

Commercial New Construction

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NATIONAL RENEWABLE ENERGY LABORATORY

Chapter n: Commercial New Construction Protocol

The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures

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1 Measure Description

This protocol is intended to describe best practices when evaluating “the whole-building performance” of new construction projects in the commercial sector. The focus is protocol focuses on measures (or packages of measures) whose where evaluators can best analyze impacts are best evaluated using building simulation. Examples of such measures include Leadership in Energy and Environmental Design (LEED) building certification, novel and/or efficient heating, ventilation, and air conditioning (HVAC) system designs, and extensive building controls systems, etc. In general, it is best to evaluate any measure (or set of measures) expected to significantly “interact” with other systems within the building, or whose and with savings are sensitive to seasonal variations in weather are best evaluated using whole-building modeling.¹ Commercial New The protocol classifies commercial new construction projects can be classified as follows:

- **Newly constructed buildings:** The design and construction of an entirely new structure on a greenfield site or wholesale replacement of a structure torn down to the ground.
- **Addition (expansion) to existing buildings:** Significant extensions to an existing structure requiring that requires building permits and triggering triggers compliance with current codes.
- **Major renovations or Tenant Improvements/tenant improvements of existing buildings:** Significant reconstruction or “gut rehab” of an existing structure, requiring that requires building permits and triggering triggers compliance with current codes.

Evaluators may find some projects in retrofit programs that must be assessed in a manner similar need to that apply the evaluation methods described here for new construction projects.² for some projects in the retrofit programs. While such some retrofit projects have much in common with new construction projects, their scope does not uniformly fall under the new construction categories previously described above. These. Evaluators should assess these projects should be evaluated according to the guidelines described for retrofit equipment (described in separate protocols).

Evaluation, measurement, and verification (EM&V) of new construction programs involves unique challenges, particularly when defining baseline energy performance. The baseline equipment against which energy impacts for new construction measures are evaluated is defined by an An agreed-upon building energy code or industry standard. Since defines the baseline equipment evaluators use to measure energy impacts for new construction measures. As the baseline equipment for new construction measures has never does not physically existed it exist and cannot be measured or monitored and, evaluators typically employ a simulation approach is usually required. Due to the nuances involved in appropriately determining baseline equipment/performance evaluations of such projects should be overseen by, experienced

¹ Note that the term whole-building modeling here does not necessitate use of sophisticated “stand-alone” simulation software (e.g., eQUEST, EnergyPlus, etc.). Engineering. It is acceptable to employ engineering models using spreadsheet calculations can be acceptable, provided they meet the guidelines set forth in section Section 4.

professionals with a good understanding of building construction practices, simulation code limitations, and the relevant building codes should oversee these types of projects.

Further, evaluators typically assess new construction measures ~~are typically evaluated in~~ within the first few years ~~after a building's~~ of building construction. During this period, there is often considerable flux in building occupancy and operation before ~~the~~ the measures design intent becomes realized. This results in additional challenges ~~when~~ for evaluators using monitored data and/or facility utility billing or energy consumption history to define as-built building performance.

DRAFT

2 Application Conditions of Protocol

The algorithms and protocols described here pertain to evaluating new construction “whole-building performance” energy-conservation measures (ECMs) installed in commercial facilities. When new construction ECMs do not directly impact HVAC energy use, it is often possible to use spot measurements and engineering calculations to evaluate savings with sufficient rigor (ASHRAE 2002, 34). This is usually the case, for example, with lighting and domestic hot water retrofits.³ The (ASHRAE 2002). This is usually the case, for example, with lighting and domestic hot water retrofits.⁴ This protocol does not cover the guidelines for selecting the appropriate monitoring and verification (M&V) rigor for such measures are not covered in this chapter. Evaluation guidelines for measures that do not require calibrated building simulation can be found in, Consult the International Performance Measurement and Verification Protocol (IPMVP), 11-24, or elsewhere measure specific protocols within the Uniform Methods Project protocols to review evaluation guidelines for measures that do not require calibrated building simulation.

2.1 Incentive Types

New Program stakeholders typically classify new construction demand-side management (DSM) program incentives as being either component-based or performance-based and can be designed design the program to offer one or both types of incentives.

2.1.1 Component-Based Incentives

Component-based (or “prescriptive”) incentives tend to involve individual technologies, and equipment. Examples of such prescriptive incentives may include, but are not limited to, lighting fixtures, occupancy sensors, motors, and small packaged (unitary) HVAC units. Rebate Evaluators often determine rebate amounts and claimed savings estimates (ex-ante) are often determined using based on stipulated “per-unit” estimates.⁵ Component Evaluators will sometimes assess component-based rebates are sometimes evaluated according to measure-specific protocols using partial or complete retrofit isolation evaluation strategies (IPMVP Option A or Option B).

³ While the general magnitude of the secondary impacts imparted by lighting measures on HVAC equipment are well established for various building types, take care to estimate these impacts appropriately in new construction building stock. New buildings typically have more efficient HVAC equipment which reduce the magnitude of heating and cooling interactive effects. Secondary impacts can be estimated using prototypical building models, representative of the physical facility. See the Commercial and Industrial Lighting Evaluation Protocol or (CPUC 2004, 128) for guidelines regarding HVAC interactive factors.

⁴ While the general magnitude of the secondary impacts imparted by lighting measures on HVAC equipment are well established for various building types, take care to estimate these impacts appropriately in new construction building stock. New buildings typically have more efficient HVAC equipment, which reduces the magnitude of heating and cooling interactive effects. Secondary impacts can be estimated using prototypical building models, representative of the physical facility. See the Uniform Method Project’s *Commercial and Industrial Lighting Evaluation Protocol* or CPUC 2004 for guidelines regarding HVAC interactive factors.

⁵ “Units” used do not necessarily represent quantity. Frequently applied units include: installed horsepower, tons of refrigeration, and square footage.

~~Evaluation~~ This protocol does not include evaluation of these ECMs ~~is not covered in this protocol~~, as they typically do not require use of calibrated building simulations (IPMVP Option D).

2.1.2 Performance-Based Incentives

Performance-based incentives tend to target more complex projects involving improvements to the overall building energy performance.

