMs address HVAC interaction for lighting measures; however the methods for computing interactive savings are not consistent. There is an opportunity for the region to standardize on an interactive effects approach. This can be an engineering-based interactive methodology or simply agreeing to include localized HVAC interaction factors in the standard C&I lighting algorithm.

3.3.12 C&I Lighting (Retrofit)

This category encompasses commercial and industrial lighting in retrofit programs. Commercial and industrial new construction lighting is discussed in Section 3.3.11.

Research Sources

Table 35 presents the technical program/measure documentation by state that KEMA reviewed for C&I retrofit lighting savings algorithms and assumptions.

Table 35: C&I Retrofit Lighting Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year 3.1.1 C&I R Standard Lighting
MA	National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP EI LIGHT: Interior Lighting (Fluorescent, CF, LED Exits, HID), Controls (Occupancy Sensors, Daylight Dimming) NSTAR eTRAC Savings Calculations Documentation by Technology Lighting – BS & CS Controls Lighting – BS Fixtures UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) 3.1.1 C&I R Standard Lighting
ME	Efficiency Maine Commercial Technical Reference Manual No. 2007-1 High Performance T8 Relamp and Reballast, Fluorescent Fixtures with Reflectors, Compact Fluorescent, High Efficiency Fluorescent Fixtures, Low Glare H.E. Recessed Fixtures, Pendant Mounted Indirect Fluorescent Fixtures, High Intensity Fluorescent (H.I.F.), Controls for H.I.F. Systems, Remote Mounted Occupancy Sensor, LED Exit
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 C&I Energy Efficiency Construction: Lighting Equipment, Prescriptive Lighting, Prescriptive Lighting Savings Table, Lighting Controls
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009 Interior and Exterior Lighting, Interior Lighting Controls
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Commercial Energy Opportunities: Lighting End Use: T8 Fixtures with Electronic Ballast, CFL Fixture, Exterior HID, LED Lighting Systems, LED Exit Sign, Lighting Controls, HID Fixture Upgrade – Pulse Start Metal Halide, CFL Screw-in, Metal Halide Track, “High Performance” T8 Fixtures and Lamp/Ballast Systems, T5 Fluorescent High-Bay Fixture, Lighting Power Density, Electronic Ballast HID Fixtures, T5 Fixtures and Lamp/Ballast Systems

Certain specialty lighting measures or fixture types were excluded from this review due to the impracticality of a comparative analysis across regional TRM documents. These include dairy farm vapor-proof fixtures and halogen infra-red bulbs in the Vermont TRM. LED traffic and pedestrian signals also were excluded from several sources in order for this document to focus on predominant and similar lighting fixtures and controls.

Prevailing Savings Algorithm

Review of the aforementioned documentation shows that the prevailing algorithms for energy and demand savings are as follows:

$$\text{kWh Saved} = (\text{Quantity}_{baseline} \text{ x Watts}_{baseline}) – (\text{Quantity}_{installed} \text{ x Watts}_{installed}) / 1000 \times (\text{Annual Hours})$$

$$\text{kW Saved} = (\text{Quantity}_{baseline} \text{ x Watts}_{baseline}) – (\text{Quantity}_{installed} \text{ x Watts}_{installed}) / 1000 \text{ x } (\text{Coincidence Factor})$$

The prevailing algorithms do not employ in-service rates or HVAC interaction, although several entities include such factors. Such variants of the prevailing algorithm are discussed below.

Commentary on the Algorithm

Some entities stipulate the wattage reduction of C&I lighting measures in lookup tables of the proposed/installed high-efficiency fixture and use a common Quantity term. In such cases, one would substitute a ΔWatts or kW/unit term for $(\text{Watts}_{baseline} – \text{Watts}_{installed})$ in the equation above. In those instances where the ΔWatts is stipulated, the unit quantity term remains to scale the demand reduction for the number of fixtures. However, program administrators have expressed a need to maintain discrete baseline and installed quantity terms for installations that are not one-to-one replacements.

Some algorithms employ an in-service rate (ISR) in the gross savings algorithm to represent the percentage of rebated units that actually get used, while others either presume 100% installation rate or account for ISR in a net savings adjustment. The ISR term is less prevalent in the commercial/industrial sector than for residential lighting measures, and most utilities in the region either exclude ISR or assume it to be 100%.

Comparative Tables of Savings Assumptions

Table 36 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for C&I retrofit lighting energy and demand savings.

Table 36: C&I Retrofit Lighting Savings Assumptions

State	Utility	Technology	Baseline Fixture	Gross kW Savings	Operating Hours	Lookup Type	Gross kWh Savings	In-Service Rate	HVAC Interaction	Summer Coinc.	Winter Coinc.
CT	CL&P and UI	Efficient lighting	Pre-existing	Calculated	*1949-7674*	Site-specific or by bldg type	Calculated	N/A	Yes	38-77%	48-90%
CT	CL&P and UI	Controls	Pre-existing (uncontrolled)	Calculated	*1949-7674*	Site-specific or by bldg type	Calculated	N/A	Yes	2-28%	7-30%
MA	NGRID	Fluorescent, CFLs, HID, LED Exit	Pre-existing	Calculated	Site-specific	N/A	Calculated	100%	Yes	88%	58%
MA	NGRID	Controls (OccSens and Dimming)	Pre-existing (uncontrolled)	Calculated	Site-specific	N/A	Calculated	100%	Yes	15-30%	0-19%
MA	NSTAR	Fluorescent, CFLs, HID, LED Exit	Pre-existing	Calculated	Site-specific	N/A	Calculated	N/A	No	Unclear	Unclear
MA	NSTAR	Controls (OccSens and Dimming)	Pre-existing (uncontrolled)	Calculated	Site-specific	N/A	Calculated	N/A	No	Unclear	Unclear
MA	WMECo	Efficient lighting	Pre-existing	Calculated	*1949-7674*	Site-specific or by bldg type	Calculated	N/A	Yes	38-77%	48-90%
MA	WMECo	Controls	Pre-existing (uncontrolled)	Calculated	*1949-7674*	Site-specific or by bldg type	Calculated	N/A	Yes	2-28%	7-30%
ME	All	T5s, HPT8s, CFLs	Pre-existing	Calculated	1270-5010	Site-specific or by bldg type	Calculated	Unclear	No	17%	100%

State	Utility	Technology	Baseline Fixture	Gross kW Savings	Operating Hours	Lookup Type	Gross kWh Savings	In-Service Rate	HVAC Interaction	Summer Coinc.	Winter Coinc.
ME	All	LED Exit	Pre-existing	Calculated	1270-5010	Site-specific or by bldg type	Calculated	Unclear	No	100%	100%
ME	All	Controls	Pre-existing (uncontrolled)	Calculated	1270-5010	Site-specific or by bldg type	Calculated	Unclear	No	Unclear	Unclear
NJ	All	CFLs, T-8s, T5s, Pulse-start MH, LED	Pre-existing	Stipulated	3677	N/A	Calculated	N/A	No	78%	78%
NJ	All	Controls	Pre-existing (uncontrolled)	Calculated	2289-7000	By building type	Calculated	N/A	Yes	35-90%	35-90%
NY	All	Lighting that provides the required illumination at reduced input power	Local energy code	Calculated	1952-7674	By building type	Calculated	N/A	Yes	100%	100%
NY	All	Controls	Pre-existing (uncontrolled)	Calculated	1952-7674	By building type	Calculated	N/A	Yes	100%	100%
VT	All	T8, HPT8, T5, CFL fixture, MH, Specialty lighting	Lookup	Stipulated	2080-5010	Prescriptive fixture-by-fixture measures	Calculated	90-98%	Yes	69-93%	36-47%
VT	All	Exterior HID	Lookup Table	Stipulated	3338	Prescriptive fixture-by-fixture measures	Calculated	98%	No	37%	70%
VT	All	Controls	Pre-existing (uncontrolled)	Calculated	2080-5010	Prescriptive fixture-by-fixture measures	Calculated	98%	Yes	69-93%	36-47%

While somewhat consistent with regard to the lighting technologies that are offered, this presentation elucidates some of the inconsistencies amongst the C&I retrofit lighting assumptions and savings methods across the Forum states with formal TRMs or program savings documentation.

Commentary on Savings Assumptions

With regard to the programs and measures offered for commercial and industrial retrofit lighting, the savings equations and assumptions are reasonably compatible. The primary distinctions involve hours of use assumptions, and the inclusion of in-service rates in the gross savings algorithms. In perhaps half of the instances are HVAC interactive effects considered for gross savings, and seasonal coincidence factors vary considerably.

Unlike new construction lighting for which allowable baseline wattages tend to be extensively documented, C&I retrofit lighting employs the pre-existing (replaced) fixture as the measure baseline with one exception: Vermont uses stipulated baseline efficiencies for prescriptive fixture-by-fixture commercial lighting measures. Most lighting is treated as custom measures in the Vermont Program. While the various TRMs indicate some differences in the allowable baseline for C&I retrofit lighting, this review focuses upon the savings algorithm and assumptions, not program rules and compliance.

In contrast to new construction installations in which most programs prescribe lighting hours-of-use from lookup tables by building type, retrofit lighting tends to employ site-specific lighting hours. A number of entities take a middle-ground approach, using site-specific hours when available, otherwise defaulting to lighting hour lookup tables by building type.

As stated earlier, documentation suggests that in-service rate is less significant in the C&I market. Amongst TRMs reviewed, only Vermont uses an ISR below 100% for C&I lighting measures. In states such as CT and MA, installation rate ends up being reflected in the gross evaluated realization rate, not an explicit ISR value.

With a few notable exceptions, most utilities/states incorporate HVAC interaction into gross savings for C&I lighting measures. National Grid and NSTAR quantify these effects via impact evaluation, while Maine's treatment of HVAC interaction is unclear.

Finally, coincidence factors for lighting measures – new construction and retrofit alike – vary considerably. Across regional lighting programs, C&I coincidence factors are prescribed in a plethora of ways: by end use, by building type, by lighting technology, etc.

Recommendations

The recommendations for C&I retrofit lighting are highly consistent with those for new construction lighting. The primary distinction between the two measures is the method for defining baseline lighting demand.

Stipulated versus Calculated. In reality, most of the lighting measures employ calculated demand impacts that reflect the difference between baseline and installed watts per fixture. Items marked as “stipulated” in Table 36 are a minor distinction, indicating that the lookup tables contain a “wattage reduction” term so that the wattage impact is effectively pre-calculated. All kWh energy impacts are calculated using the prevailing savings equation, and a calculated savings methodology would facilitate regional consistency better than stipulated savings.

Adopt Flexible Hours-of-Use Strategy. Operating hours are likely to be the most contentious issue for C&I lighting measures. As stated before, there are two distinct approaches in the region: lookups by building type and site-specific hours. Technically speaking, the blended approach employed by Vermont and Maine appears to be a logical and reasonable compromise between these two extremes. Site-specific lighting hours should be employed in retrofit situations whenever available, but it is reasonable for programs to make allowance for default hours-of-use by building type or other relevant dimension.

Use or Lose the In-Service Rate. The majority of *residential* lighting programs reviewed incorporate an in-service rate into estimates of gross savings, but only Vermont employs discrete ISR estimates for fixture-by-fixture prescriptive commercial/industrial lighting measures. It is a valid effect; the only question remains whether to account for it in preliminary or evaluated savings. KEMA recommends dropping the ISR from the C&I lighting algorithm and capturing its effect in the gross evaluated realization rate.

Develop Localized Assumptions. Standardizing on a single algorithm for C&I lighting should be achievable, even if some entities choose to stipulate of assign baseline wattage differently. But given demographic, geographic (longitude and latitude affect lighting hours of use), program maturity, and possibly behavioral differences in lighting usage across the Forum region, it is reasonable for specific states or utilities to pursue localized assumptions for lighting hours and peak coincidence.

Improve Interactive Consistency. Currently, most TRMs address HVAC interaction for lighting measures; however the methods for computing interactive savings are not consistent. There is an opportunity for the region to standardize on an interactive effects approach. This can be an engineering-based interactive methodology or simply agreeing to include localized HVAC interaction factors in the standard C&I lighting algorithm.

3.3.13 C&I Motors

This category is limited to the installation of premium efficient motors in commercial and industrial facilities as a prescriptive measure. Motors installed in conjunction with other measures such as with variable speed drives are not included in this document.

Research Sources

Table 37 presents the technical program/measure documentation by state that KEMA reviewed for the motors savings algorithms and assumptions. Any notable issues or exceptions are described below the table.

Table 37: C&I Motors Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year C&I Lost Opportunity: Motors
MA	National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP Design 2000 Plus and Energy Initiative: Motors NSTAR eTRAC Savings Calculations Documentation by Technology Business Solutions and Construction Solutions: Motors UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) C&I Lost Opportunity: Motors
ME	Efficiency Maine Commercial Technical Reference Manual No. 2007-1 Motors: Efficient Motors.
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 C&I Energy Efficient Construction: Motors
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs Commercial & Industrial Measures: Motors
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Commercial Energy Opportunities: Motor End Use – Efficient Motors

Prevailing Savings Algorithms

The energy and demand savings calculations applied to the installation of premium efficient motors are uniform across all TRM's. The general formula can be summarized as:

$$\text{kWh savings} = \text{HP} \times 0.746 \times (1/\text{Efficiency}_{baseline} - 1/\text{Efficiency}_{installed}) \times \text{load factor} \times \text{annual operating hours} / 1{,}000$$

$$\text{kW savings} = \text{HP} \times 0.746 \times (1/\text{Efficiency}_{baseline} - 1/\text{Efficiency}_{installed}) \times \text{load factor} \times \text{demand factors} / 1{,}000$$

HP refers to the motor horsepower and 0.746 converts the horsepower to kW. The difference in efficiency between the base and installed motors drives the savings. The load factor refers to the load on the motor [the actual work being performed] as operating in the field. Without a load factor, savings would be calculated with all motors operating at 100% load. Annual operating hours refer to the amount of time the motors operate.

