Northeast Energy Efficiency Partnerships

REGIONAL EM&V METHODS AND SAVINGS ASSUMPTIONS GUIDELINES

A Product of the Regional Evaluation, Measurement & Verification Forum

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PREFACE

Regional EM&V Methods & Assumptions Guidelines

Background and Purpose: These Regional Evaluation, Measurement and Verification (EM&V) Methods & Assumptions Guidelines ('the Guidelines') were prepared for the Regional EM&V Forum ('the Forum'). The Forum, established in 2008, is a regional project facilitated and managed by Northeast Energy Efficiency Partnerships (NEEP) representing states in New England[1], New York, New Jersey, Maryland, Delaware, and the District of Columbia.

The intent of these guidelines is to provide clarity, transparency, and a common understanding of methods to consider in determining gross energy and demand savings, and savings assumptions for a priority set of energy efficiency program/project types or measures. The Forum initiated this project because it is believed that some form of EM&V guidance, if implemented and used, can provide the following benefits to the Region:

- Improve the credibility and comparability of energy efficiency resources to support state and regional energy, climate change and other environmental policy goals;
- Remove barriers to the participation of energy efficiency resources in regional markets by making EM&V practices and savings assumptions more transparent, understandable and accessible;
- Reduce the cost of EM&V activities by leveraging resources across the region for studies of common interest (where a need for new data has been identified); and
- Inform the potential development of national EM&V protocols.

Basis for Guidelines: The Guidelines are based on research that captures existing EM&V methods used in the industry today[2]. They are presented in the format of cross-cutting recommendations that are applicable to fourteen measures/programs (covering topics such as rigor, site inspections and measure life determination), and in the form of measure specific recommendations. The Guidelines recommend basic EM&V methods, and alternative or additional approaches for conducting EM&V which Forum participants can use independently for any one program/measure type, and/or in combination, depending on the specific energy efficiency project, program or portfolio objectives.

The Guidelines are also based on a review and comparison of savings input assumptions and algorithms for the set of measures/programs. The Guidelines recommend and provide commentary on: where greater consistency on certain savings assumptions makes sense; where consistency is neither appropriate nor warranted; and where better documentation (or

[1] Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont.
[2] The Guidelines are based on the EM&V Forum project *Develop Common EM&V Methods and Savings Assumptions* conducted by KEMA Consulting, April 2010. To view full report, see http://neep.org/emv-forum/forum-products-and-guidelines.

new research) is needed to support savings assumptions, in particular those that are deemed or stipulated.

Use of Guidelines: The Guidelines are not intended to be mandatory, as it is recognized that identical EM&V requirements and practices may be difficult to implement for the entire Forum Region given states or jurisdictions can have different program and EM&V objectives, budgets, and uses for their EM&V analyses. As such, these guidelines attempt to capture an appropriate balance of being flexible and not overly prescriptive, while providing sufficient detail so as to be meaningful and useful so that the Region can move towards greater consistency in how energy efficiency savings are determined.

The Guidelines are intended only to guide the design of comprehensive studies that estimate multiple impact parameters for one of the fourteen measures addressed in this report – *once a determination has been made to conduct such a comprehensive study*. The Guidelines should not be interpreted as suggesting that such comprehensive studies are always desirable, should be conducted with any particular frequency or should be routinely integrated into annual savings verification procedures. Decisions on when such comprehensive studies should be conducted will necessarily be based on local factors, including local trade-offs between the benefits of additional accuracy of savings estimates and the cost of such studies.

The Guidelines are also not necessarily applicable to studies intended to focus only on individual parameters or subsets of parameters. Further, the Guidelines do not make recommendations regarding transferability of evaluated results from one service territory to another within a state or region. While use of secondary data is generally accepted within the Forum region as a means to reduce evaluation costs (including for certain Forum projects e.g., commercial lighting loadshape study), validity implications of data transferability have yet to be explicitly and consistently addressed. It is recommended that the Forum develop guidelines on the transferability of evaluation results and review evaluation cycles to help ensure that the results are valid, appropriate, and reasonable.

Evaluators, program administrators, policymakers and others are encouraged to refer and use these recommended Guidelines, along with other Forum products on common EM&V terminology and common reporting formats, and to make suggestions for improvements and/or changes going forward. These Guidelines, as such, are viewed as a living document, and may lead to future projects that expand the measures/programs covered beyond those included herein. Additional efforts may also include exploring how the Forum's efforts, with respect to consistency, can support or perhaps even lead to similar efforts in other regions and nationally as efficiency becomes an increasingly greater strategy in energy and climate change mitigation efforts.