Whole-building performance incentives can:

- Encompass various specific (above-code) upgrades; ~~and~~
- Fund design, analysis, equipment, and/or installation (labor) costs.⁶

An example of a performance-based project is LEED certification. Buildings that are LEED certified ~~buildings~~ often encompass ECMs that range from envelope improvements to high-efficiency equipment installations (often going beyond just HVAC) and complicated controls algorithms. ~~The complex interactions between these ECMs can only be reliably determined through the use of calibrated building simulation models.~~

Performance-based incentive amounts are typically determined by the expected annual energy and/or demand impacts (e.g., per ~~kWh~~ kilowatt-hour, therm, ~~kW, etc.~~ kilowatt).⁷ Annual energy ~~savings estimates for performance-based projects (and therefore programs) are require~~ evaluators to use custom calculations involving the use of ~~via~~ whole-building simulation modeling tools. Therefore ~~these programs require~~ highly skilled technical labor ~~to is required to~~ successfully implement and evaluate successfully ~~these programs~~.⁸

⁶ ~~Some new construction programs have been successfully implemented without direct financial incentives (design assistance, financing, etc.).~~

⁷ Depending on program design, the “expected” energy impacts can be either *ex-ante* or *ex-post*.

⁸ ~~See (Johnson and Nadel 2000)~~ Johnson & Nadel 2000 for more information.

3 Savings Calculations

~~Energy Use~~ the following algorithm to calculate energy savings for new construction measures are calculated using the following algorithm. ~~(~~ Note that evaluators can calculate demand savings ~~can be calculated~~ using the same algorithms by simply substituting “demand” for “energy use.”⁹

Equation 1

~~Energy Savings = Projected Baseline Energy Use — Post Construction Energy Use~~
where:

$$\text{Energy Savings} = \text{Projected Baseline Energy Use} - \text{Postconstruction Energy Use}$$

Where,

Projected Baseline Energy Use = Projected energy use of baseline systems at full design occupancy and “typical” building operating conditions

~~Post Construction~~Postconstruction Energy Use = Energy use of measure systems at full design occupancy and “typical” building operating conditions

As described in Section 4, ~~Projected Baseline Energy Use~~ Measurement and Post Construction Energy Use are calculated Verification Plan, calculate projected baseline energy use and postconstruction energy use using a whole-building simulation model that is calibrated to monthly (or hourly) utility energy consumption histories. ~~Four~~ Evaluators can use four components ~~are used~~ to report savings for new construction ECMs. ~~Each is discussed further in Section 4.~~

- Expected ~~Measure Savings~~ measure savings (*ex-ante*)
- Rebated ~~Measure Savings~~ measure savings
 - ~~Non Rebated Measure Savings~~
 - Nonrebated measure savings
- Total ~~Achieved Savings~~ achieved savings

Section 4 discusses each component.

⁹ ~~When~~ When calculating the coincident peak demand savings, average the hourly demand savings over the “peak demand window” period, as defined by the utility.

4 Measurement and Verification Plan

4.1 IPMVP Option

4.1 Savings International Performance Measurement and Verification Protocol Option

The preferred approach to calculate savings for whole-building performance new construction projects ~~are calculated using~~ is calibrated building simulation models according to IPMVP Option D. ~~The (IPMVP 2006). The recommended approach requires sufficient resources be allocated to the project to allow for detailed onsite data collection, preparation of the simulation models, and careful calibration. The method is less costly when a functioning ex-ante model is available to the evaluator, though obtaining the ex-ante model is not a prerequisite to its application.~~

Determine the appropriate modeling software ~~is determined~~ by the specifics of the evaluated buildings ~~being evaluated~~ (e.g., HVAC system and zoning complexity, building constructions, complexity of the ECMs) ~~and~~; there is no single software (currently available) that can simulate all variations of HVAC system types, building constructions, and ECMs. Thus, it may be necessary to use multiple tools to evaluate building performance accurately.

In general, the appropriate software for modeling building systems and energy performance must ~~have the following capabilities:~~

- ~~Creates~~ Create outputs that comply with American National Standards Institute (ANSI)/ASHRAE Standard 140-2011;¹⁰
- Accurately simulate the building's systems and controls;
- ~~Uses~~ Use an hourly or ~~sub-hourly~~ subhourly time step to perform simulation;¹¹ and
- ~~Simulates~~ Simulate building performance using user-defined weather data at hourly intervals;

For more information on specific requirements for simulation software, see pp. 133 in The California Evaluation Framework (CPUC 2004, 133) and pp. 26-27 in Appendix J – Quality Assurance for Statistical, Engineering, and Self-Report for Estimating DSM Program Impacts (CADMAC 1998, 26-27).¹²

The U.S. Department of Energy's (DOE) ~~EERE Website~~ Energy Efficiency and Renewable Energy website¹³ contains a list of building energy simulation software. Although some tools listed are proprietary, the website also lists public-domain DOE-sponsored tools. Summary comparisons and descriptions of commonly used software can be found in Crawley (2005).

¹⁰ ——— ANSI/ASHRAE Standard 140-2011 establishes test procedures validating software used to evaluate thermal performance of buildings (and ~~the~~ applicable HVAC equipment).

¹¹ ——— It is preferable the software use unique time steps for each interval (8760 e.g., 8.760 hours, for example).

¹² ——— ~~Further~~ For further commentary on simulation software requirements ~~can be found in (ASHRAE 2002, 18 & 32), (IPMVP 2001, 33), see ASHRAE 2002, IPMVP 2001, and (IPMVP 2006, 19) IPMVP 2006.~~

¹³ ——— ~~http://apps1.eere.energy.gov/buildings/tools_directory/~~ The DOE's Energy Efficiency and Renewable Energy website can be found at: http://apps1.eere.energy.gov/buildings/tools_directory/.

Comment [KW1]: I think it might be confusing to begin the section with the exception. I propose moving it to the end.

The preferred full Option D approach will in some cases be intractable due to limited data availability or evaluation budgetary limitations. In such cases, alternate methodologies are acceptable but the following guidelines should be followed:

- Onsite verification and review of as-built drawings and commissioning reports (as available) should be performed to verify which energy saving features were actually installed and are functioning
- Ex-ante savings calculations should be based in a whole building simulation model of the building or of a building that is representative of the actual facility
- Results should be compared with billing data (when available), engineering rules of thumb, and/or secondary literature to review reasonability.