The demand savings algorithm excludes operating hours and incorporates demand factors. These multipliers are called coincidence factors that estimate seasonal demand impact of the measure. The same load factors that modify motor operation are used in peak kW calculations.

Commentary on the Algorithm

The savings algorithm is accurate, concise, and generates strong prescriptive savings for efficient motor measures. The same basic savings algorithm is used in all TRM's and most use the same input values. Motor horsepower is the base for the savings calculations. Horsepower is converted to kW using the same conversion factor. The difference between the installed and baseline motor efficiencies drive the demand and energy savings. Load factors modify motor loads to reflect operation in the field and prevent the assumption that all units operate fully loaded continuously. Operating hours annualize the energy savings. This standard approach and formula provides a strong foundation for a common regional approach.

Comparative Tables of Savings Assumptions

Table 38 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for efficient motor energy and demand savings. Italicized values are stated in the program documentation but not substantiated with sources for the estimates themselves.

Table 38: C&I Motors Savings Assumptions

State	Utility	Application	Savings Estimation Method	Baseline Efficiency	Minimum Installed Efficiency	Eligible Unit Size	Operating Hours	Lookup Type	Load Factor	Summer Coinc.	Winter Coinc.
CT	CL&P and UI	New Construction/ Replacement only	Calculated	EPACT 1992	NEMA Premium Effic.	1 HP to 200 HP	*564-7674*	By bldg type and end use	N/A	*73%*	*60-80%*
MA	NGRID	New Construction/ Replacement only	Calculated	EPACT 1992	NEMA Premium Effic.	1 HP to 200 HP	Site specific	N/A	62%	76%	60%
MA	NSTAR	Retrofit and New Construction	Calculated	EPACT 1992	NEMA Premium Effic.	1 HP to 200 HP	Site-specific (min. 2000)	N/A	80%	58%	64%
MA	WMECo	New Construction/ Replacement only	Calculated	EPACT 1992	NEMA Premium Effic.	1 HP to 200 HP	*564-7674*	By bldg type and end use	N/A	*73%*	*60-80%*
ME	All	Retrofit and New Construction	Calculated	EPACT 1992	NEMA Premium Effic.	1 HP to 200 HP	*2000-8374*	Site-specific or lookup by bldg type	*75%*	*100%*	*100%*
NJ	All	Retrofit and New Construction	Calculated	EPACT 1992	NEMA Premium Effic.	Not specified	Com: 2,502 Ind: 4,599	By sector	70-80%	35%	35%
NY	All	Retrofit and New Construction	Calculated	EPACT 1992	NEMA Premium Effic.	1 HP to 200 HP	1120-7666	By bldg type and end use	Site-specific	N/A	80%
VT	All	Market Opportunity and New Construction	Calculated	EPACT 1992	NEMA Premium Effic.	1 HP to 200 HP	2000-8374	Site-specific or lookup by bldg type	75%	0-100% (by type)	0-100% (by type)

Commentary on Savings Assumptions

The savings factors used in the algorithm are consistent across all TRM's. This is due to the reference material each TRM employs to identify equipment type and efficiency.

Motor horsepower is the key savings variable. All TRM's refer to EPACT and NEMA motor tables as the source of motor types and efficiencies. Motor type can be either Totally Enclosed Fan Cooled (TEFC) or Open Drip Proof (ODP). Motors are further defined according to speed 1200 rpm, 1800 rpm, or 3600 rpm. Efficiencies are provided for 19 motor sizes ranging from 1.0 horsepower to 200.0 horsepower for each of the motor types and speeds.

There is little variation in baseline and installed efficiencies because of the common database values. One TRM references EPACT 1992 as the data source, but there are sight variations in efficiency (1.0% to 3.5% greater) in one document. Baseline efficiencies for all other TRM's range from 75.5% for a 1.0 HP TEFC 3600 rpm motor to 95.0% for certain 200 HP motors. Premium efficiencies range from 77.0% to 96.2%. Table 39 and Table 40 outline the standard baseline and installed motor efficiencies:

Table 39: EPACT Baseline Motor Efficiencies

Baseline motor Efficiencies (EPACT 1992)						
	Open Drip Proof			Totally Enclosed Fan Cooled		
HP	1200 rpm	1800 rpm	3600 rpm	1200 rpm	1800 rpm	3600 rpm
1	80.0	82.5	77.5	80.0	82.5	75.5
1.5	84.0	84.0	82.5	85.5	84.0	82.5
2	85.5	84.0	84.0	86.5	84.0	84.0
3	86.5	86.5	84.0	87.5	87.5	85.5
5	87.5	87.5	85.5	87.5	87.5	87.5
7.5	88.5	88.5	87.5	89.5	89.5	88.5
10	90.2	89.5	88.5	89.5	89.5	89.5
15	90.2	91.0	89.5	90.2	91.0	90.2
20	91.0	91.0	90.2	90.2	91.0	90.2
25	91.7	91.7	91.0	91.7	92.4	91.0
30	92.4	92.4	91.0	91.7	92.4	91.0
40	93.0	93.0	91.7	93.0	93.0	91.7
50	93.0	93.0	92.4	93.0	93.0	92.4
60	93.6	93.6	93.0	93.6	93.6	93.0
75	93.6	94.1	93.0	93.6	94.1	93.0
100	94.1	94.1	93.0	94.1	94.5	93.6
125	94.1	94.5	93.6	94.1	94.5	94.5
150	94.5	95.0	93.6	95.0	95.0	94.5
200	94.5	95.0	94.5	95.0	95.0	95.0

Table 40: EPACT Installed Motor Efficiencies

Minimum Motor Compliance Efficiencies						
	Open Drip Proof			Totally Enclosed Fan Cooled		
HP	1200 rpm	1800 rpm	3600 rpm	1200 rpm	1800 rpm	3600 rpm
1	82.5	85.5	77.0	82.5	85.5	77.0
1.5	86.5	86.5	84.0	87.5	86.5	84.0
2	87.5	86.5	85.5	88.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91.0	88.5	91.0	91.7	89.5
10	91.7	91.7	89.5	91.0	91.7	90.2
15	97.7	93.0	90.2	91.7	92.4	91.0
20	92.4	93.0	91.0	91.7	93.0	91.0
25	93.0	93.6	91.7	93.0	93.6	91.7
30	93.6	94.1	91.7	93.0	93.6	91.7
40	94.1	94.1	92.4	94.1	94.1	92.4
50	94.1	94.5	93.0	94.1	94.5	93.0
60	94.5	95.0	93.6	94.5	95.0	93.6
75	94.5	95.0	93.6	94.5	95.4	93.6
100	95.0	95.4	93.6	95.0	95.4	94.1
125	95.0	95.4	94.1	95.0	95.4	95.0
150	95.4	95.8	94.1	95.8	95.8	95.0
200	95.4	95.8	95.0	95.8	96.2	95.4

A load factor is included in savings calculations is all TRMs except one. Load factors are used to modify both energy and demand savings. Few motors operate continuously at 100% load. The load factors are essential in estimating true part load operation. Load factors ranging from 70% to 80% are used as the load modifiers. Two TRM's apply seasonal load factors. A 60% factor is applied to winter cooling loads.

The motor horsepower, conversion factor, difference in efficiencies between the base and installed equipment, and load factors generate the demand savings for the motor. This kW reduction is multiplied by annual operating hours to obtain annual energy savings.

Four TRMs permit site specific operating hours. One TRM uses site specific hours, but applies an hour of use realization rate based on evaluation. Two of these TRM's also provide default lookup hours for 12 facility types and four end uses. Default operation ranges from 2000 to 8374 hours in both TRM's. The default range for the other two TRM's is 2000 hours to 8760 hours.

One TRM categorizes motor operation by commercial use (2502 hours) and industrial use (4599 hours). The remaining three TRM's allocate operation according to facility type. The Connecticut and Western Mass Electric TRM's provide operating hours for 60 facility types and 3 end uses.

New York referenced the Connecticut document as the source for operating hours. That TRM also utilizes the same 60 facility types. Annual operating hours applicable to New York were allocated across the same three end uses.

Recommendations

The efficient motor measure is already close to a regional standard. The availability and uniformity of base and installed motor data has been widely adopted making only minor adjustments necessary to create a regional measure.

Expanded Operating Hour Diversity. New York, Connecticut, and Western Mass Electric provide annual operating hours for 60 facility types and three HVAC end uses. This provides an excellent range of diversity for default motor operation and should be extended to other TRM's with operating hours unique to service territory. TRM's that permit site specific operating hours should continue to do so. The expansion on the default operating hours will provide more accurate prescriptive estimates when site specific values are not available or the values are in doubt. Shared research and operating hour assumptions may help expand efficiency offerings for programs that do not offer non-HVAC prescriptive motors.

Utilize Load Factors. All the TRM's except one utilizes a load factor in the demand and energy savings calculations. The load factor accounts for motor over sizing and prevents the assumption that all motors operate continuously at full load. Typical load factors range from 70% to 80%. Load factors should be developed and used for all regions and TRM's.

3.3.14 C&I Variable Speed Drives

For the purposes of this research study, this category is limited to variable speed drives (VSD) installations in commercial and industrial facilities as a prescriptive measure. Custom VSD applications are covered under C&I Custom Measures in Section 3.3.6 of this report.

Research Sources

Table 41 presents the technical program/measure documentation by state that KEMA reviewed for C&I variable speed drive savings algorithms and assumptions. Any notable issues or exceptions are described below the table.

Table 41: C&I Variable Speed Drives Sources

State	Program/Measure Documentation
CT	UI and CL&P Program Savings Documentation for 2009 Program Year C&I Lost Opportunity: HVAC VFD
MA	National Grid Database Reference of Energy Efficiency Measures (DREEM) 2009 QP Design 2000: VSD for Fan, Pump, and Process Equipment Energy Initiative: VSD for Fan, Pump, and Process Equipment NSTAR eTRAC Savings Calculations Documentation by Technology VSDs UI and CL&P Program Savings Documentation for 2009 Program Year (WMECo) C&I Lost Opportunity: HVAC VFD
ME	Efficiency Maine Commercial Technical Reference Manual No. 2007-1 Motors: Variable Frequency Drives (VFD) Agricultural: Vacuum Pumps with Adjustable Speed Drives Agricultural: Adjustable Speed Drives on Ventilation Fans
NJ	New Jersey Clean Energy Program Protocols to Measure Resource Savings, Dec. 2007 C&I Energy Efficient Construction: Variable Frequency Drives
NY	New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs VFD Pumping Variable Frequency Drive for HVAC Fan Central Air Conditioning
VT	Efficiency Vermont Technical Reference User Manual (TRM) No. 2008-53 Commercial Energy Opportunities: Variable Frequency Drives (VFD) Commercial Energy Opportunities: Variable Frequency Drives (VFD) for Dairy Farms

Prevailing Savings Algorithms

Review of the documentation shows that the prevailing algorithms for energy and demand savings are as follows:

kWh Saved = Motor horsepower x energy savings factor (ESF) x annual operating hours

kW Saved = Motor horsepower x demand savings factor (DSF)

Horsepower is the common unit for the equations. Horsepower is converted to kW by two methods. The first method multiplies the motor horsepower by the 0.746 kW/HP conversion factor. The ESF and DSF are then applied to estimate energy and demand savings. The conversion factor is part of the ESF and DSF in the second calculation scenario. All the prevailing algorithms start with motor horsepower and then do a conversion to kW.

Commentary on the Algorithm

While variable speed drive measures can cover a wide range of equipment, operating profiles, and facility types, the approach to calculating variable speed drive savings was fairly uniform across the TRM's. All algorithms start with the same base structure – *motor horsepower* x *savings factor*. Other modifiers are added throughout the TRM's, but this basic concept is the common starting point.

Four of the TRM's include annual operating hours in the energy savings algorithm. Annual operating hours are provided for 60 facility types in two TRM's, 10 facility types in the third, and for two types in the last.

Annual operation is included in the ESF for the other for TRM's. There is limited operational and savings diversity in measures that annualize operation via the ESF. The ESF is typically a single value that generates savings based only upon motor horsepower. Savings are deemed to be typical for all applications of the measure end use without modification by facility type.

Connecticut and WMECo use brake horsepower as the base for savings calculations. Brake horsepower reflects the percent load of work that is done by the motor as opposed to full nameplate horsepower. New York includes Rated Load Factor in the algorithm to account for partial loading. The TRM describes the load factor as the ratio of motor load at the design flow rate to the nameplate rating. A Parameter Table later recommends a 1.0 RLF.

Energy and demand savings factors typically are one or more values which can include unit conversion (kW/hp), motor loading, motor/drive efficiencies, peak coincidence, and/or operating hours. Some entities use several discrete factors and others may combine them; either way, the fundamental algorithm remains a straight product of motor horsepower times engineering-derived savings factors. While nearly all prescriptive VSD programs in the region follow this high-level approach, diversity in the ranges of savings factors for similar measures varies considerably.

Demand savings share the same methodology and approach as the energy savings without the annual operating component. The DSF can also include coincidence and other modifiers.

In general, while there are significant differences in the modifiers that generate final energy and demand savings, there is an underlining foundation for all prescriptive VSD measures. The prevailing algorithm can provide acceptable energy and demand savings.

Comparative Tables of Savings Assumptions

Table 42 presents a comparative matrix of savings assumptions pertaining to the aforementioned algorithms for C&I Variable Speed Drives energy and demand savings. Italicized values are stated in the program documentation but not substantiated with sources for the values themselves.