A special thanks is noted to this project's subcommittee members for their input and guidance in the development of these Forum guidelines: Gail Azulay, Mary Cahill, Alexey Cherniack, Gian DeLuca, Niko Dietsch, Helen Eisenfeld, Victoria Engel-Fowles, Kristy

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The Project was managed by Julie Michals (NEEP), with Steve Schiller (Schiller Consulting) serving as project advisor.

Regional EM&V Methods and Savings Assumptions Guidelines

These Guidelines 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. The Guidelines cover the following program and technology types (fourteen in total)

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

The Guidelines address each of the following EM&V elements:

- 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 elements are discrete for each of the fourteen electric and gas efficiency measures herein. For the latter two areas, Cross-Cutting Guidelines are provided.

1.1 Cross-Cutting Guidelines

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

1.1.1 Installation Verification

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 equates 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 to also justify the cost. However, some measures, such as compact fluorescent lamps, in aggregate can have an equivalent impact if not installed.

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.

1.1.2 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 to 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 the law is being followed.

It is recommended that a regular review of baselines in use be undertaken 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 calculations.

1.1.3 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.

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, there should be a regular review cycle to assure that each measure lifetime assumption is not so old as to be out of date. A full measure life study is not needed for each measure every three or five years. Rather, an intentional process to determine if a study is appropriate is recommended.

Temporal factors “persistence” and “in-service rate” are not uniformly used. Some use these factors, some report them as incorporated in the measure life, and in some cases it is not clear if they are addressed. Measure life should be defined to include these factors if they are deemed necessary by the Forum or by external stakeholders, and should be considered in the design of measure life research.

1.1.4 Statistical Precision

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’ one’s 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. 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% 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 New England, PJM Interconnection, Federal Energy Management Program (FEMP), American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)) include guidelines for controlling these other sources of error.

1.1.5 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."[3]

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;

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

- collinearity;
- outlier data points; and
- missing data.

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 this brief overview draws attention to the vast number of threats to validity beyond statistical precision.

1.2 Measure-Specific Guidelines

This section presents guidelines for fourteen measures or program types. 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. 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 manuals.* These regional capacity market M&V

requirements are the prevailing compliance concern in the Forum region, and are largely based on the International Performance Measurement and Verification Protocol (IPMVP).

Finally, while the following guidelines focus upon primary M&V research, the readers should be aware of a recent EM&V Forum effort[4] that investigated the usability and transferability of load shape data from other sources, i.e. secondary data. Many jurisdictions have expressed support for 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.

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

1.2.1 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. Other algorithms 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 Air-Conditioning, Heating, and Refrigeration Institute 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 central air conditioning.

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.

1.2.2 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.

1.2.3 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 INPUT) 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 to 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.

1.2.4 Residential Lighting

RESIDENTIAL LIGHTING

Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

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

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

Notes on Algorithm:

1. Some Technical Reference Manuals (TRMs) stipulate the wattage reduction, utilizing a common Quantity term and substituting a ▫Watts or kW/unit term for $(\text{Watts}_{baseline} - \text{Watts}_{installed})$ 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.

1.2.5 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 (TRMs) 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 TRMs. 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.

1.2.6 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 (TRMs) 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.

1.2.7 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 INPUT) 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 INPUT) 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 (AHRI) 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 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. 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 to 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 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.

1.2.8 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.

1.2.9 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

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

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 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.

1.2.10 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.

1.2.11 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. Recommend 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 (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.

1.2.12 C&I Lighting (Retrofit)

C&I LIGHTING (RETROFIT)

Savings Assumptions for Initial Gross Energy and Demand

Prevailing Algorithm for Energy and Demand:

kWh Saved = ($Quantity_{baseline}$ x $Watts_{baseline}$) – ($Quantity_{installed}$ x $Watts_{installed}$) / 1000 × (Annual Hours)

kW Saved = ($Quantity_{baseline}$ x $Watts_{baseline}$) – ($Quantity_{installed}$ x $Watts_{installed}$) / 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; 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. Recommend 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.

1.2.13 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 TRMs 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.

1.2.14 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.