4.1.1 Verification Process

~~The Figure 1 depicts the overall process by which to verify savings are verified under Option D is illustrated in Figure 1, from the The California Evaluation Framework (CPUC 2004, 177). (CPUC 2004). The process starts by developing an M&V plan in specifying which site data collection and equipment monitoring requirements are specified in an M&V plan. Additionally, the M&V plan should specify the following:~~

- ~~• The applicable version of the building codes and equipment standards which determination that determine the baseline; (or applicable 'practice' that may determine baseline). This is discussed in more detail in Section 4.3.~~
- ~~• The above-code technologies present in the building which are (claimed as EEMs;ECMs)~~
- ~~• The software that will be used to model for modeling building performance;~~
- ~~• The Appropriate data that will be used to calibrate for calibrating the simulations;~~
- ~~• How to address modeling uncertainties will be addressed; and~~
- ~~• Against what statistical indices calibration will be measured.~~

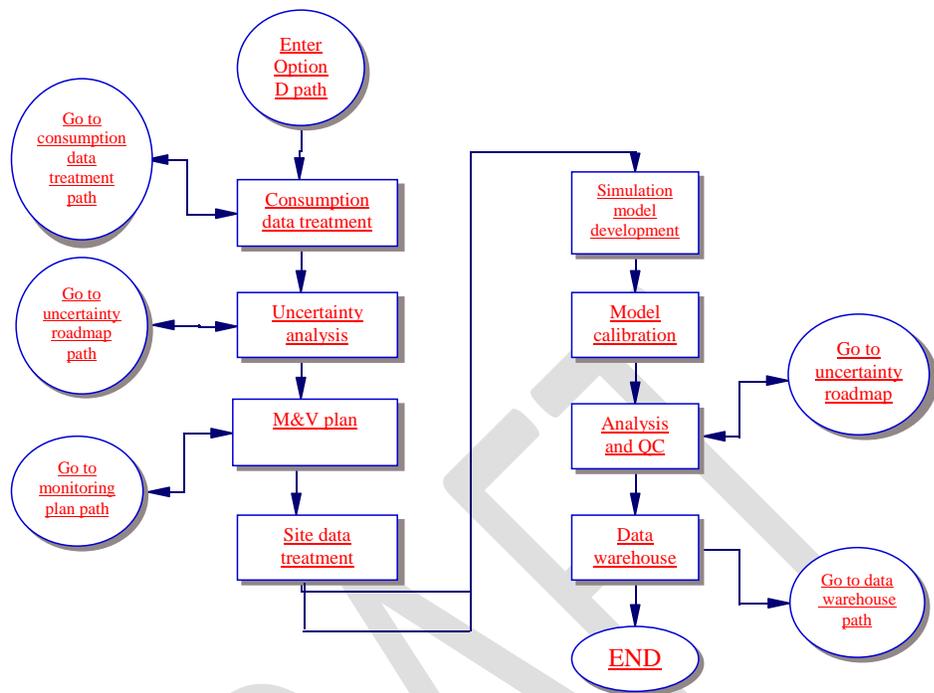
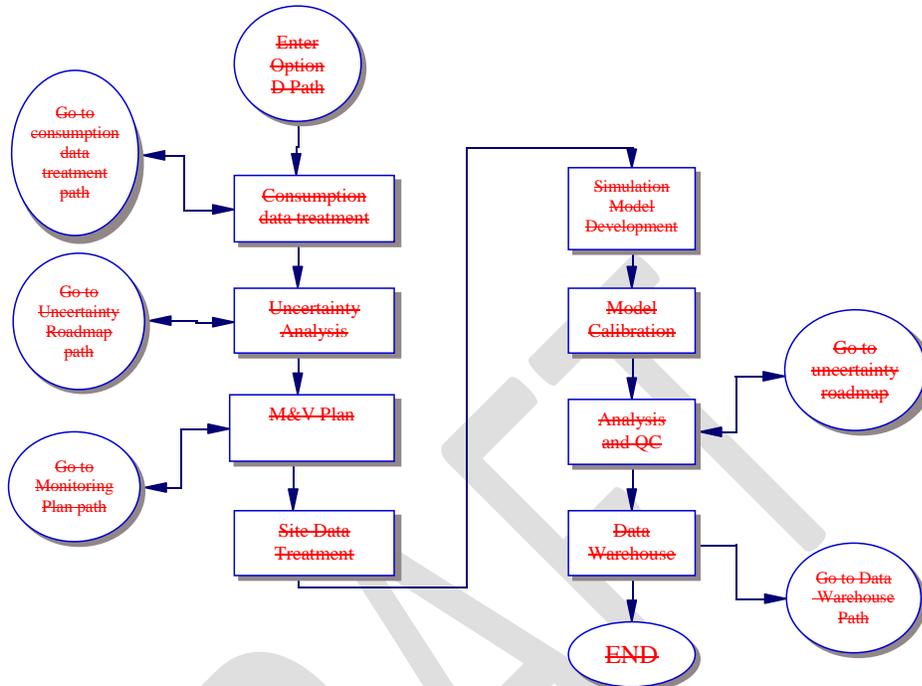


Figure 1. Roadmap for IPMVP Option D



While reviewing the energy consumption data can be useful in developing data collection needs, it is not ~~pre-requisite~~ prerequisite to creating and implementing the M&V plan. However, ~~the length of time that the when developing the M&V plan, evaluators should consider how long a building has been occupied and therefore the because that will determine~~ amount and granularity of energy consumption data available ~~should be considered when developing the M&V plan.~~ The fewer, Fewer months of consumption data, or the availability of only monthly data, usually means there will be a greater emphasis on metering specific pieces of equipment. Conversely, the presence of a Building Automation System, Energy Monitoring System, Lighting Control Panels ~~building automation system, energy monitoring system, lighting control panels~~, (collectively referred to here as BAS) or other devices to control and/or store data about the operational characteristics of the building would will allow for a lesser dependence upon utility usage data. ~~The remainder of this section describes each of the steps shown in the roadmap.~~

4.1.2 Data Requirements and Collection Methods

Data collected during this step includes all of the information required to define and calibrate the building simulation model. Due to the unique nature of each new construction project, it is impractical to prescribe a comprehensive list of specific parameters ~~to be collected~~ evaluators should collect on-site. Instead, use the following guidelines to identify key data points and minimize the uncertainty in the final calibrated simulations. ~~Once~~ After identifying specific parameters ~~are identified~~, refer to Chapter 4 ~~Chapter on~~ the Uniform Methods Project's Metering Cross-Cutting Protocols for instructions regarding the methods by which ~~to submeter~~ the physical parameters ~~are sub-metered~~.

The data used to define building simulation models come from stipulated and physical sources. Furthermore, these data can be static or dynamic in nature, as described here:

- *Static data points.* These are essentially constant values that describe physical properties of the equipment and the building surfaces or the set points and operational range to which controlling the building equipment is controlled.¹⁴ Examples of these static data points are window glazing, motor efficiencies, and thermostat set points.
- *Dynamic data.* These are time-dependent variables that describe building and equipment operations. These data capture the behavioral and operational details (such as e.g., weather, motor loading, and building occupancy) needed to establish a building's energy use characteristics. Dynamic data, which are often the most difficult to collect, represent the greatest source of uncertainty in a building simulation.

Use IPMVP Option D (IPMVP 2006) allows use of stipulated data is allowed under IPMVP Option D (IPMVP 2006, 19-20), although it is important to minimize the number of these inputs, as they represent degrees of freedom (and, therefore, additional uncertainty) in the model. Sources for such data include peer-reviewed research, engineering references, simulation program defaults, manufacturers' specifications, and/or survey information from on-site visits (such as e.g., mechanical and architectural drawings and visual inspection of nameplate information).