Table 42: C&I Variable Speed Drive Savings Assumptions

State	Utility	Application	Type	Savings Estimation Method	Energy Savings Variable	Eligible Capacity Range	Load Factor	Operating Hours	Summer Coinc.	Winter Coinc.
CT	CL&P and UI	New Construction Only	Condenser and cooling tower fans	Brake HP x kW/BHP Savings Factor x Hours	0.092-0.534 kW/BHP	< 7.5 HP	N/A	1119-3180	0.029-0.347 kW/BHP	0.137-0.651 kW/BHP
CT	CL&P and UI	New Construction Only	VAV Fans	Brake HP x kW/BHP Savings Factor x Hours	0.092-0.534 kW/BHP	< 15 HP	N/A	1952-7666	0.029-0.347 kW/BHP	0.137-0.651 kW/BHP
CT	CL&P and UI	New Construction Only	Chilled Water Pumps	Brake HP x kW/BHP Savings Factor x Hours	0.433 kW/BHP	<= 50 HP	N/A	1119-3180	0.299 kW/BHP	N/A
CT	CL&P and UI	New Construction Only	Hot Water Pumps	Brake HP x kW/BHP Savings Factor x Hours	0.092-0.534 kW/BHP	<= 50 HP	N/A	6000	N/A	0.208 kW/BHP
MA	WMECo	New Construction Only	Condenser and cooling tower fans	Brake HP x kW/BHP Savings Factor x Hours	0.092-0.534 kW/BHP	< 7.5 HP	N/A	1119-3180	0.029-0.347 kW/BHP	0.137-0.651 kW/BHP
MA	WMECo	New Construction Only	VAV Fans	Brake HP x kW/BHP Savings Factor x Hours	0.092-0.534 kW/BHP	< 15 HP	N/A	1952-7666	0.029-0.347 kW/BHP	0.137-0.651 kW/BHP
MA	WMECo	New Construction Only	Chilled Water Pumps	Brake HP x kW/BHP Savings Factor x Hours	0.433 kW/BHP	<= 50 HP	N/A	1119-3180	0.299 kW/BHP	N/A

State	Utility	Application	Type	Savings Estimation Method	Energy Savings Variable	Eligible Capacity Range	Load Factor	Operating Hours	Summer Coinc.	Winter Coinc.
MA	WMECo	New Construction Only	Hot Water Pumps	Brake HP x kW/BHP Savings Factor x Hours	0.092-0.534 kW/BHP	<= 50 HP	N/A	6000	N/A	0.208 kW/BHP
MA	NGRID**	New Construction	Chilled Water Pump Heating HW Pump	HP x kWh/HP Savings Factor	*CHW Pump 0.051 kW/HP HHW Pump 0.248 kW/HP*	<= 20 HP	N/A	N/A	9%-100% N/A HHWP	100% N/A CHWP
MA	NGRID**	New Construction	Supply Fan, Return/Exhaust Fan	HP x kWh/HP Savings Factor	*Supply Fan 0.338 kW/HP RF/Exh Fan 0.327 kW/HP*	<= 20 HP	N/A	N/A	9%-100%	100% N/A CHWP
MA	NGRID**	New Construction	Water Source Heat Pump Circulating Pump	HP x kWh/HP Savings Factor	*0.199 kW/HP*	<= 20 HP	N/A	N/A	9%-100%	100% N/A CHWP
MA	NGRID**	Retrofit	Water Source Heat Pump Circulating Pump	HP x kWh/HP Savings Factor	*0.207 kW/HP*	<=100 HP	N/A	N/A	83%-100%	100%
MA	NGRID**	Retrofit	Supply Fan, Return/Exhaust Fan	HP x kWh/HP Savings Factor	*Supply Fan 0.347 kW/HP RF/Exh Fan 0.335 kW/HP*	<=100 HP	N/A	N/A	83%-100%	100%
MA	NGRID**	Retrofit	Chilled Water Pump Heating HW Pump	HP x kWh/HP Savings Factor	*CHW Pump 0.054 kW/HP HHW Pump 0.256 kW/HP*	<= 100 HP	N/A	N/A	83%-100% HHWP N/A	100% N/A CHWP
MA	NGRID**	Retrofit	Process Cool Pumps & Exhaust Fans <= 50 HP	HP x kWh/HP Savings Factor	*Process cool 0.099 kW/HP Process exh 0.109 kW/HP*	<= 50 HP	N/A	N/A	100%	0%
MA	NGRID**	Retrofit	CTF <= 30 HP	HP x kWh/HP Savings Factor	*0.114 kW/HP*	<= 30 HP	N/A	N/A	100%	0%
MA	NGRID**	Retrofit	Boiler Draft Fan	HP x kWh/HP Savings Factor	*0.325 kW/HP*	<= 75 HP	N/A	N/A	95%	100%
MA	NSTAR	New Construction	Cooling Tower Fan	∑(HP x LF x hrs) of 11 load bins	Facility type End use	<= 7.5 HP	*Variable**	*Variable**	*0%-100%*	*0%-100%*

State	Utility	Application	Type	Savings Estimation Method	Energy Savings Variable	Eligible Capacity Range	Load Factor	Operating Hours	Summer Coinc.	Winter Coinc.
MA	NSTAR	New Construction	VAV Fans	∑(HP x LF x hrs) of 11 load bins	Facility type End use	<= 25 HP	*Variable**	*Variable**	*0%-100%*	*0%-100%*
MA	NSTAR	New Construction	EXF, CHWP, Boiler Feed Pump, HHWP, MUA Fan, SF, RF, HP Loop Pump	∑(HP x LF x hrs) of 11 load bins	Facility type End use	5-50 HP	*Variable**	*Variable**	*0%-100%*	*0%-100%*
MA	NSTAR	Retrofit	EXF, CHWP, Boiler Feed Pump, HHWP, MUA Fan, SF, RF, HP Loop Pump	∑(HP x LF x hrs) of 11 load bins	Facility type End use	5-100 HP	*Variable**	*Variable**	*0%-100%*	*0%-100%*
ME	All	New Construction or Retrofit	Supply, Return, Exhaust Fans, Chilled Water and Boiler Feed Water Pump	HP X kWh/HP Savings Factor	745-1746 kWh/HP	< 20 HP	N/A	N/A	0.098-0.263 kW/HP	0.098-0.263 kW/HP
NJ	All	New Construction Only	Chilled Water Pumps	HP X kWh/HP Savings Factor	1360 kWh/HP	All	N/A	N/A	Site specific	Site specific
NJ	All	New Construction Only	VAV Fans	HP X kWh/HP Savings Factor	1653 kWh/HP	All	N/A	N/A	Site specific	Site specific
NY	All	New Construction or Retrofit	Secondary chilled water pumping loops	HP x kW/BHP Savings Factor x LF x Hours	0.599 - 0.744 kW/HP	All	*Site or 100%*	5361 - 8760	100%	100%
NY	All	New Construction or Retrofit	VAV air handler supply fan	HP x kW/BHP Savings Factor x LF x Hours	0.248 - 0.647 kW/HP	All	*Site or 100%*	5180 - 6211	100%	100%
VT	All	New Construction or Retrofit	Supply, Return, Exhaust Fans, Chilled Water and Boiler Feed Water Pumps	HP X kWh/HP Savings Factor	745-1746 kWh/HP	< 10 HP	N/A	N/A	0.098-0.263 kW/HP	0.098-0.263 kW/HP

*NSTAR computes savings across eleven load bins (0%-100% inclusive in 10% increments). These savings factors also vary by 10 facility and 9 fan/pump types.
Applications that exceed the Eligible Capacity Range are analyzed as Custom Measures

**NGRIDs savings factors have been calculated using a theoretical engineering bin model. Load Factor and Operating Hours Assumptions are internal to the model.

This presentation outlines the similarities and differences of the commercial and industrial variable speed drive applications across the Forum states with formal TRMs or program savings documentation. VSD's ranks amongst the most complex and diverse prescriptive measures in regional technical reference manuals.

Commentary on Savings Assumptions

In general, the C&I variable speed drive analyses begin with motor horsepower and then calculate savings using a diverse range of lookup values and modifiers.

Variable speed drives are applicable across a wide range of systems and facility types. Several equipment end uses are repeated throughout the TRM's. These include:

1. Chilled Water Pumps
2. Heating Hot Water Pumps
3. Boiler Feed Water pumps
4. Heat Pump Loop Pumps
5. Supply Fans
6. Return Fans
7. Exhaust Fans
8. Cooling Tower Fans

Other equipment covered varies across the documentation. The New York TRM limits pumping applications to secondary chilled water pumps. National Grid is one of the few utilities offering prescriptive variable speed drives for process measures as shown in Table 43.

Table 43: National Grid VSD Equipment Types

End-Use Equipment Types
1. REF = HVAC RETURN OR EXHAUST FAN 2. SF = HVAC SUPPLY FAN 3. PE = PROCESS EXHAUST AND MAKEUP AIR FAN 4. HWP = HEATING HOT WATER PUMP 5. PCP = PROCESS COOLING PUMP 6. HPP = WSHP CIRCULATION PUMP 7. BDF = BOILER DRAFT FAN 8. CT = COOLING TOWER FAN 9. WSP = WATER SUPPLY OR WASTEWATER PUMP 10. CWP = CHILLED WATER DISTRIBUTION PUMP 11. FWP = BOILER FEED WATER PUMP

Differences in equipment type within each end use are also the source of variations of the savings factors. In Connecticut's Program Savings Documentation (PSD), savings factors vary according to the fan or pump baseline type shown in Table 44. There are three savings factors, one for kWh, one for summer kW, and one for winter kW. The factors were derived using a temperature bin spreadsheet and typical heating, cooling and fan load profiles.

Table 44: CT Equipment and Fan/Pump Types for VSD Savings Factors

End-Use Equipment Types	Fan or Pump Types
1. Condenser Fan 2. Cooling Tower Fan 3. VAV Fans 4. Chilled Water Pump 5. Hot Water Pump	1. AF/BI = Air foil / backward incline 2. AF/BI IGV = AF/BI Inlet guide vanes 3. FC = Forward curved 4. FC IGV = FC Inlet guide vanes 5. CHWP = Chilled Water Pump 6. HWP = Hot Water Pump

NSTAR employs the most complex prescriptive VSD method by utilizing an eleven-bin analysis based on percentage of flow. Equipment operating hours are assigned to each bin according to the selection of building type; likewise, a percentage of full load brake horsepower is assigned to each bin according to the selected equipment type (see Table 45). Percent brake horsepower and operating hours are unique for each flow bin according to building and equipment type.

Table 45: NSTAR Equipment and Building Types for VSD Bin Factors

NSTAR End-Use Equipment Types	NSTAR Building Types
1. Building Exhaust Fan 2. Cooling Tower Fan 3. Chilled Water Pump 4. Boiler Feed Water Pump 5. Hot Water Circulating. Pump 6. MAF - Make-up Air Fan 7. Return Fan 8. Supply Fan 9. WS Heat Pump Circulating Loop	1. Office 2. Grocery 3. Retail 4. Restaurant 5. Warehouse 6. Health 7. Hotel/Motel 8. Multi-Family 9. Elementary or High School 10. University or College

While this approach is detailed and provides extensive operational diversity, the foundation of the savings remains *motor horsepower* x *savings factor* x *annual operating hours*. The savings factors in this case are individualized lookup values that are linked to facility and equipment types and are unique to each bin.

Peak demand is also calculated predominantly using lookup modifiers applied to horsepower. New York assumes that the added burden of the variable speed drive will result in greater kW consumption in the post scenario when compared with the baseline. The fans and pumps are operating at 100% design speed plus the power consumed by the variable speed drive. This can also occur in NSTAR cooling tower applications. Adjustment factors for other TRMs assume or apply a load factor of less than 100% summer usage to generate summer kW estimates.

The HP modifiers reflect the unique geographic and demographic structure of the individual utilities. New York provides annual operating hour lookup values for two building types across six specific geographic regions. The Connecticut TRM breaks annual operating hours out according to heating/cooling end use across 60 facility types. NSTAR also uses lookup operating hours in their bin approach.

Recommendations

Standardize Savings Formula. A savings factor applied to motor horsepower is the core of the savings algorithms. Variations of the formula include other load factors or multiple modifiers. If methodological consistency is a regional objective, a choice needs to be made between detailed analyses and simple calculations. A database of energy and/or demand savings factors could be created to represents typical equipment across the region.

Include Annual Operating Hours In Calculations. Half of the TRM's provide a range of default operating hours for use in calculations. Annual operation is annualized in the remainder of the TRM's by the "ESF" savings factor, but this has the consequence of limiting the portability of the method, since most VSD's are installed on equipment with weather-dependent operations. Accordingly, a standardized VSD approach might be best served by kW/hp factor(s) and localized assumptions for operating hours and peak coincidence.

Standardize Equipment Types and Sizes Covered. The various TRMs show that a wide range of equipment and size (motor horsepower) is covered by the variable speed drive application. Eleven types of equipment are covered in one TRM while another list only two applicable types. A common method would benefit from some standardization. There are some applications that might make sense as a prescriptive measure in one state and not in others. A core group of prescriptive measures should be identified that apply across all regions, with other measures being utility/location specific. .

Standardize Facility Types Covered. Similarly, the number of discrete facility types ranges from two to sixty in the Table 42 sources. A common set of facility types would facilitate regional methodological consistency.

Document Measure Exclusions. The TRMs clearly identify motor size and application but do not always document exclusion criteria. For example, the Maine TRM states that eddy current drives, inlet vanes, or other controls should be calculated using custom calculations. Any compliance or exclusion criteria should be clearly documented.

3.4 Part B: Conclusions

Part B of the project involved reviewing and comparing, for a priority set of both electric and gas efficiency measures, existing gross energy and demand savings determination methods, assumptions (e.g. deemed values, effective useful life, and savings calculation input assumptions) and algorithms across the region (and across the U.S. as appropriate).

In hindsight, the Part B: Savings Assumptions effort may have benefited from more specificity with regard to technology and program delivery element within the fourteen measures above. In the case of both residential and C&I lighting, the breadth of technologies (fluorescents, CFLs, HIDs, exterior, etc.) made for lengthy comparative tables which did not always facilitate meaningful comparisons. And some technologies such as residential compact fluorescent lamps (CFLs) can have different savings assumptions under a retail program than under a direct install program. These issues complicated some of the individual program type/measure write-ups and should be considered when interpreting or employing the comparative data.