The following are convenient categories of important physical data to collect on site (ASHRAE 2002, 35-36): (ASHRAE 2002):

- Lighting Systemssystems
- Plug Loadsloads
- HVAC Systemssystems
- Building Envelopeenvelope and Thermal Massthermal mass
- Building Occupantsoccupants
- Other Major Energy Using Loadsmajor energy-using loads.¹⁵

Another important element of the data collection process entails the use of sub-meteringsubmetering to define behavioral and dynamic aspects of a building and its sub-systemssubsystems. In this protocol, the term "sub-metering" submetering encompasses both direct placement of monitoring equipment by evaluation personnel and collecting data from the building automation systems (BAS) ("also known as trend" data) when available. Even when the absolute accuracy of the collected data is unknown, sub-meteredsubmetered data is useful for informing operational schedules (e.g., lighting, and ventilation, etc.) and calibrating the model.

¹⁴ ——— Set points can refer to a control zone, thermostat, control valve, flow rate, voltage, photocell, or other parameter whichthat is designed to maintain optimal environmental conditions within the building. Some set points are "dynamic" in that they may change according to the time of day.

¹⁵ ——— This category is particularly important in buildings such as grocery stores, refrigerated warehouses, and some retail.

The degree of ~~sub-meteringsubmetering~~ required is largely dependent upon the quality and resolution of the facility's energy consumption history. ~~Note that the~~The following descriptions of ~~sub-meteringsubmetering~~ represent the minimum amount of data collected for calibrating simulation models. -Additional ~~sub-meteringsubmetering~~ may be necessary to verify complex control schemes and/or set points. Perform additional ~~sub-meteringsubmetering~~ as budget and time permit.¹⁶ ~~SuchUse such~~ data ~~would be used~~ to inform model inputs rather than to function as a calibration target.

4.1.2.1 ~~Sub-MeteringSubmetering~~ with Monthly Bills

When only a monthly utility billing history is available for a facility, it is important to ~~sub-metersubmeter~~ both HVAC fan schedules¹⁷ and interior lighting fixtures. Also, if the facility has unique or considerable equipment loads (~~for example, e.g.,~~ data centers), meter these, as well.

When monitoring unitary HVAC equipment, isolate the power used by fans from that used by compressors. This ensures ~~that evaluators can use~~ the resulting data ~~can be used in when~~ calibrating time-of-use and magnitude of fan power.

If, due to site or budget limitations, the electrical monitoring must comprise the unitary system as a whole, use motor nameplate information and fan ~~curves~~ in conjunction with local weather data to disaggregate the fan and compressor power.¹⁸

Alternatively, use one-time power measurements to establish a unit's demand for each operation mode. ~~TheseCombine these~~ measurements ~~can be combined~~ with time-series data to identify time spent in each operation mode and, thereby, determine the fan schedules.

4.1.2.2 ~~Sub-MeteringSubmetering~~ with Hourly Bills

Hourly (or ~~sub-hourlysubhourly~~) energy consumption histories contain much more information for model calibration than monthly usage alone. While this additional information reduces ~~sub-meteringsubmetering~~ requirements, it does not eliminate the need to ~~sub-metersubmeter~~ HVAC fan schedules, as they are important for disaggregating base loads from ventilation. As described for monthly billing data, ~~sub-meteringconsider submetering~~ other large energy-using features (e.g., ~~poolspool-heating and space-cooling equipment, atria, and decorative lighting features~~) ~~should be considered, and internet technology loads~~ if possible given evaluation budgets.

4.2 Simulation Model Development

It is important to model several iterations of the simulated building so as to fully capture the various aspects of the savings ~~from~~ for new construction ECMs. ~~This iteration~~Table 1 lists this

¹⁶ ——— For example, verifying functionality of chilled water reset controls or condensing water relief set points.

¹⁷ ——— It is important to capture a building's ventilation schedule when HVAC systems are used to supply outside air to maintain required fresh requirements. -If ~~sub-metering is performed~~performing submetering on a sample of HVAC fans, ~~theplace~~ priority ~~should be placed~~ on accurately capturing when (and how much) outside air is introduced into the building.

¹⁸ ——— ~~ThisTo employ this~~ method ~~has been written with the expectation,~~ the modeler ~~hasmust have~~ the requisite expertise to apply appropriate statistical and engineering modeling techniques to perform this analysis. -For further information on energy consumption analysis, see [the Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol](#).

iterative process, which ~~is shown in Table 1,~~ entails three versions of the as-built building and two versions of the baseline building, including:

- As-built physical;
- As-built design;
- As-built expected design;
- Whole-building reference; ~~and~~
- Measure building reference.

~~This list~~ Table 1 does not include intermediate modeling of individual ECMs. Intermediate modeling can be used to disaggregate individual measure impacts and interactive effects. If measure-level savings estimates (and ~~therefor~~ therefore, intermediate modeling of measures) is required, work with the governing jurisdiction for the evaluation process to establish an appropriate hierarchy to govern the order in which measures are stacked and individual measure savings assessed.

Table 1. List of Models Used to Simulated Savings for New Construction ECMs

Model	Model Name and Purpose	Model Description
1	As-Built Physical <i>To calibrate simulations and assess uncertainty.</i>	<p>Model and Simulatesimulate, as found during site visit.</p> <p>Use the occupancy and building operation, as reflected in billed energy history and sub-meteredsubmetered data.</p> <p>Simulate using actual local weather observations matching the consumption history period. Base on As-Built Physicalas-built physical model.</p>
2	As-Built Design <i>To estimate typical usage at full occupancy.</i>	<p>Use full design occupancy and expected "typical" building schedules.</p> <p>Use constructionconstruction and equipment efficiencies, as found during site visits.</p> <p>Simulate using normalized weather data (e.g., typical meteorological year [TMY] datasets).^a Base on As-Built Designas-built design model.</p>
3	As-Built Expected Design <i>To estimate difference between original and as-built models.</i>	<p>Use full design occupancy and expected "typical" building schedules.</p> <p>Use assumed (<i>ex-ante</i>) constructions and equipment efficiencies.</p> <p>Simulate using normalized weather data (e.g., TMY datasets). Base on As-Built Designas-built design model.</p>
4	Whole-Building Reference <i>To estimate savings of the ECMsECMs</i>	<p>Use full design occupancy and expected "typical" building schedules.</p> <p>Apply baseline requirements defined by reference codes or standards.</p> <p>Simulate using normalized weather data (e.g., TMY). Base on Whole-Building Referencewhole-building reference model.</p>
5	Measure Building Reference <i>To isolate savings claimed by the participant.</i>	<p>Use full design occupancy and expected "typical" building schedules.</p> <p>Apply baseline requirements defined by reference codes or standards.</p> <p>Include ECMs not incentivized by DSM program.</p> <p>Simulate using normalized weather data (e.g., TMY).</p>

^aNote the TMY are referenced here as an example series of normalized weather data. When incorporating TMY weather data, use TMY3 weather data when available. While TMY weather represents a common standard, review the reporting needs of the project, as other normalized weather datasets may be more appropriate (e.g. Weather year for Energy Calculations [WYEC] or California Thermal Zones [CTZ]).