Some common themes resounded throughout the preceding measure-specific reviews, such as:

Combine Coincidence Factors. Some measure/entities disaggregate the demand factors that are used to derive seasonal coincident peak demand impact from a non-coincident or connected demand impact. Such factors include discrete load, diversity, and coincidence factors. A single, combined factor that reflects local loading, diversity, and coincidence effects would simplify computations and permit “apples to apples” comparison of coincidence factors across states/regions.

Develop Localized Assumptions. While nearly all measures examined herein have potential for regional standardization of savings methods, there are few measures for which savings assumptions or stipulated values are truly portable, i.e. appropriate for use across all markets, geographies, technologies, etc. Just as weather-dependent measures require savings assumptions that reflect typical meteorological conditions, other measures require similar consideration. Regional consistency does not mean adopting identical assumptions; it will be appropriate to develop localized assumptions for hours-of-use and peak coincidence for most measures in order to reflect local characteristics of climate, demographics, and behavior.

Standardize or Expand Dimensions. Depending upon the nature of the measure or savings algorithm, researchers see benefit in some selective standardization or expansion of the breadth of savings assumptions. For instance, residential programs that currently use a single, whole-home estimate of lighting hours-of-use might benefit from expanding to room-level (e.g.

bedroom, kitchen, garage) hours-of-use resolution. Conversely, commercial motor measures with discrete savings assumptions for dozens of facility types might benefit from standardizing on a more manageable set of buildings.

Eliminate or Utilize Loading Factors. For several of the priority measures, one of the recommendations is to eliminate a discrete "loading factor" from the savings algorithm. Also evident in "Combine Coincidence Factors", this recommendation strives to eliminate unnecessary complexity from prescriptive savings algorithms. In principle, all measures employing "Equivalent Full Load Hours" as the time term in the equation should recognize that the EFLH already handles part-loading effects. One technical manual needs to *add* a loading factor to the efficient motors algorithm in the interest of accuracy and consistency.

Stipulate or Calculate. Amongst the more basic priority measures such as lighting, some entities use stipulated savings values. In general, stipulated estimates are in the minority, but the method offers consistent, reasonable, and quick savings estimation for highly standard measures. While a regional consistency effort might necessitate a decision between stipulated or calculated estimates, a compromise seems appropriate for lighting measures. Demand reductions by lighting technology are logical stipulations as inputs, and a consistent algorithm would allow for localized tuning of hours and coincidence for savings impacts. Ultimately, stipulated savings values for lighting should be based upon calculations that include clear assumptions for fixture wattage, hours, in-service rate, coincidence, etc.

The last section of this report, Part C: Guidelines, employs the results of Parts A and B activities to develop a recommended set of guidelines for fourteen priority measures. These broad guidelines were intended to establish the basis for common EM&V methods and levels of rigor to be implemented consistently in the Region.

4. Part C: Guidelines

For Part A: Common EM&V Methods, KEMA performed research and interviews with Forum program administrators to identify and define the range of EM&V methods that are applied in the industry and can serve as guidelines for Forum participants' programs. This effort strived to identify and define common and consistent methods for preliminary (ex-ante) savings, gross and net evaluated (ex-post) savings, measure baseline, life, and persistence, and strategies for dealing with uncertainty/rigor.

In Part B: Savings Assumptions, KEMA performed a technical review of existing documentation on gross energy and demand savings determination methods, assumptions, and algorithms across the region for the priority set of fourteen electric and gas efficiency measures. This effort culminated in comparative tables of commonalities and differences in savings assumptions and algorithms and specific methods recommendations for improving consistency.

This Part C: Guidelines employs the results of Parts A and B activities to develop a recommended set of guidelines for fourteen priority measures. These broad guidelines were intended to establish the basis for common EM&V methods and levels of rigor to be implemented consistently in the Region. These recommendations cover different program and technology types for each of the following:

- Estimating initial/preliminary gross energy and demand savings;
- Calculating gross evaluated energy and demand savings;
- Determining baseline conditions; and
- Determining measure life and persistence.

The first two recommendations are discrete for each of the fourteen electric and gas efficiency measures and contained in Section 4.2: Measure-Specific Guidelines. However, the Part A interviews and research did not support distinct recommendations by measure for the latter two and other important issues. In these instances, recommendations are summarized in the following Section 4.1: Cross Cutting Guidelines.

4.1 Cross Cutting Guidelines

This section presents guidelines for specific aspects of evaluation, measurement and verification practice that apply across the measures selected for the Part A research and are equally appropriate for all current and future measures that may be added to these guidelines.

Within this section we only offer basic guidelines, as defined above. We believe these recommendations are both necessary and sufficient for all current and anticipated uses of EM&V products.

4.1.1 Installation Verification

In the Part A survey, verification was reported for 60% of measures. In the interview context, verification refers to a program implementation process by which in-house staff or contracted inspectors verify the installation of all or a sample of installed measures. For most measures, this "quality control" procedure is performed prior to issuance of an incentive payment. This sort of verification is impractical for some small prescriptive and self-install measures, e.g. residential retail CFLs. In the context of evaluation, verification is a method of assessing impacts without direct measurement, e.g. phone surveys, on-site inspections, etc. Only when paired with measurement does verification become "M&V".

Verification of a sample of installations is highly recommended for all programs and measure categories. Verification incurs a cost, but as system reliability becomes more closely linked to energy efficiency resource performance, this cost provides increasing benefits. Assuming that payment of an incentive or proof of purchase equate to energy savings becomes riskier as the margins for error decrease.

Verification is often limited to projects/measures with the greatest cost and savings. When much is at stake in large projects, it is easier to verify and also justify the cost. However, some measures, such as compact fluorescent lamps, in aggregate can have an equivalent impact if not installed. Anecdotal evidence, and to be honest our own behavior, shows that just because a CFL is in the home does not mean it is saving energy.

Installations should be verified by either a third party or by program administration staff. We emphasize that sampling approaches and regularly scheduled verification studies may be appropriate for some measures/programs instead of continuous verification for the full population. Procedures should be implemented to ensure that differences noted in inspection get reflected in program tracking. A higher verification fraction is recommended in program infancy, very large installations, or following substantive program revisions.

4.1.2 Determining Baseline Conditions

Within each of the measure-specific guidelines below there is a definition for the measure's baseline efficiency, a critical input into the savings calculation. In its simplest formulation, the savings forecast is the difference between what is (the baseline) and what will be (the intended condition). From there it gets more complicated. The baseline for a specific measure is not a single number.

For most measures there will be at least two baselines, one for market-driven choices (often called "lost opportunity" and either replacing equipment that has failed or new installations) and one for discretionary installations (often called retrofit or early retirement). In the first case, the baseline may be a jurisdictional code, a national standard, or the prevailing level of efficiency in the marketplace. For retrofit installations, the efficiency of the existing equipment may be the baseline, but at some point the savings calculation must incorporate changes of the baseline for new installations, e.g. code or market changes. Even at this level of differentiation, the baseline may not be correct.

A prime example of this phenomenon occurs when code is used as a baseline. The assumption that a legal requirement translates into action is foresworn by the full gamut of human behavior, even when there is enforcement to encourage compliance, as with speed limits. In the realm of efficiency, where compliance mechanisms often lag regulation and the "behavior" is much more private, it is even riskier to assume that law is being followed.

As part of the proposed regional guidelines for EM&V, we recommend a regular review of baselines in use to determine and prioritize baseline research on a three to five year cycle. This process is critical to achieving, and maintaining, alignment between the conditions as they are and the conditions as they are used in savings calculation.

4.1.3 Determining Measure Life and Persistence

The measure-specific guidelines can be used to determine the savings for a discrete period of time. The capacity savings (kW) are instantaneous and calculated with reference to the maximum load. The energy savings (kWh) are typically presented for the first year. However, most measures last for more than one year. Respondents to the Part A survey reported using a variety of sources for measure life and the related factor of measure persistence.

Comprehensive guidelines should define a process for determining measure life for each measure, and then memorializing both the process and the outcome in comprehensive resources. While any of the methods currently used, e.g. vendor estimates & stipulated value, may be accurate, without structured review and analysis they may misrepresent actual performance. As for baseline conditions above, we recommend a regular review cycle to assure that each measure lifetime assumption is not so old as to be out of date. We do not recommend that a full measure life study be undertaken for each measure every three or five years. Rather, we recommend an intentional process to determine if a study is appropriate.

We found that the temporal factors “persistence” and “in-service rate” were not uniformly used. Some respondents used these factors, some reported them as incorporated in the measure life, and in some cases it was not clear if they were addressed. We recommend that measure life be defined to include these factors if they are deemed necessary by the Forum or by external stakeholders, and that they be considered in the design of measure life research.

4.1.4 Statistical Precision

As discussed in Part A: Section 2.6, the matter of quantifying the statistical precision of a composite domain such as an energy-efficiency portfolio is a complex one, and analytical consultants can assist with this process. One of the practical implications is that the statistical precision for dominant measures/sectors can ‘carry’ ones portfolio, i.e. ensure the portfolio achieves precision targets regardless of the precision in other program areas. In a strictly statistical sense, the level of precision for dominant program areas such as Large C&I Retrofit or Residential Lighting tends to be far more important than the precision of lesser areas such as HVAC tune-ups or ENERGY STAR Appliances. In fact, the statistical precision of ‘minor’ portfolio components can remain immaterial even with assumed ±100% precision.

Program administrators must also consider that statistical precision in impact evaluation is not solely a matter of regulatory and capacity market rules compliance. Statistical precision is an important means of expressing the validity of estimated tracking and evaluation impacts. Further, one must remember that statistical precision often positively correlates with evaluation cost. This is true because sample size increases with statistical precision, and for each sample point that improves statistical precision there is an added burden of evaluation cost (i.e. added travel costs, monitoring equipment, interviews etc.) Despite increased rigor from capacity market rules, sample designs must remain efficient and optimized to achieve appropriate precision at a reasonable cost.

Recommendations: In order to establish and achieve statistical precision objectives in all required/sought dimensions, the following process should be considered:

1. <u>Identify statistical confidence/precision requirements</u>. These should include key requirements (e.g. capacity market specifications) and legacy objectives (e.g. 90/10 for annual energy savings). Also, establish the domain for each requirement, be it the portfolio, program, state, load-zone, etc.

2. Establish your unique precision targets and dimensions. Regulatory and market requirements may offer program administrators either a threshold or a range of confidence intervals and precision. In either case, program administrators may make an independent assessment of the precision targets that are necessary for their particular needs relative to the domain of the evaluation (i.e. sector, program, end use,), their intended use and audience for the evaluation results, and considerations of expected variability and the financial or system impact of varying degrees of uncertainty.
3. Pursue the most challenging target. In most cases, statistical objectives will be multi-pronged, e.g. 80/10 for summer kW, 80/10 for winter kW, and 90/10 for energy kWh. Designing a single sample to meet all objectives can be difficult and is dependent upon the unique population characteristics and expected variability for each parameter. In practice, one often can achieve all objectives by pursuing the element with the greatest variability; for New England large C&I programs, this tends to be the winter coincident demand impact. For example, a recent KEMA large C&I impact evaluation achieved ±10.6% precision for winter kW and ±8.2% precision for summer kW (both at 80% confidence as per ISO New England requirements) and ±4.7% precision at the 90% confidence level.

It is important to note that these confidence/precision requirements are for statistical sampling alone and do not reflect other sources of uncertainty such as measurement error, equipment accuracy, and parameter bias. Most M&V manuals (ISO-NE, PJM, FEMP, ASHRAE) include guidelines for controlling these other sources of error.

4.1.5 Other Sources of Uncertainty and Threats to Validity

Statistical precision gets a lot of attention in efficiency program evaluation. Most evaluators are familiar with error bounds, confidence intervals, and relative precision, the most commonly used techniques for reporting statistical precision. However, many do not realize that statistical precision can be misleading if there is bias or non-statistical error in the underlying data. Bias can be hard to identify and extremely difficult to quantify, but it ought not be ignored or dismissed. One must remain vigilant for sources of error such as response bias, hand-picked (or excluded) sample projects, and measurement error. The California Evaluation Framework offers some good advice on mitigating bias and strengthening validity:

"In a high quality evaluation, those implementing the study would strive to mitigate the risk of bias and to honestly report any circumstances about the study that might increase the likelihood of bias. Unfortunately, it usually takes extra time and money to reduce the risk of bias, and the usual measures of the statistical precision of the results may not be improved at all. For example, in order to reduce the risk of non-response bias in a telephone survey, a substantial investment may be needed in more extensive training for the surveyors, more call backs, and perhaps to offer a financial incentive to each respondent. It may be tempting to accept a higher non-response rate and divert these resources to a larger sample size since this strategy will almost certainly give a narrower confidence interval. This strategy can seriously compromise the integrity of a study. To make appropriate judgments in planning and executing sound evaluation studies and in interpreting their results, evaluators, reviewers, and those using evaluation results need to understand what bias is, how it can arise, and how it can undermine an evaluation study."[23]

In sections on Statistical Significance, both the ISO New England and PJM Interconnection M&V manuals require Project Sponsors to describe methods for mitigating and controlling bias in demand estimates. These manuals list many sources of potential bias beyond statistical precision. According to these manuals, relevant types of potential bias for estimates based upon engineering and direct measurement include but are not limited to:

- accuracy and calibration of the measurement tools;
- measurement error;
- engineering model bias;
- modeler bias;
- deemed parameter bias;
- meter bias;
- sensor placement bias; and
- sample selection bias or non-random selection of equipment and/or circuits to monitor.

For estimates based upon regression or statistical analysis, relevant types of potential bias include but are not limited to:

- model misspecification;
- statistical validity;
- error in measuring variables;
- autocorrelation;
- heteroscedasticity;
- collinearity;
- outlier data points; and
- missing data.

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[23] *The California Evaluation Framework*, Chapter 12: Uncertainty, January 2006, p. 290.