Begin the development of the model by generating a model of the building as it was built and is operating during the site visit—and as reflected by utility energy consumption data. ~~This~~ Use this initial model, the ~~As-Built Physical~~ as-built physical model, ~~is used~~ to calibrate the modeled building to available physical data. This ensures ~~that~~ evaluators can use successive iterations ~~can be used~~ in a predictive capacity. A detailed discussion of the calibration process falls outside the scope of this protocol; however, for detailed calibration procedures and guidelines see Section 6.3.3.4 in ASHRAE Guideline 14-2002, 37-41- (ASHRAE 2002).

Once calibrated, use the ~~As-Built Physical~~ as-built physical model ~~is used~~ to generate the ~~As-Built Design~~ as-built design model, which should reflect the building at full-design occupancy and operation, according to expected “typical” schedules. The only differences between these models are building occupancy, operational schedules, and any modeling guidelines incorporated from codes or standards used to define baseline performance. For buildings currently operating at full occupancy, there may be very little difference between these models. Examples Refer to Tables 11.3.1 and G3.1 in ASHRAE Standard 90.1-2007 (ASHRAE 2007) for examples of modeling requirements specified by codes and standards ~~can be found in Tables 11.3.1 and G3.1 in ASHRAE Standard 90.1-2007 (ASHRAE 2007)~~.

~~The As-Built Design~~ Then, use the as-built design model ~~is then used~~ to generate the ~~As-Built Expected Design~~ as-built expected design model. While this model simulates the building’s operation according to its design intent, it also includes claimed assumptions regarding envelope constructions and equipment efficiencies. ~~If no~~ Review the model for discrepancies ~~are found~~ between claimed assumptions and the physical building; ~~if no discrepancies exist~~, this model will be identical to the ~~As-Built Design~~ as-built design.

~~Once As-Built Models have been developed,~~ After developing as-built models, evaluators can model baseline building performance ~~can be modeled, resulting, which results~~ in the ~~Whole-Building Reference~~ whole-building reference model. ~~This is generated from the As-Built Design~~ whole-building reference model ~~by applying;~~ to generate this model, apply the appropriate codes and standards used to define baseline building performance. ~~Such standards should be identified in~~ to the as-built design model. The M&V plan should identify such standards before modeling begins. ~~Additional considerations for baseline selection are discussed in the~~ The following section, “Baseline Considerations”; discusses additional considerations for baseline selection. Similar to the ~~As-Built Design~~ as-built design model, the ~~Whole-Building Reference~~ whole-building reference model should reflect the building’s operation according to its expected long-term patterns while using equipment and construction that minimally complies with the reference code or standard.

Finally, start with the ~~Measure Building Reference~~ whole-building reference model ~~is generated from~~ to generate the ~~Whole-Building Reference~~ measure building reference model, ~~and it includes—this model will include~~ ECMs not incentivized by the DSM program. ~~It is likely all~~ the implemented ECMs are included in the whole-building performance incentives; therefore, both the baseline models may be identical. However, as incentives often are applied for during the building’s design and construction process, additional above-code equipment or construction may be implemented that ~~has~~ were not ~~been~~ included in the final incentive.

4.3 Baseline Considerations

Defining baseline building physical characteristics and equipment performance is one of the most important (and difficult) tasks in evaluating savings for new construction ECMs. This is for several reasons. As noted ~~at this document's beginning~~, new construction ECMs do not have a physical baseline to observe, measure, or document. Rather, evaluators must define the baseline ~~must be defined~~ "hypothetically" through an appropriate interpretation of the applicable energy codes and standards. ~~Establishing~~ It is typically complicated to establish an *appropriate* interpretation ~~is typically complicated by~~ due to the overlapping scope of ~~Federal, State~~ federal, state, and local codes. Conversely, some states do not have a building energy-efficiency standard separate from the ~~Federal~~ federal standards. Typically, evaluators determine baseline building characteristics and equipment performance requirements ~~are determined~~ by locally adopted building energy codes. In some cases, however, applying a more rigorous, above-code baseline may better reflect standard local construction or industry-standard practices. Thus, in addition to a good understanding of the relationship between ~~Federal, State~~ federal, state, and ~~Local~~ local standards, evaluators may need to consult with program guidelines (which often specify greater than code stringency or other technical specifications) or statewide evaluation frameworks.

~~It should also be noted that while the enforcement~~ Enforcement of the state codes is the responsibility of the local building officials. ~~the~~ The EM&V effort of energy-efficiency programs is usually carried out by utility or other program administrators or by a ~~Public Utilities Commission~~ public utilities commission (PUC). Whereas the PUC usually has no enforcement responsibility for the codes and standards, they often point to the official ~~State~~ state standards as the governing document regardless of the degree of enforcement of those codes at the local level.

In general, the baseline must satisfy the following criteria ~~(IPMVP 2006)~~ (IPMVP 2006):

- It must appropriately reflect how a contemporary, nonparticipant building would be built in the program's absence.¹⁹
- ~~Evaluators~~ must be rigorously ~~defined~~ define it with sufficient detail to prescribe baseline conditions for each individual ECM and for the building components simulated; ~~and~~.
- ~~Evaluators~~ must be developed develop it with sufficient clarity and documentation to be repeatable.

The BCAP-OCEAN website (<http://energycodesocean.org/>) can be a useful resource in identifying locally adopted energy codes and standards when starting the evaluation of a whole-building or commercial new construction project.

¹⁹ ~~For~~ Locally adopted building codes will define gross savings of new construction programs. ~~this is defined by locally adopted building codes. Standard. Only consider standard~~ construction practices of nonparticipant buildings ~~are only considered~~ when performing a net-to-gross analysis. One notable exception is when the evaluated program defines its own baseline, according to an above-code standard (for example, ASHRAE Standard 189.1-2011).

4.4 Calculating Savings

~~Savings are calculated by applying~~To calculate savings, apply simulation outputs (from models 2 through 5 in ~~Table 1~~Table 2) to the formulas described in Section 3. In all cases except ~~As-Built Physical~~as-built physical, simulate the ~~Post-Construction Energy Use~~postconstruction energy use and the ~~Projected Baseline Energy Use should be simulated~~projected baseline energy use using normalized weather data (TMY).