For estimates based upon survey or interview data, relevant types of potential bias include but are not limited to:

- construct validity;
- sampling frame versus population;
- selection bias (for a sample and for a census attempt where not all sites within the census received usable data);
- non-response bias;
- error in measuring variables;
- sample homogeneity relative to project (external validity);
- outlier data points; and
- missing data.

Beyond a few vocal experts and advocates, the evaluation community is only beginning to grasp the importance and implications of these sources of uncertainty. The Forum is calling for a more balanced treatment of the true sources of uncertainty bearing on evaluation results, and KEMA hopes that this brief overview draws attention to the vast number of threats to validity beyond statistical precision.

4.2 Measure-Specific Guidelines

This section presents summary recommendations for the fourteen measures reviewed. These suggested methods reflect the synthesis of results from program administrator interviews, review of other M&V protocols and evaluation reports, regulatory requirements, and consultant judgment.

The measure specific recommendations use a concise, two-section format to present guidelines on the following issues:

- Estimation methods and savings assumptions for initial/preliminary gross energy and demand; and
- Recommended M&V methods for pursuing gross evaluated energy and demand.

The first piece of each guideline presents the prevailing savings algorithm with a listing of inputs and savings assumptions. Detailed, comparative tables of savings assumptions are provided in Section 3.3 of this main report. This piece concludes with concise recommendations to improve regional consistency on the initial/preliminary gross savings methods.

The second piece of each guideline is a brief outline of recommendations pertaining to program tracking and recommended/alternative M&V methods. Tracking recommendations relate to the data management processes and systems employed to document and database the savings associated with energy efficiency program measure installations. These recommendations emphasize completeness of pre-evaluation "initial gross" and "net" estimates of energy and demand impacts. The recommended and alternative M&V methods correspond to the "Options" defined in either the ISO New England or PJM Interconnection M&V manual. These regional capacity market M&V requirements are the prevailing compliance concern in the Forum region, not the IPMVP guidelines upon which the ISO/PJM manuals were based.

Finally, while the following recommendations focus upon primary M&V research, the readers should be aware of a recent EM&V Forum effort[24] that investigated the usability and transferability of load shape data from other sources, i.e. secondary data. Many jurisdictions have expressed support the use of secondary data for measures such as residential lighting. This is an emerging issue and guidelines for applicability of evaluation results and/or demand savings have yet to be fully explored in the Northeast. Nonetheless, the authors wish to emphasize that the evaluation industry seems to be embracing the transferability of results in select program areas as a substitute for (or sometimes in combination with) the direct M&V methods recommended below.

[24] End-Use Load Data Update Project Final Report, Phase1: Cataloguing Available End-Use and Efficiency Measure Load Data, September 2009. Available for download from http://neep.org/emv-forum/forum-products-and-guidelines

4.2.1 Residential Central Air Conditioning

RESIDENTIAL CENTRAL AIR CONDITIONING
Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

kWh Saved = (Size in Btu/hr) x ($1/SEER_{baseline}$ – $1/SEER_{installed}$) / 1000 x (Full Load Cooling Hours)
kW Saved = (Size in Btu/hr) x ($1/EER_{baseline}$ – $1/EER_{installed}$) / 1000 x (Coincidence Factor)

Notes on Algorithm:

1. Some entities express unit size or cooling capacity in terms of "tons" of cooling, a unit of power equivalent to 12,000 Btu/hr but lacking accuracy due to nominal tonnage nomenclature.
2. Others algorithm use discrete estimates of load factor, diversity factor, and coincidence factor in place of a combined "coincidence" factor to account for all these effects. The product of the three discrete factors is equivalent to the single combined loading/diversity/coincidence factor.
3. Most Technical Reference Manuals (TRMs) cite "full load hours" or "equivalent full load hours" in their algorithm, but one TRM uses "cooling load hours" which separates the influence of electrical efficiency from the time term in the equation.

Description of Inputs:

Baseline Efficiency: Rated Seasonal Energy Efficiency Ratio (SEER) and Energy Efficiency Ratio (EER) of baseline equipment as per established standard or baseline study. Approximately 13 SEER and 11 EER. "Early retirement" tracks either prorate the existing and new construction baselines over the measure life or assume 9 or 10 SEER for baseline.

Installed Efficiency: Rated SEER and EER of installed equipment as per AHRI database. Approximately 14 SEER and 12 EER or refer to "Energy Star or higher".

Units of Cooling Capacity: Engineering units for cooling capacity in Btu/hr for accuracy and to ensure efficiency compliance.

Full Load Cooling Hours: The ratio of annual cooling unit energy to nameplate peak demand. Cooling hours should reflect localized climate conditions and be based upon technical research studies. With few exceptions, most states in the Forum region have distinct climate zones which warrant distinct estimates of cooling hours.

Demand Factors: Adjustments to rated demand for use in deriving coincident impacts; recommendation is to consolidate these discrete adjustments into one coincidence factor for each season, i.e. Summer and Winter. As with full load cooling hours, seasonal coincidence should reflect localized climate conditions and should be based upon technical research studies.

- **Loading**: The ratio of peak observed to rated maximum load for a piece of equipment. A discrete factor to express equipment over sizing effects at the typical unit level.
- **Diversity**: The ratio of the maximum combined demand to the sum of non-coincident demands across a group. A discrete factor which expresses the extent to which a group contributes to a combined maximum.
- **Summer Coincidence**: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 70% to 100% across the regional TRMs.
- **Winter Coincidence**: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. The winter coincidence factor should be 0% for residential CAC.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Standardize on Btu/hr as the unit of cooling capacity in the interest of accuracy and compliance.
2. Include both SEER and EER in algorithms for the best expression of both seasonal and peak performance.
3. Consolidate load, diversity, and coincidence factors into single factor combining all peak coincidence drivers.
4. Document credible sources for all savings assumptions. Currently, not all savings assumptions are clearly documented, and TRMs ought to cite credible sources for all savings assumptions to improve methodological transparency.
5. Develop (or continue to use) localized assumptions for cooling hours and peak coincidence. Consistent assumptions used for cooling hours across some states may not be warranted due to climate zones.
6. Consider differentiating by home vintage and location in program estimates of full load cooling hours.

RESIDENTIAL CENTRAL AIR CONDITIONING Summary of Recommended EM&V Methods		
This category is limited to central air conditioning (CAC) installed as a stand-alone measure and excludes CAC installed through comprehensive new construction programs. This category does not include ENERGY STAR room air conditioners or "space cooling" measures.		
Aspect	**Detailed Approach**	**Comments**
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, unit capacity, baseline and installed efficiency, and full load cooling hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with short-term metering can offer the most defensible approach to residential CAC programs.	Metering methods often include time-of-use loggers and spot power measurements
Alternative M&V Methods	An enhanced alternative to the above would be on-site inspections with metering that fully isolates the entire CAC system (Option B).	Metering would be interval kW measurements on both the outdoor compressor and indoor fan units
	Billing analysis (Option C) can be a reasonable energy evaluation method for residential CAC at lower cost. Central AC tends to be rather evident in whole-premise metering, although other substantial electric loads can be an obstacle.	Billing analysis alone cannot quantify demand impacts.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at capturing measure interaction. While perhaps excessive for stand-alone CAC, simulation modeling is particularly appropriate for evaluating comprehensive cooling measures.	Metering would mirror Option B probably with whole premise interval kW and some temperature measurements.

4.2.2 Residential Comprehensive Multi-Measure Retrofit

RESIDENTIAL COMPREHENSIVE MULTI-MEASURE RETROFIT
Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

No prevailing algorithm. These comprehensive retrofits are comprised of a wide variety of measures and technologies. Savings methods for the component measures are not well documented in TRMs.

Notes on Algorithm:

1. The various energy-efficiency vendors that deliver residential comprehensive multi-measure retrofit measures tend to employ in-house software for developing/reporting savings. While the vendors and software methods are approved by the program, the savings methods are not necessarily unified or consistent.
2. A detailed review of the algorithms and savings assumptions for the remaining component measures such as appliances, insulation, weatherization, and water heating necessitates an examination of each vendor's methods. Research is warranted in this area to promote methodological consistency.
3. Technical reference manuals tend not to document residential comprehensive multi-measure retrofits as an umbrella offering and do not provide sufficient data to facilitate a comparison of savings assumptions.

Description of Inputs:

Not available.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Some of the simpler, component measures within residential comprehensive retrofit programs – such as domestic hot water - lend themselves well to a stipulated savings approach.
2. For lighting measures, a calculated approach using stipulated parameters, e.g. wattage reduction and hours-of-use, offers consistency for connected demand impact and localized tuning for energy and coincident peak demand savings.
3. Administrators should require transparency and consistent savings methodologies across all vendors delivering residential comprehensive retrofits in a given program or state.
4. Given the differences in climate and demographics across the Forum region, it is appropriate for program administrators to continue to develop certain localized assumptions that reflect local characteristics such as lighting hours-of-use, coincidence factors, and market standard insulation levels.

RESIDENTIAL COMPREHENSIVE MULTI-MEASURE RETROFIT Summary of Recommended EM&V Methods		
This category encompasses comprehensive multi-measure retrofit installations in residential homes. Sometimes called "deep retrofits" or "home energy services", these measures are characterized by a whole-home approach which typically involves an audit followed by efficiency recommendations for multiple end uses and technologies. The comprehensive residential approach tends to be electric-centric but also may span fuel measures such as water heating, boilers, or furnaces.		
Aspect	**Detailed Approach**	**Comments**
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: detail on individual measures, such as: air conditioner, heat pump, boiler/furnace, water heater quantities and sizes; baseline and installed equipment efficiencies; home square footage; insulation and weatherization actions.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with visual inspections, quality of installation assessments, interviews, and short-term metering for select measures. Simple engineering models of savings impacts.	Metering limited to time-of-use loggers on lighting and HVAC equipment supported by spot power measurements.
Alternative M&V Methods	A dual-fuel option is to pair the Option A approach with a billing analysis (Option C) of gas impacts. Diagnostic testing of HVAC equipment, blower door, and duct blaster tests can add rigor and certainty to savings for envelope measures.	Billing analysis alone cannot quantify demand impacts.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at capturing measure interaction. Particularly appropriate for comprehensive multi-measures.	Metering would pursue HVAC system and whole premise interval kW and possibly some temperature measurements.

4.2.3 Residential Natural Gas Boilers and Furnaces

RESIDENTIAL NATURAL GAS BOILERS AND FURNACES
Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

Therms saved = (Size in Btu/hr) x ($1/AFUE_{baseline}$ – $1/AFUE_{installed}$) x (Full Load Heating Hours) / 100,000

Alternative Algorithm

Therms savings = (Size in Btu/hr INPUT) x EFLHeff x (AFUEeff/AFUEbase - 1)/100,000
Where the size of the unit and EFLHeff is for the installed high efficiency unit

Notes on Algorithm:

1. Most Technical Reference Manuals (TRMs) cite "full load hours" or "equivalent full load hours" (EFLH) in their algorithm, but one TRM uses "heating load hours" which separates the influence of thermal efficiency from the time term in the equation.
2. One TRM adds a heating load factor to explicitly adjust for over-sizing of the heating unit.
3. One state's algorithm accounts for the size of the installed and baseline units separately, using a fixed baseline capacity of 91,000 Btu/hr to represent the "typical heating unit" based on a baseline study.

Description of Inputs:

Baseline Efficiency: Rated Annual Fuel Utilization Efficiency (AFUE) of baseline equipment as per established standard or baseline study. Efficiency depends upon program type (early replacement, time of replacement, or new construction) as well as equipment type. Prevailing AFUE baselines are 75% for steam boilers, 78%-80% for furnaces, and 80-83% for hot water boilers.

Installed Efficiency: Rated AFUE of installed equipment as per Air-Conditioning, Heating and Refrigeration Institute (AHRI) database. Approximately 82% for steam boilers, 85% for non-condensing hot water boilers, 90% for condensing hot water boilers, and 92% for furnaces or refer to "Energy Star or higher".

Operating Hours: The ratio of annual heating unit energy to nameplate peak demand. Heating hours should reflect localized climate conditions and be based upon technical research studies. With few exceptions, most states in the Forum region have distinct climate zones which warrant distinct estimates of heating hours.

Summer Coincidence Factor: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. The summer coincidence factor should be 0% for residential heating equipment.

Winter Coincidence Factor: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Currently, most regional TRMs do not specify coincidence factors for natural gas measures. Coincidence should reflect localized climate conditions and should be based upon technical research studies.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Programs should take credit for electric impacts associated with efficient furnace fans within the natural gas furnace measure.
2. States currently using a custom approach for "point of sale" residential gas furnace and boiler measures should consider a prescriptive approach using the prevailing savings algorithm described above.
3. Develop (or continue to use) localized assumptions for heating hours and peak coincidence. Consistent assumptions used for heating hours across some states may not be warranted due to climate zones.
4. Consider differentiating by home vintage and location in program estimates of heating hours.

RESIDENTIAL NATURAL GAS BOILERS AND FURNACES Summary of Recommended EM&V Methods		
This category is limited to residential natural gas boilers and furnaces and excludes: space heating equipment such as portable or room space heaters; electric or oil space heating equipment; and associated controls such as boiler reset controls. This category addresses stand-alone heating equipment and excludes natural gas boilers/furnaces installed through comprehensive new construction programs.		
Aspect	**Detailed Approach**	**Comments**
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, unit capacity, baseline and installed efficiency, and full load heating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	Billing analysis (Option C) supported by telephone surveys or on-site inspections. Telephone surveys can be used confirm installation and gather data on household demographics and other operational characteristics to support the billing analysis.	Billing analysis is only valid when the pre-existing (electric bills from the pre-retrofit period) is the appropriate baseline to be used in the impact analysis
Alternative M&V Methods	Adding on-site inspections to the basic method above improves confidence in household characteristics and supports collection of equipment nameplate data. Basic short-term measurements (Option A) can be added on electrical support equipment such as furnace fans and boiler pumps to refine savings estimates.	Metering methods would include time-of-use CT loggers and spot power measurements
	Calibrated simulation modeling (Option D) is a high rigor alternative which is probably excessive for stand-alone gas heating but would be appropriate for evaluating measures in a comprehensive package.	Natural gas sub-meters can be installed to isolate the heating equipment from other end uses.