As discussed in Section 3, there are four components that comprise calculated energy savings (defined in ~~Table 2~~Table 2 and shown in ~~Figure 2~~Figure 2). ~~Determine the~~ final reported (verified) savings values ~~are determined~~ in the context of M&V objectives.

Table 2. Comparison of Savings Components for New Construction ECMs

Savings Component	Model Subtraction	Description
Expected Measure Savings	N/A	Energy savings expected by the building designers and/or the DSM program application. (Also (also known as the project's ex-ante energy savings-)).
Rebated Measure Savings	5 – 2	Evaluated (or realized) energy savings for incentivized ECMs, often determined by an independent third-party evaluator. Calculate these savings by subtracting the difference in simulated energy use of the As-Built Design as-built design from the Measure Building Reference (The measure building reference (the result is also known as the project's ex-post savings-)).
Non-Rebated Nonrebated Measure Savings	4 – 5	Energy savings resulting from ECMs implemented in the final building design, but not rebated by the DSM program. Calculate these savings by subtracting the difference in simulated energy use of the Measure Building Reference measure building reference (the result is also known as the spillover savings-)). from the Whole Building Reference (The whole-building reference (the result is also known as the spillover savings-)).
Total Achieved Savings	4 – 2	Evaluated (or realized) energy savings for all implemented ECMs, whether rebated or not. These are often determined using an independent third-party evaluator, and calculated by subtracting the difference in simulated energy use of the As-Built Design as-built design from the Whole Building Reference whole-building reference . Some DSM programs report this (rather than Rebated Measure Savings rebated measure savings) as the project's ex-post savings.

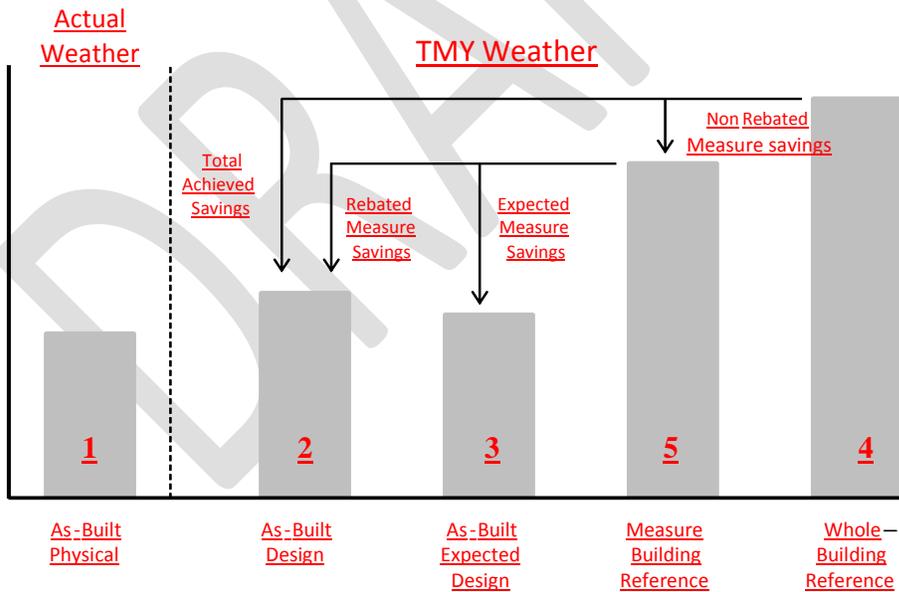
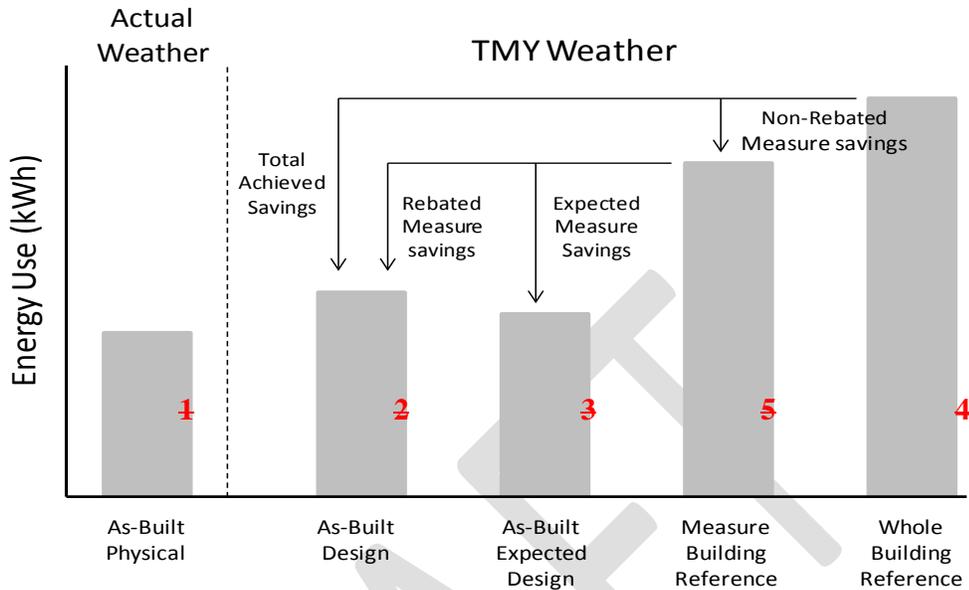


Figure 2- Illustration of Savings Components for New Construction ECMs



4.5 Quantify and Locate Modeling Uncertainty

Due to the complex set of physical, thermodynamic, and behavioral processes ~~that are being~~ simulated, it is difficult to fully characterize the uncertainty in modeled outputs without multiple statistical and analytical tools. Additionally, practical limitations on budgets and time allotted for M&V activities frequently result in qualifying uncertainty in final simulated savings by reporting uncertainty in the model's calibration to energy consumption history. ~~Calibration~~ Quantify calibration uncertainty ~~is quantified~~ using Normalized Mean Bias Error ~~the normalized mean bias error~~ (NMBE) and Coefficient ~~coefficient~~ of Variation ~~variation~~ of the Root Mean Square Error ~~root mean square error~~ (CVRMSE).²⁰ Pages 13-16 of ASHRAE Guideline 14-2002, 13-16, (ASHAE 2002), provides detailed descriptions of these calculations and their applications.

~~Calibration~~ Determine calibration uncertainty ~~is determined~~ by comparing outputs from the calibrated ~~As-Built Physical~~ as-built physical model with the facility's consumption history. Table 3 shows calibration uncertainty targets for monthly and hourly consumption history resolutions ~~(ASHRAE 2002)~~ (ASHRAE 2002).

Table 3. Acceptable Tolerances for Uncertainty in Calibrated Building Simulations

Resolution of Energy Consumption History	NMBE Tolerance	CVRMSE Tolerance
Monthly	±10%	±30%
Hourly	±5%	±30%

²⁰ These two statistical measurements provide an assessment of the variance between the simulated and measured (by the utility meter) energy use and electric demand. ~~The~~ This protocol considers modeling uncertainty ~~is determined~~ acceptable when this variance is below the thresholds suggested in Table 3.

As newly constructed buildings have a short energy consumption history, it is important to consider how many monthly observations are required to attain a suitably calibrated model. The amount of consumption history required for calibration depends on building type and occupancy. Buildings with little seasonal variations in energy use²¹ and short ramp-up periods may need as little as three or four months of consumption history, assuming building occupancy and usage are well-defined and stable. ~~Buildings typically included~~Typically, buildings in this category ~~are include~~ grocery stores, restaurants, and data centers.

Conversely, buildings that experience significant seasonal variation, or that are not fully occupied for extended periods, may require a complete year (or more) of consumption history before ~~modelers can determine~~ a reliable calibration ~~can be determined~~. For these buildings, occupancy and usage must be well-defined and stable during all observations used for calibration. ~~Typical buildings of this type include offices, schools, and malls (both strip and enclosed).~~

~~Providing prescriptive~~Mandating definitive requirements for the minimum number of observations required to sufficiently calibrate a simulation would unduly constrain modelers and could place impractical limitations on EM&V efforts. However, this protocol recommends the following as guidelines:

- Observations should sufficiently characterize a building's energy use, so ~~modelers can extrapolate~~ reliable annual energy-use values ~~can be extrapolated~~.
- Observations should sufficiently describe expected seasonal variations in building operations.
- Building occupancy and operating conditions must be known for the set of observations.
- Building occupancy and operating conditions must remain stable for the duration of observations used for calibration.

While NMBE and CVRSME may prove useful in describing uncertainty in final savings, it is important to minimize the uncertainty in the simulation inputs. ~~Uncertainty in the inputs~~These ~~metrics~~ will not ~~be completely captured by these metrics~~capture uncertainty in the inputs.

All software packages acceptable for use in Option D require ~~that modelers specify~~ a significant number of physical parameters ~~be specified~~ before ~~simulating~~ a building ~~can be simulated~~. Often, many of these parameters have default settings in the software package; however, ~~evaluators can base~~ the parameter inputs ~~can be based~~ on experience or standard practices.

Any parameter not directly based on a physical building or its equipment represents a degree of freedom for calibrating the model against a facility's consumption data.²² By varying these

²¹ — Although energy used by HVAC systems can vary seasonally, such usage generally correlates well with outside weather. Thus, the energy simulation model can sufficiently extrapolate such seasonality (when simulated using the appropriate weather data), reducing the number of billed observations required to calibrate buildings having HVAC use that is dominated by weather.

²² — Each parameter must be constrained by a physically realistic range of values.

parameters, the ~~modeler can calibrate the~~ same model ~~can be calibrated~~ to meet uncertainty targets in multiple ways, although for very different reasons.

Lack of a unique calibration point can cause misleading results for NMBE and CVRSME. Furthermore, the resultant calibrations respond differently to changes in other parameters, which can lead to significantly divergent savings estimates. Therefore, it is very important ~~that the modeler~~ modelers minimize calibration uncertainty ~~and that such they accomplish the~~ calibration ~~is accomplished~~ for the correct reasons. ~~Model inputs~~ Modelers should not ~~be~~ unreasonably ~~altered~~ alter inputs simply to reduce NMBE or CVRSME.

The following guidelines minimize uncertainty in the calibration process:

- ~~Modeling should be performed by)~~ Experienced simulators (or ~~be~~ modelers directly supervised by) an experienced simulator.
- ~~Each~~ must perform the modeling.
- Modelers must document each simulation process step ~~should be documented,~~ so ~~that~~ reviewers can audit the model, its outputs, and its assumptions.
- Simulators and auditors should determine the most influential default model parameters and confirm their appropriateness.
- Simulated equipment (e.g., HVAC coils, chillers, pumps, ~~etc.~~) should not ~~be allowed to~~ “auto-size” in final simulations.²³
- Simulators should identify the parameters to which the simulation outputs are most sensitive.²⁴

In addition to quantifying NMBE and CVRSME errors, ~~simulators~~ modelers should analyze the sensitivity of final savings to variations in key model inputs. ~~Such~~ Modelers should also report such parameters, ~~(including~~ their effects on simulated energy savings, and the uncertainty in their values ~~should be reported)~~ with calibration uncertainty.

²³ ~~When specific data are unavailable, auto-sizing can be helpful in determining appropriate coil capacities, fan speeds, etc. However, it should only be used~~ use it for initial equipment sizing. Once equipment sizes have been determined, ~~they should be input them~~ directly. Often, modelers must use auto-sizing ~~must be used~~ to define baseline equipment, as the measures impact building loads. In such cases, calculate an oversize ratio ~~must be calculated~~ for as-built equipment and applied ~~apply it~~ to the baseline simulation.

²⁴ ~~Further discussion regarding sensitivity analysis of simulation parameters falls outside this chapter’s scope. For additional material on this topic, see Spittle~~ ~~(Spittle, Fisher and Zietlow 1989).~~ Fisher, & Zietlow 1989.

5 Sample Design

~~Sampling can be used~~Use sampling under the following conditions:

- ~~Sub-metering is performed~~When performing submetering on building equipment; ~~or~~
- ~~Performing~~When performing a detailed survey of an entire building proves impractical.

Evaluators determine the specific targets for sampling certainty and relative precision in the context of the evaluation. ~~For detailed information regarding sample design and for calculating certainty and precision, see the~~ [Uniform Method Project's Sample Design Cross-Cutting Protocol](#)~~Protocols~~.

5.1 Sampling for ~~Sub-metering~~Submetering

Perform ~~sub-meteringsubmetering~~ to collect information regarding a building's operational schedules. Monitored systems include lighting, ventilation, large equipment (e.g., data centers), and HVAC zone temperatures. Generally, it is acceptable to assume a coefficient of variation (CV) of 0.5 for most ~~sub-meteringsubmetering~~; however, while many of these schedules are a function of the overall building type, significant variation in schedules can occur from space to space within a facility. Therefore, interview site personnel to identify any operational differences (and the magnitude of such differences) within the facility before creating a sample design. Account for variations in operating schedules and usage patterns by using a larger CV or by stratifying unique usage groups. ~~See the [...cross reference to monitoring chapter...]~~See the [Uniform Method Project's Metering Cross-Cutting Protocols](#) for additional considerations for commonly monitored equipment.