4.2.4 Residential Lighting

RESIDENTIAL LIGHTING
Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

kWh Saved = $(\text{Quantity}_{\text{baseline}} \times \text{Watts}_{\text{baseline}}) - (\text{Quantity}_{\text{installed}} \times \text{Watts}_{\text{installed}}) / 1000 \times (\text{Annual Hours})$

kW Saved = $(\text{Quantity}_{\text{baseline}} \times \text{Watts}_{\text{baseline}}) - (\text{Quantity}_{\text{installed}} \times \text{Watts}_{\text{installed}}) / 1000 \times (\text{Coincidence Factor})$

Notes on Algorithm:

1. Some Technical Reference Manuals (TRMs) stipulate the wattage reduction, utilizing a common Quantity term and substituting a ΔWatts or kW/unit term for $(\text{Watts}_{\text{baseline}} - \text{Watts}_{\text{installed}})$ in the equation above.
2. For retail programs, an in-service rate (ISR) often is added to the gross savings algorithm to represent the percentage of rebated units that actually get used. Some entities presume 100% installation rate or account for ISR in a net savings adjustment.

Description of Inputs:

Baseline Fixture Quantity: The number of fixtures in the corresponding baseline. The same as **Installed Fixture Quantity** for one-to-one replacements.

Baseline Fixture Wattage: For CFLs, baseline is typically 3.4 times **Installed Fixture Wattage**. For other fixture/lamp types, baseline wattage obtained from lookup tables developed and refined by technical and baseline studies.

Installed Fixture Quantity: The number of installed fixtures.

Installed Fixture Wattage: The rated wattage of the installed fixture, inclusive of both lamp and ballast. Obtained from nameplate data.

Annual Hours: The number of operating hours for the fixture in a typical year. Depending upon the program delivery vehicle, this can be derived from site-specific information, research-based estimates of lighting hours by room type, or – for retail programs – assigned a typical whole-home estimate which reflects the uncertainty of the lamp location. Residential lighting lends itself well to shared hours-of-use studies.

Coincidence Factors: Adjustments to rated demand for use in deriving coincident impacts; recommendation is to consolidate the Diversity into the Summer and Winter coincidence factors.

- **Diversity**: The ratio of the maximum combined demand to the sum of non-coincident demands across a group. A discrete factor which expresses the extent to which a group contributes to a combined maximum.
- **Summer Coincidence**: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 9% to 35% across the regional TRMs.
- **Winter Coincidence**: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors range from 5% to 100% across the regional TRMs.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. A calculated savings methodology would facilitate regional consistency better than stipulated savings. Demand reductions by lighting technology are logical stipulations as inputs, and a consistent algorithm would allow for localized tuning of hours and coincidence for savings impacts.
2. Direct install residential lighting programs in the region assign lighting hours by both room type and fixture type. Improved consistency would come from agreeing on one hours-of-use dimension – either room type or fixture type.
3. The majority of residential lighting programs factor the ISR into gross savings, while a few reflect this adjustment in net savings. Achieving regional consistency suggests inclusion of ISR as a gross effect.
4. Combine coincidence factor with diversity. This should help to address significant differences observed in winter coincidence factors.
5. Given demographic, geographic, program maturity, and behavioral differences in lighting usage across region, specific states/utilities should consider localized assumptions for lighting hours, peak coincidence, and HVAC interactive factors.

RESIDENTIAL LIGHTING Summary of Recommended EM&V Methods		
This category is limited to single-family residential lighting exclusive of specialty low-income and multi-family programs. These measures span new construction, retrofit, direct install, and retail lighting programs.		
Aspect	**Detailed Approach**	**Comments**
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: baseline quantity and wattage, installed quantity and wattage, location (as available), hours of use, in-service rate, HVAC interaction.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Complete "socket counts" by room and fixture type provide key data for impact evaluations, baseline studies, and hours-of-use studies. Questions on purchasing habits and "shelf" stock inform in-service rate research. Site visits with time-of-use lighting loggers are the most defensible approach to residential lighting programs.	Time-of-use lighting loggers on a sample of lamps and fixtures, typically by room type.
Alternative M&V Methods	An alternative method is to rely upon telephone surveys to obtain information such as socket counts, hours of use, and purchasing habits. Research has shows that verbal hours tend to be overstated, but this type of Verification (not true M&V) is considered reasonable rigor for certain applications.	Not literally M&V without measurement, but this may comply with ISO-NE/PJM "Option A" with well-documented stipulations.

4.2.5 C&I Comprehensive Multi-Measure New Construction

C&I COMPREHENSIVE MULTI-MEASURE NEW CONSTRUCTION

Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

Technical reference manuals do not provide calculations or algorithms for commercial and industrial comprehensive multi-measures; each project is unique. Comprehensive projects are often directed towards large facilities and cover wide ranges of equipment, schedules, approaches, and measure interactions.

Notes on Algorithm:

1. Comprehensive multi-measures are akin to multiple, interactive custom measures, and custom measures do not have prevailing algorithms. Nonetheless, the fundamental approach is to characterize the full dynamics of energy usage for the baseline and installed conditions across all hours of the year.
2. Hourly building simulations are a popular method, however advanced 8,760 spreadsheets can model energy usage in a more transparent manner.
3. With regard to measure interaction, the sequence in which the multiple measures are assessed affects the total savings for the combined measures.

Description of Inputs:

Not applicable.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. It is not possible to anticipate all possible factors and assumptions that comprise comprehensive multiple measures. However, criteria when comprehensive measures are required should be established and stated clearly in technical program documentation.
2. Calculations using site-specific baselines, installed equipment, and savings assumptions provide the most appropriate and rigorous path to savings impacts. Establishing interactive requirements for custom multiple measures is essential in obtaining true energy and demand savings.
3. Comprehensive projects can be comprised of both custom and prescriptive measures, and interaction should be handled in such a way to avoid double counting. Interactive hierarchies should be developed to provide a uniform track to calculate and report savings.
4. Comprehensive measures are inherently unique and project-specific. Even if methodological consistency is pursued (e.g. using eQUEST models), each project should employ local weather and operational characteristics.

C&I COMPREHENSIVE MULTI-MEASURE NEW CONSTRUCTION

Summary of Recommended EM&V Methods

This category is limited to the installation of commercial and industrial comprehensive multi-measure new construction projects. The comprehensive and multi-measure category is not clearly defined or specifically mentioned in many of the TRM's. References to multiple measures are included in custom measure discussions.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: savings by measure component; description of individual measures with, as applicable, unit quantities, sizes/capacities, baseline and installed efficiencies, and operating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	Calibrated simulation modeling (Option D) which is especially effective at capturing measure interaction. On-site data collection would gather parameters, specifications, and operational characteristics to inform the model.	Metering would include whole premise interval kW and some end use metering.
Alternative M&V Methods	A viable alternative would be on-site inspections with metering that encompasses the entire set of measures (Option B). A complex engineering spreadsheet model would capture the dynamics and interactions on an hourly basis. Less rigorous metering (Option A) could be performed if accuracy and validity is not a significant concern.	Metering would be interval kW measurements on all or select end use equipment.

4.2.6 C&I Custom Measures

C&I CUSTOM MEASURES

Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

Technical reference manuals do not provide calculations or algorithms for custom calculations since the category covers a wide range of equipment, approaches, and measures. Where custom measures are discussed, the TRMs require site specific equipment, operating schedules, baseline and installed efficiencies, and calculation methodologies in the development of energy and demand savings.

Notes on Algorithm:

1. Custom measures are non-standard which do not 'fit' prescriptive savings methods and assumptions.
2. While custom measures do not have prevailing algorithms, the fundamental approach is to characterize the full dynamics of energy usage across all hours and temperature conditions of a typical year.
3. Sometimes building simulations or vendor software are used to assess savings for custom measures. Advanced 8,760 spreadsheets can model energy usage in a more transparent manner than software.

Description of Inputs:

Not applicable.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. The custom approach is indispensable for delivering energy efficiency to customers, markets, or building/process systems that are not conducive to a standardized, prescriptive approach. However, custom measures are more costly and require technical in-house resources to examine and qualify non-prescriptive applications. Where program funding and technical resources permit, include a custom measure offering to capture more complex efficiency opportunities.
2. It is not possible to anticipate all possible factors and assumptions that comprise custom measures, so the scope of custom TRM entries should be limited. Custom calculations using site-specific baselines, installed equipment, and savings assumptions provide the most appropriate and rigorous path to savings impacts. Accordingly, there are no specific recommendations for the standardization of custom measure algorithms or approach.
3. Custom measures are inherently project-specific. Even if methodological consistency is pursued (e.g. standardized calculation models), the savings assumptions should employ localized weather and operational characteristics.

C&I CUSTOM MEASURES Summary of Recommended EM&V Methods		
This category is limited to the installation of commercial and industrial custom measures in both retrofit and new construction situations. The custom category includes measures that either do not comply with or benefit from examination beyond a prescriptive calculation approach. In general, these are more complex measures that necessitate site-specific information and detailed calculations to estimate energy and demand savings. In this context, custom measures may entail any end use or technology.		
Aspect	**Detailed Approach**	**Comments**
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: measure description with, as applicable, unit quantities, sizes/capacities, baseline and installed efficiencies, and operating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial (Option A) or complete (Option B) measurements on a sample of program participants. Site visits with short-term metering represent the most defensible approach to C&I Custom measures. A complex engineering spreadsheet model would capture the dynamics and interactions on an hourly basis.	Metering methods often include time-of-use loggers, interval kW recorders, and spot power measurements.
Alternative M&V Method	If the Custom measure involves significant HVAC equipment and/or controls, calibrated simulation modeling (Option D) offers a high rigor alternative which is especially effective at capturing measure dynamics and interaction.	Metering would include whole premise interval kW and some end use metering.

4.2.7 C&I Natural Gas Boilers and Furnaces

C&I NATURAL GAS BOILERS AND FURNACES
Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

Furnaces < 225 MBH and boilers < 300 MBH

Therms saved = (Size in Btu/hr) x ($1/AFUE_{baseline}$ – $1/AFUE_{installed}$) x (Full Load Heating Hours) / 100,000

Furnaces ≥ 225 MBH and boilers ≥ 300 MBH

Therms saved = (Size in Btu/hr) x ($1/Efficiency_{baseline}$ – $1/Efficiency_{installed}$) x (Full Load Heating Hours) / 100,000

Alternative Algorithm

Therms savings = (Size in Btu/hr INPUT) x EFLHeff x (AFUEeff/AFUEbase - 1)/100,000

Where the size of the unit and EFLHeff is for the installed high efficiency unit

Notes on Algorithm:

1. The prevailing algorithm only employs Annual Fuel Utilization Efficiency (AFUE), however the Air-Conditioning, Heating and Refrigeration Institute limits the use of AFUE to furnaces under 225 MBH and boilers less than 300 MBH. Units above this size have efficiency ratings in thermal efficiency and combustion efficiency. Accordingly, the recommended algorithm above includes a distinct expression for units above this size threshold.
2. Most Technical Reference Manuals (TRMs) cite “full load hours” or “equivalent full load hours” (EFLH) in their algorithm, but one TRM uses “heating load hours” which separates the influence of thermal efficiency from the time term in the equation.

Description of Inputs:

Baseline Efficiency: Rated AFUE or thermal efficiency of baseline equipment as per established standard or baseline study. Prevailing AFUE baselines are 75% for steam boilers, 78% for furnaces, and 80 for hot water boilers.

Installed Efficiency: Rated AFUE of installed equipment as per AHRI database. Approximately 82% for steam boilers, 85% for non-condensing hot water boilers, 90% for condensing hot water boilers, and 92% for furnaces.

Operating Hours: The ratio of annual heating unit energy to nameplate peak demand. Heating hours should reflect localized climate conditions and be based upon technical research studies. With few exceptions, most states in the Forum region have distinct climate zones which warrant discrete of heating hours.

Summer Coincidence Factor: The ratio of peak demand at the same time as a “summer” period to the peak demand across all periods. Most programs do not estimate peak coincidence for gas measures; however one TRM specifies a 12% summer coincidence factor for commercial gas heating equipment.

Winter Coincidence Factor: The ratio of peak demand at the same time as a “winter” period to the peak demand across all periods. Most programs do not estimate peak coincidence for gas measures; however one TRM specifies an 88% winter coincidence factor for commercial gas heating equipment. Coincidence should reflect localized climate conditions and should be based upon technical research studies.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. While there is reasonable consensus on savings calculation methodologies and assumptions for small commercial natural gas heating equipment, it may be appropriate to treat large commercial boilers as custom measures. States currently using or considering a custom approach for small commercial gas heating equipment might consider a prescriptive approach under a given size threshold.
2. Differing limits placed on eligible capacities throughout the region may pose a barrier to greater consistency for commercial natural gas boiler and furnace measures. In two states, boiler capacity is used to determine whether a measure is treated as a custom measure, so capacity limits also impact how savings are calculated.
3. Given the differences in climate across the Forum region, it is appropriate for specific states or utilities to continue to develop localized assumptions for heating hours due to local characteristics of climate, demographics, and behavior.
4. Different types of commercial buildings may also have different operating patterns, and thus different heating hours. When shown to be relevant, savings parameters by location, vintage, or other dimensions should be employed.

C&I NATURAL GAS BOILERS AND FURNACES Summary of Recommended EM&V Methods		
This category is limited to commercial natural gas boilers and furnaces. Accordingly, the research did not include other types of space heating equipment, such as individual or room space heaters, electric or oil space heating equipment, or associated controls such as boiler reset controls.		
Aspect	**Detailed Approach**	**Comments**
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, unit capacity, baseline and installed efficiency, and full load heating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	Billing analysis (Option C) supported by telephone surveys and/or on-site inspections. Telephone surveys can be used confirm installation and gather data on facility size and operating hours to support the billing analysis.	Billing analysis is only valid when the pre-existing (electric bills from the pre-retrofit period) is the appropriate baseline to be used in the impact analysis
Alternative M&V Methods	Adding on-site inspections to the basic method above improves confidence in building characteristics and supports collection of equipment nameplate data. Basic short-term measurements (Option A) can be added on electrical support equipment such as furnace fans and boiler pumps to refine savings estimates.	Metering methods would include time-of-use CT loggers and spot power measurements
	Calibrated simulation modeling (Option D) is a high rigor alternative which is probably excessive for stand-alone gas heating equipment but would be appropriate for evaluating significant measures or those in a comprehensive package.	Natural gas sub-meters can be installed to isolate the heating equipment from other end uses.

4.2.8 C&I HVAC: Prescriptive Chillers

C&I HVAC: PRESCRIPTIVE CHILLERS

Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

kWh savings = Tons x Δefficiency x Annual operating hours
kW savings = Tons x Δefficiency x Demand factors

Notes on Algorithm:

1. "Δefficiency" (kw/ton) refers to the difference in efficiency between the baseline and installed equipment, i.e. ($Efficiency_{baseline}$ – $Efficiency_{installed}$).
2. "Annual operating hours" are either equivalent full load hours (EFLH) or cooling load hours (CLH).
3. The demand savings algorithm excludes operating hours and incorporates demand factors. These multipliers are called coincidence factors or load factors that modify the chillers peak kW consumption.
4. Prescriptive chiller savings algorithms neglect the impacts of support systems such as pumps, controls, and tower fans.

Description of Inputs:

Baseline Efficiency: Rated efficiency of baseline equipment as per energy code, established standards, or baseline study. Often in units of Energy Efficiency Ratio (EER) for air cooled chillers, kW/ton for water cooled chillers, or the dimensionless coefficient of performance (COP). Depending upon the application, an integrated part load value (IPLV) may be a more appropriate efficiency, particularly for annual energy savings. Baseline efficiencies vary greatly by type (air-cooled/water-cooled, reciprocating/screw/centrifugal) and size and should be supported by technical baseline studies.

Installed Efficiency: Rated efficiency of installed equipment as per manufacturer's performance data.

Full Load Cooling Hours: The ratio of annual cooling unit energy to nameplate peak demand, as informed by technical metering studies designed to update hours-of-use assumptions. Regional Technical Reference Manuals (TRMs) employ estimates ranging from 497 to 3653 full load hours, depending upon region and building type.

Demand Factors: Adjustments to rated demand for use in deriving coincident impacts; recommendation is to consolidate these discrete adjustments into combined Summer and Winter coincidence factors.

Loading: The ratio of peak observed to rated maximum load for a piece of equipment. A discrete factor to express equipment over sizing effects at the typical unit level.

Diversity: The ratio of the maximum combined demand to the sum of non-coincident demands across a group. A discrete factor which expresses the extent to which a group contributes to a combined maximum.

Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 67% to 100% across the regional TRMs. Coincidence must reflect localized climate conditions and should be based upon technical research studies.

Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors range from 0% to 67% across the regional TRMs.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Load factors are included in some calculations to account for average seasonal loading and/or oversized systems. By standardizing on Equivalent Full Load Hours, a load factor term is no longer needed.
2. Consolidate load, diversity, and coincidence factors into single factor combining all peak coincidence drivers.
3. Standardize Efficiency. KW/ton is most commonly used to estimate savings, but Integrated Part Load Value (IPLV) can be a better representation of seasonal performance under varying loads.
4. Facility type is unspecified across most TRMs but default operating hours rely on average operation of multiple facility types across regions. Identifying annual operating hours by selected facility types will provide more accurate estimation of prescriptive savings by capturing the unique operating profiles for each facility.

C&I HVAC: PRESCRIPTIVE CHILLERS

Summary of Recommended EM&V Methods

This category is limited to air-cooled and water-cooled chiller installations in commercial and industrial facilities as a prescriptive measure. Custom chiller installations are covered under C&I Custom Measures.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, chiller capacity, baseline and installed efficiency, and full load cooling hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with short-term metering can offer the most cost-effective approach to prescriptive chiller projects.	Metering methods include interval amp/kW recording or time-of-use loggers coupled with spot power measurements.
Alternative M&V Methods	An enhanced alternative to the above would be on-site inspections with metering that fully captures the entire chiller water system including supporting pumps and tower fans (Option B). Engineers can analyze hourly energy consumption for baseline and installation conditions in a dynamic spreadsheet model using Typical Meteorological Year (TMY) data.	Additional parameters of value include supply and return water temperature and water flow in gallons/minute.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at capturing measure interaction. Simulation modeling is particularly good at temperature dependent equipment, but requires a wealth of building and operational characteristics for an accurate model.	Metering would mirror Option B probably with whole premise interval kW and some space temperatures.

KEMA

4.2.9 C&I HVAC: Unitary/Split

C&I HVAC: UNITARY/SPLIT
Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

Cooling Calculations:

kWh Saved = (Size in kBtu/hr) x (1/Efficiency$_{baseline}$ – 1/Efficiency$_{installed}$) x (Full Load Cooling Hours) / 1,000

Heating Calculations:

kWh Saved = (Size in kBtu/hr) x (1/Efficiency$_{baseline}$ – 1/Efficiency$_{installed}$) x (Full Load Heating Hours) / 1,000

Demand Calculations:

kW Saved = (Size in kBtu/hr) x (1/Efficiency$_{baseline}$ – 1/Efficiency$_{installed}$) x (Coincidence Factor) / 1,000

Notes on Algorithm:

1. Seasonal Energy Efficiency Ratio (SEER) is used to calculate cooling energy savings for air source heat pumps and AC units that are < 65,000 Btu/hr in size.
2. Energy Efficiency Ratio (EER) is used to calculate cooling energy savings for all water source heat pumps and for air source heat pumps and AC units that are < 65,000 Btu/hr in size. EER is also used for cooling demand savings.
3. Heating Seasonal Performance Factor (HSPF) is used to calculate heating savings for air source heat pumps < 65,000 Btu/hr.
4. COP (Coefficient of Performance) is used to calculate heating savings for units that are < 65,000 Btu/hr in size. COP is also used for heating demand savings.
5. Equivalent Full Load Hours (EFLH) is used to annualize savings. Separate operating hours are required for heating and cooling modes.

Description of Inputs:

Baseline Efficiency: Rated efficiency of baseline equipment as per energy code, established standards, or baseline study. Units vary as outlined above. Baseline efficiencies vary greatly by type (air conditioner/heat pump, air-source/water-source) and unit capacity and should be supported by technical baseline studies.

Installed Efficiency: Rated efficiency of installed equipment as per the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) database or manufacturer data.

Full Load Cooling/Heating Hours: The ratio of annual cooling/heating unit energy to nameplate peak demand, as informed by technical metering studies designed to update hours-of-use assumptions. Regional Technical Reference Manuals (TRMs) employ widely varying estimates depending upon cooling/heating mode, region, and building type.

Demand Factors: Adjustments to rated demand for use in deriving coincident impacts; recommendation is to consolidate these discrete adjustments into combined Summer and Winter coincidence factors.

Loading: The ratio of peak observed to rated maximum load for a piece of equipment. A discrete factor to express equipment over sizing effects at the typical unit level.

Diversity: The ratio of the maximum combined demand to the sum of non-coincident demands across a group. A discrete factor which expresses the extent to which a group contributes to a combined maximum.

Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 44% to 100% across the regional TRMs. Coincidence must reflect localized climate conditions and should be based upon technical research studies.

Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Regional estimates tend to assume 100% for heating mode, but this warrants improvement via further research.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Operating hours is the most dynamic savings input variable, and a consistent method should embrace inputs that reflect operational diversity by location, building type, or vintage. A consistent regional approach can still reflect regional and operational differences: New York should continue using Equivalent Full Load Hours lookup tables by city, but Rhode Island need not.
2. Electric resistance operation is not included in savings estimates, but these savings should be included

C&I HVAC: UNITARY/SPLIT
Savings Assumptions for Initial Gross Energy and Demand

when water source heat pumps replace air-to-air systems.

3. Standardize Cooling Capacity Units on Btu/hr. Using capacity estimates in kBtu/hr instead of tons prevents rounding errors by excluding nominal designations (10 tons) that may cover several different units.
4. Eliminate Loading/Sizing Factor. Load factors are included in some calculations to account for over sizing systems in the field, but this can be addressed in the Equivalent Full Load Hours parameter.
5. Given the differences in climate across the Forum region, it is appropriate for specific states or utilities to continue to develop localized assumptions for cooling and heating hours due to local characteristics of climate, demographics, and behavior.

C&I HVAC: UNITARY/SPLIT
Summary of Recommended EM&V Methods

This category is limited to unitary HVAC installations in commercial and industrial facilities as a prescriptive measure. Unitary equipment covers split system AC, packaged systems, air-source heat pumps, and water source heat pumps. Custom unitary air conditioning applications are covered under C&I Custom Measures.

Aspect	Detailed Approach	Comments
Program Tracking	<u>At a minimum</u>: initial gross energy and demand savings, as well as initial net impacts as applicable. <u>Additional</u>: number of installed units, HVAC unit capacity, baseline and installed efficiency, and full load cooling *and heating* hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Site visits with short-term metering can offer the most cost-effective approach to prescriptive chiller projects.	Metering methods include interval amp/kW recording or time-of-use loggers coupled with spot power measurements.
Alternative M&V Methods	An enhanced alternative to the above would be on-site inspections with metering that fully surrounds the measurement boundary (Option B). Engineers can analyze hourly energy consumption for baseline and installation conditions in a dynamic spreadsheet model using Typical Meteorological Year (TMY) data.	Interval kW metering on whole package units or both indoor/outdoor components of a split system.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at capturing measure interaction. Simulation modeling is particularly good at temperature dependent equipment, but requires a wealth of building and operational characteristics for an accurate model. May be a viable option for buildings with many HVAC units, zones, or solar coupling effects.	Metering would mirror Option B probably with whole premise interval kW and some space temperatures.

4.2.10 C&I HVAC: Other Measures

C&I HVAC: OTHER MEASURES
Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

kWh savings = (Size in Tons) x (Energy Savings Factor)
kW savings = (Size in Tons) x (Demand Savings Factor)

Notes on Algorithm:

1. The prevailing savings approach for all three measures - economizers, dual enthalpy controls, and programmable thermostats - is to employ "savings factors" which scale by HVAC unit size.

Description of Inputs:

Unit Size: HVAC unit capacity in tons of cooling. Nominal value from equipment nameplate.
Energy Savings Factor: Derived from an impact study. Estimates in Forum region Technical Reference Manuals (TRMs) vary greatly from 25 to 289 kWh/ton for dual enthalpy controls.
Demand Savings Factor: Most TRMs do not take credit for kW impacts. One TRM uses 0.289 kW/ton for dual enthalpy controls.
Summer Coincidence: Most TRMs do not take credit for kW impacts. One TRM uses 40% for summer coincidence. Recommend technical research to support savings factors and improve coincidence estimates.
Winter Coincidence: Most TRMs do not take credit for kW impacts. One TRM uses 0% for winter coincidence. Recommend technical research to support savings factors and improve coincidence estimates.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. The lack of reliable source documentation makes it difficult to compare savings assumptions and state what variables are the most accurate and reliable. Given the lack of uniformity between the models, assumptions, and savings factors, more measurement-based research (and perhaps simulation modeling) is warranted to improve consensus and confidence of HVAC economizer and control savings across the Forum region.

C&I HVAC: OTHER MEASURES Summary of Recommended EM&V Methods		
The Forum subcommittee for this project elected to limit this Other HVAC category to HVAC control measures such as thermostats, economizers, and dual-enthalpy controls. This category is limited to prescriptive installations in commercial and industrial facilities. Custom HVAC applications are covered under C&I Custom Measures.		
Aspect	**Detailed Approach**	**Comments**
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, unit capacity and efficiency, full load cooling hours, free cooling/setback hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling.
Recommended M&V Method	On-site inspections with limited measurements on a sample of program participants (Option A). Site visits for HVAC control measures often focus upon accurately inspecting and verifying operation of the controls.	Metering methods may include strategically placed time-of-use loggers to verify controls.
Alternative M&V Methods	An enhanced alternative to the above would be on-site inspections with metering that fully captures the impacts of the control (Option B). An hourly impact analysis would isolate the control impacts from the monitored data stream and assess across a Typical Meteorological Year (TMY) dataset.	Metering would be interval kW measurements on the affected HVAC units. Advanced metering can include enthalpy readings and damper position.
	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at measure interaction but also control schema. Simulation modeling requires a wealth of building and operational characteristics for an accurate model. May be a viable option for buildings with many HVAC units and complex controls.	Metering would mirror Option B probably with whole premise interval kW and some space temperatures.

4.2.11 C&I Lighting (New Construction)

C&I LIGHTING (NEW CONSTRUCTION)

Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

kWh Saved = $(Quantity_{baseline} \times Watts_{baseline}) - (Quantity_{installed} \times Watts_{installed})$ / 1000 × (Annual Hours)

kW Saved = $(Quantity_{baseline} \times Watts_{baseline}) - (Quantity_{installed} \times Watts_{installed})$ / 1000 x (Coincidence Factor)

Notes on Algorithm:

1. Some Technical Reference Manuals (TRMs) stipulate the wattage reduction, utilizing a common Quantity term and substituting a ∆Watts or kW/unit term for $(Watts_{baseline} - Watts_{installed})$ in the equation above.
2. While some algorithms employ an in-service rate (ISR), it is less prevalent in the C&I sector than for residential; many C&I programs either exclude ISR or assume it to be 100%.

Description of Inputs:

Baseline Fixture Quantity: The number of fixtures in the corresponding baseline. The same as **Installed Fixture Quantity** for one-to-one replacements.