5.1.1 Example: Monitoring the Lighting Schedule in a Two-Story Office Building

A two-story commercial office building receives a whole-building performance rebate for LEED certification. For the certification process, a DOE2.2 model is built, for which ~~evaluators develop~~ lighting loads and schedules ~~are developed~~. During the on-site visit, evaluators note ~~that~~ the same tenant occupies both floors, and the building remains open from 6:30 a.m. to 10:00 p.m. The evaluators also identify two unique lighting usage patterns:

- Enclosed offices are located on the building's perimeter, ~~and~~
- Open office space is located in the building's core.

As ~~the evaluators identified~~ two distinct usage patterns ~~have been identified~~, ~~they should design~~ the sampling ~~should be designed~~ to capture the variability within the schedules for both space types.

- As ~~the~~ open office space is located in the building's core, lighting fixtures likely operate continuously during the building's open hours. ~~Additionally, lighting is commonly shared by all workspaces in the building's core. Therefore, a CV =of 0.5 is justified, and may prove conservative in determining how many fixtures should be monitoredto monitor.~~
- Lighting fixtures located in enclosed office ~~spacespaces~~ typically experience significantly more usage variation due to exaggerated behavioral and external influences. ~~Also, the~~

enclosed office space fixtures receive additional light from perimeter windows, thereby reducing the need for interior lighting during daytime hours. These impacts can be exaggerated (or diminished), depending on fixture control types, building aspects, weather, and times of year. Such additional variability would necessitate a higher assumed CV and additional monitoring points.

5.2 Sampling for Building Surveys

The on-site data collection encompasses a detailed survey of building systems, such as:

- Lighting fixtures;
- Plug loads;
- HVAC equipment and controls;
- Elevator and auxiliary equipment;
- Fenestration, and
- Envelope constructions.

For many buildings, surveyors can perform a complete ~~walkthrough~~walk-through and can install monitoring equipment within a single day. However, larger buildings (such as high-rise office buildings, hotel casinos, and hospitals) present logistical and budgetary complexities that make it impractical (and often impossible) to perform a complete facility ~~walkthrough~~walk-through. In these cases, it is permissible to perform a walkthrough of a representative sample of building areas and extrapolate the findings to the rest of the building. ~~This~~Evaluators can ~~be applied~~apply the findings to individual spaces or to entire floors. ~~(The (the exact sample design depends on the facility design, including any considerations, such as access to space-)).~~

5.2.1 Example: On-Site Audit of a High-Rise Office Building

A 34-story, high-rise, commercial building located in a major city's downtown region receives a whole-building performance rebate. Various retail businesses rent the first floor, and various tenants use the remaining floors as office space, including a United States Department of Agriculture office. Evaluators collect data during the on-site visit to build a DOE2.2 model; however, the building owner will only provide evaluation personnel access to the building for a single day.

The building is too large to conduct a thorough ~~walkthrough~~walk-through in one day. Additionally, it is expected at least one tenant will have areas within its occupied space ~~which will not allow that~~ evaluators ~~will not be allowed~~ to access. Therefore, ~~sampling~~evaluators will have to ~~be performed~~perform sampling for both floors and space types. Evaluators should audit enough floor space to sufficiently characterize internal loads and usage patterns for each tenant and for the building as a whole. The exact number of floors visited will depend on the number of tenants and on the homogeneity between spaces/floors. The evaluators should:

- Identify unique operating conditions, such as occupancy schedules, lighting power density (and schedules), and equipment power density (and schedules).
- Identify currently vacant areas (or floors).

- Interview facility staff to:
 - Identify differences in space temperatures or ventilation requirements for each tenant;
 - Determine variations in building occupancy (by month or as appropriate) since its opening.
- Audit all central plant equipment.
- Sample air distribution system equipment using sampling criteria described in ~~[Sampling Chapter]~~[the Uniform Method Project's Sample Design Cross-Cutting Protocols.](#)

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6 Program Evaluation Elements

These elements differentiate evaluations of new construction programs from those of other programs:

- ~~Significantly~~Evaluators need significantly more resources ~~are required~~ to define and justify a hypothetical baseline;
- Evaluators have a limited selection of methods for determining site-level savings; ~~and~~
- Buildings rarely operate at a “steady state” at the time of evaluation.

While this is not a comprehensive list, it specifies critical factors that evaluators must consider in developing an evaluation plan, ~~—~~ particularly with regard to budget resources for defining and justifying the baselines used to determine energy savings.

Commonly applied codes (such as ASHRAE 90.1) provide multiple compliance pathways, but leave room for local jurisdictions to maintain their own interpretations. Therefore, evaluators should work with local jurisdictions, program implementers, and evaluation managers and oversight agencies to identify the most appropriate baseline for a building. Further, local jurisdictions may adopt an updated building code during implementation of a program, so the evaluator may have to develop baselines from multiple building codes for a given program year.

Given the limited information available to assess new construction ECMs, using calibrated building simulations is often ~~offers~~ the only option for determining energy savings. Significant planning ~~is required to ensure~~ensures:

- ~~Detailed~~Evaluators develop detailed M&V plans ~~are developed for~~ each project site ~~evaluated; and~~
- ~~Sufficient~~The evaluation allows sufficient time ~~is allotted~~ to perform the analyses.

~~Additional~~Evaluators often collect additional information ~~is often collected~~ using ~~sub-metering~~submetering and/or consumption data analysis. As this information is important for model calibration ~~(rather than generating savings estimates directly)~~ sufficient time, the M&V plan should ~~be allotted~~allot sufficient time for a thorough analysis of all ~~sub-metered~~submetered data and consumption data.

~~Traditionally, incentivized buildings are evaluated~~For programs offering incentives, evaluators usually assess energy efficiency measure performance during ~~the~~the first few years of ~~their~~their operation. During this period, building systems and controls typically require troubleshooting,²⁵ and buildings have low-but-growing ~~building~~building occupancy rates.

~~As a final consideration,~~Evaluators should also keep in mind that owners (or tenants) may use building spaces differently than ~~was intended in the original design as originally designed~~. Thus, the specific codes or standards ~~to which governing~~ the ~~original~~originally permitted building

²⁵ ~~—~~ Troubleshooting is formally done through a commissioning process; however, not all buildings are professionally commissioned. ~~In~~ many facilities, facility management must “dial in” building controls.

|
| drawings ~~were intended to comply~~ may ~~prove inappropriate~~ not be appropriate for evaluation ~~of assessing actual energy use or~~ energy savings. ~~Such~~ This protocol strongly recommends evaluators consider these and other such factors ~~must be considered during calibration~~ when calibrating models and ~~when~~ simulating annual energy savings.

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