Baseline Fixture Wattage: Connected wattage of the baseline fixture. For C&I new construction, usually obtained from lookup tables or derived from lighting power density tables in American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1.

Installed Fixture Quantity: The number of installed fixtures.

Installed Fixture Wattage: The rated wattage of the installed fixture, inclusive of both lamp and ballast. Obtained from nameplate data.

Annual Hours: The number of operating hours for the fixture in a typical year. For C&I lighting, either site-specific or assigned by building type. Lighting hours-of-use studies by building type inform program estimates when site-specific hours are not available.

Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 35% to 100% across the regional TRMs.

Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors range from 36% to 100% across the regional TRMs.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. A calculated savings methodology would facilitate regional consistency better than stipulated savings. Demand reductions by lighting technology are logical stipulations as inputs, and a consistent algorithm would allow for localized tuning of hours and coincidence for savings impacts.
2. Two distinct approaches are used in the region: lookups by building type and site-specific hours. A blended approach appears to be a logical and reasonable compromise between these two extremes. Site-specific lighting hours could be employed when available, but prescriptive lighting hours would default to lookup tables by building type or other relevant dimension.
3. In-Service Rate is a valid effect; the only question remains whether to account for it in preliminary or evaluated savings. KEMA recommends dropping the ISR from the C&I lighting algorithm and capturing its effect in the gross evaluated realization rate.
4. There is an opportunity for the region to standardize on an interactive effects approach for C&I lighting. This can be an engineering-based interactive methodology or simply agreeing to include localized HVAC interaction factors in the standard C&I lighting algorithm.
5. Given demographic, geographic, program maturity, and behavioral differences in lighting usage across the Forum region, localized assumptions are prudent for lighting hours, peak coincidence, and HVAC interaction.

KEMA

C&I LIGHTING (NEW CONSTRUCTION) Summary of Recommended EM&V Methods		
This category encompasses commercial and industrial lighting in new construction programs.		
Aspect	**Detailed Approach**	**Comments**
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: installed quantity and wattage, corresponding baseline, fixture location, annual operating hours, in-service rate, HVAC interaction factor.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling. Fixture location is critical for evaluation.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Complete inspection and count of all installed lighting with spot verification of lamp/ballast type. Characterize cooling/heating zones and equipment for assessment of HVAC interactive effects. Analysis with simple engineering models.	Time-of-use lighting loggers on a broad sample of fixtures, typically stratified by savings, room type, and or operating schedule.
Alternative M&V Methods	Some C&I lighting installations warrant very high, in-building sample rates or advanced interval metering (Option B). Examples include private office spaces with high uncertainty/diversity, hotel rooms/dormitories, and lighting systems with extensive controls. Interval kW meters have proven useful for recording load on lighting circuits with many, individual occupancy sensors or dimming controls. Analysis with simple engineering models or 8,760 spreadsheets for rigorous assessment of coincident impacts.	More liberal use of lighting loggers. Or: many commercial buildings isolate lighting systems in 277V power panels which can offer a prime opportunity for interval metering on large amounts of lighting.

4.2.12 C&I Lighting (Retrofit)

C&I LIGHTING (RETROFIT) **Savings Assumptions for Initial Gross Energy and Demand**
Prevailing Algorithm for Energy and Demand: kWh Saved = $(\text{Quantity}_{baseline} \times \text{Watts}_{baseline}) - (\text{Quantity}_{installed} \times \text{Watts}_{installed})$ / 1000 × (Annual Hours) kW Saved = $(\text{Quantity}_{baseline} \times \text{Watts}_{baseline}) - (\text{Quantity}_{installed} \times \text{Watts}_{installed})$ / 1000 x (Coincidence Factor) **Notes on Algorithm:** 1. Some Technical Reference Manuals (TRMs) stipulate the wattage reduction, utilizing a common Quantity term and substituting a ΔWatts or kW/unit term for $(\text{Watts}_{baseline} - \text{Watts}_{installed})$ in the equation above. 2. While some algorithms employ an in-service rate (ISR), it is less prevalent in the C&I sector than for residential; most programs either exclude ISR or assume it to be 100%. **Description of Inputs:** **Baseline Fixture Quantity**: The number of pre-existing fixtures. **Baseline Fixture Wattage**: Connected wattage of the pre-existing fixture for C&I retrofit. **Installed Fixture Quantity**: The number of installed fixtures. **Installed Fixture Wattage**: The rated wattage of the installed fixture, inclusive of both lamp and ballast. Obtained from nameplate data. Rarely measured independently. **Annual Hours**: The number of operating hours for the fixture in a typical year. For C&I lighting, either site-specific or assigned by building type. Lighting hours-of-use studies by building type inform program estimates when site-specific hours are not available. **Summer Coincidence**: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors range from 17% to 100% across the regional TRMs. **Winter Coincidence**: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors range from 36% to 100% across the regional TRMs. **Opportunities for Improved Consistency or Areas Where Differences are Warranted:** 1. A calculated savings methodology would facilitate regional consistency better than stipulated savings. Demand reductions by lighting technology are logical stipulations as inputs, and a consistent algorithm would allow for localized tuning of hours and coincidence for savings impacts. 2. Two distinct approaches are used in the region: lookups by building type and site-specific hours. A blended approach appears to be a logical and reasonable compromise between these two extremes. Site-specific lighting hours could be employed when available, but prescriptive lighting hours would default to lookup tables by building type or other relevant dimension. 3. In-Service Rate is a valid effect; the only question remains whether to account for it in preliminary or evaluated savings. KEMA recommends dropping the ISR from the C&I lighting algorithm and capturing its effect in the gross evaluated realization rate. 4. There is an opportunity for the region to standardize on an interactive effects approach for C&I lighting. This can be an engineering-based interactive methodology or simply agreeing to include localized HVAC interaction factors in the standard C&I lighting algorithm. 5. Given demographic, geographic, program maturity, and behavioral differences in lighting usage across the Forum region, localized assumptions are prudent for lighting hours, peak coincidence, and HVAC interaction

C&I LIGHTING (RETROFIT)
Summary of Recommended EM&V Methods

This category encompasses commercial and industrial lighting in retrofit programs.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: installed quantity and wattage, corresponding baseline, fixture location, annual operating hours, in-service rate, HVAC interaction factor.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling. Fixture location is critical for evaluation.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Complete inspection and count of all installed lighting with spot verification of lamp/ballast type. Characterize cooling/heating zones and equipment for assessment of HVAC interactive effects. Analysis with simple engineering models.	Time-of-use lighting loggers on a broad sample of fixtures, typically stratified by savings, room type, and or operating schedule.
Alternative M&V Methods	Some C&I lighting installations warrant very high, in-building sample rates or advanced interval metering (Option B). Examples include private office spaces with high uncertainty/diversity, hotel rooms/dormitories, and lighting systems with extensive controls. Interval kW meters have proven useful for recording load on lighting circuits with many, individual occupancy sensors or dimming controls. Analysis with simple engineering models or 8,760 spreadsheets for rigorous assessment of coincident impacts.	More liberal use of lighting loggers. Or: many commercial buildings isolate lighting systems in 277V power panels which can offer a prime opportunity for interval metering on large amounts of lighting.

4.2.13 C&I Motors

C&I MOTORS
Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

kWh savings = HP x 0.746 x (1/$Efficiency_{baseline}$ – 1/$Efficiency_{installed}$) x (loading) x (annual hours) / 1,000

kW savings = HP x 0.746 x (1/$Efficiency_{baseline}$ – 1/$Efficiency_{installed}$) x (loading) x (demand factors) / 1,000

Notes on Algorithm:

1. Standard motor algorithm; highly consistent in Forum region.

Description of Inputs:

Baseline Efficiency: Rated efficiency of baseline motor as per EPACT 1992. Lookup tables by motor horsepower (HP), type (open drip proof, totally enclosed fan cooled), and speed (rpm).

Installed Efficiency: National Electrical Manufacturers Association (NEMA) efficiency of installed motor as per nameplate data.

Loading: The average percent motor loading. While often ball-parked at 70-80%, best informed by spot power measurement of motor under typical loading conditions.

Annual Hours: The number of hours per year that the motor operates. While some prescriptive motor programs provide for site-specific estimates of operating hours, most Technical Reference Manuals (TRMs) provide default lookup hours by 12-60 facility types and 3-4 end uses.

Summer Coincidence: The ratio of peak demand at the same time as a “summer” period to the peak demand across all periods. Summer coincidence factors vary widely for prescriptive motors across the Forum region.

Winter Coincidence: The ratio of peak demand at the same time as a “winter” period to the peak demand across all periods. Winter coincidence factors vary widely for prescriptive motors across the Forum region.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. Stay on Track. The efficient motor measure is already close to a regional standard. The availability and uniformity of base and installed motor data has been widely adopted making only minor adjustments necessary to create a regional measure.
2. Some TRM’s prescribe motor operating hours for an extensive list of facility types and applications, while others are more limited. Shared research and operating hour assumptions may help expand efficiency offerings for programs that do not offer non-HVAC prescriptive motors.
3. Do not neglect loading factor; use site-specific when available. The loading factor accounts for motor over sizing and prevents the assumption that all motors operate continuously at full load.

C&I MOTORS
Summary of Recommended EM&V Methods

This category is limited to the installation of premium efficient motors in commercial and industrial facilities as a prescriptive measure. Motors installed in conjunction with other measures such as with variable speed drives are not included in this document.

Aspect	Detailed Approach	Comments
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, motor horsepower, end use and application (e.g. HVAC supply fan), location, baseline and installed efficiency, loading factor, and annual operating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling. Motor location is critical for evaluation.
Recommended M&V Method	On-site inspections with partial measurements on a sample of program participants (Option A). Basic site visits with time-of-use metering offers the most defensible and cost-effective approach to constant-speed, prescriptive motors.	Metering methods include time-of-use CT or "magnetic field" loggers and spot power measurements
Alternative M&V Methods	An enhanced alternative to the above would be on-site inspections with interval kW metering that tracks the electrical performance of the motor throughout its load range (Option B). This added rigor captures part-load efficiency effects that tend to be neglected in a time of use (TOU) metered approach with simple engineering models.	Metering would be interval kW measurements for a reasonable duration to span a variety of motor loading situations.

4.2.14 C&I Variable Speed Drives

C&I VARIABLE SPEED DRIVES
Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

kWh Saved = Motor horsepower (HP) x energy savings factor (ESF) x annual operating hours
kW Saved = Motor horsepower x demand savings factor (DSF)

Notes on Algorithm:

1. All variable speed drive algorithms in the Forum region boil down to a "savings factor" method, however most programs differentiate factors by building type, equipment type, and/or fan/pump type.
2. The most complex prescriptive variable speed drive (VSD) method utilizes an eleven-bin analysis based on percentage of flow. This adds greater resolution to the calculations, but the underlying algorithm remains consistent.

Description of Inputs:

Motor Horsepower: Motor size in nominal horsepower. From nameplate.
Energy Savings Factor: Estimated from impact studies or theoretical engineering models. Estimates range from 745-1,746 kWh/hp.
Demand Savings Factor: Estimated from impact studies or theoretical engineering models. Estimates range from 0.098-0.744 kW/hp.
Annual Hours: Estimated from impact studies or theoretical engineering models. Estimates range from 1,119-8,670 hours/year.
Summer Coincidence: The ratio of peak demand at the same time as a "summer" period to the peak demand across all periods. Summer coincidence factors vary from 0-100% for prescriptive VSDs depending upon the building type and drive application.
Winter Coincidence: The ratio of peak demand at the same time as a "winter" period to the peak demand across all periods. Winter coincidence factors vary from 0-100% for prescriptive VSDs depending upon the building type and drive application.

Opportunities for Improved Consistency or Areas Where Differences are Warranted:

1. If methodological consistency is a regional objective, a line may need to be drawn between prescriptive and custom VSDs, likely with a simpler line-item calculations and savings factors for prescriptive approach.
2. To improve portability of the VSD method, develop standardized kW/hp factor(s) and localized assumptions for operating hours and peak coincidence. Some algorithms provide a range of default operating hours while others embed annual operation in the "ESF" savings factor.
3. The region would benefit from some standardization, for Technical Reference Manuals (TRMs) vary widely in the range of equipment and size (motor horsepower) covered by the prescriptive variable speed drive application. Eleven types of equipment are covered in one TRM while another list only two applicable types. Installations outside the "standard" offerings simply would become a Custom measure.
4. Similarly, a common set of facility types would facilitate regional methodological consistency. The number of discrete facility types ranges from two to sixty amongst TRMs reviewed.
5. Any compliance or exclusion criteria should be clearly documented. The TRMs clearly identify motor size and application but do not always document exclusion criteria.

C&I VARIABLE SPEED DRIVES Summary of Recommended EM&V Methods		
This category is limited to variable speed drives (VSD) installations in commercial and industrial facilities as a prescriptive measure. Custom VSD applications are covered under C&I Custom Measures.		
Aspect	**Detailed Approach**	**Comments**
Program Tracking	At a minimum: initial gross energy and demand savings, as well as initial net impacts as applicable. Additional: number of installed units, motor horsepower, end use and application (e.g. HVAC supply fan), location, savings factors, and annual operating hours.	Additional parameters useful for quality control and also for evaluation design, e.g. sampling. VSD location is critical for evaluation.
Recommended M&V Method	On-site inspections with interval kW metering that tracks the electrical performance of the motor/VSD combination throughout its load range (Option B). Lesser rigor would not capture the variability intrinsic to a VSD application.	Metering would be interval kW measurements for a reasonable duration to span a variety of loading situations.
Alternative M&V Methods	Calibrated simulation modeling (Option D) is a high rigor alternative which is especially effective at measure interaction but also control schema. Simulation modeling requires a wealth of building and operational characteristics for an accurate model. May be a viable option for facilities with many VSDs on HVAC systems units.	Metering would mirror Option B perhaps with whole premise interval kW and some space temperatures.