Best Practice Guideline for Emerging Technology Assessments: California Statewide Emerging Technologies Program

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ENERGY + WATER + EFFICIENCY

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1. Introduction

This document describes best practices for designing and conducting a Technology Assessment (TA) for an Emerging Technology (ET) as part of the California Emerging Technologies Program (ETP). The goal of a TA is to reliably estimate the likely energy and demand impacts of an ET.

This document is a companion to the ETP reporting template (see references in ***8.1. Document the Assessment***). The practitioners responsible for ETP technology assessments should follow the guidance provided here to develop the data and analyses required by the reporting template.

This document is subject to future updates as assessment techniques evolve or as the needs and requirements of the ETP change, therefore it is considered a “living document”.

1.1. Background

The 2006–2008 evaluation of the ETP included rigorous peer reviews of a sample of technology assessment reports and found significant variability in the quality of those technology assessments.

The evaluation offered specific recommendations for producing more consistent and reliable technology assessments. Revisions to the ETP template incorporated many of these recommendations.

1.2. Methodology

Development of this guideline started with the TA descriptions included in the ETP report templates for PG&E and SCE. It then added detailed descriptions and enhancements based on information from a variety of northwest regional, national and international resources, as listed in Section 8. References. With these combined resources, it is anticipated that following this guideline will produce superior TA results over currently described TA procedures. CPUC staff and contractors, and staff from PG&E, SCE, SDG&E, and SCG collaborated to develop this guideline on how to achieve a consistent level of quality and reliability in the statewide program’s estimates of energy and demand impacts. Multiple rounds of review were completed in an attempt to produce a concise and comprehensive document consistent with TA goals for ET projects. However, it is acknowledged that there was some IOU disagreement that this guideline should be titled a “best practices” document since it has not been empirically proven to produce superior TA results.

1.3. Purpose

The purpose of this guideline is to describe best practices for conducting technology assessments that obtain energy and/or demand savings either in a testing laboratory or in situ, i.e., in an operating residential or non-residential building or facility. This guideline does not address how to select the testing sites or the technologies to be assessed.

This guideline assumes that the technology and test sites have been selected and that their equipment, systems, and operating practices can be configured to fairly represent the incumbent technology[1]. Therefore, the guidance is useful once the practitioner begins designing and conducting the test. This includes guidance for specifying an appropriate energy-performance model, selecting and installing appropriate measurement systems, collecting the necessary data, and applying the energy-performance model[2] to determine the ET impacts.

1.4. Intended Audience

The primary audience for this guideline is the practitioners (IOU staff and/or contractors) responsible for completing a technology assessment. This guideline will help both IOU project managers and contractors by clarifying the expected scope of work for technology assessments. The guideline should also be useful to other IOU staff who authorize and supervise work conducted by the ETP. Finally, those who evaluate the effectiveness of the ETP should find this guideline useful in establishing quality benchmarks for technology assessments conducted by the ETP.

1.5. Using Independent Practitioners

The practitioner is the person primarily responsible for conducting the technology assessment. It is critical that this person has no stake in the outcome of the assessment. For example, a person holding a patent in a technology should not be allowed to assess an application of that technology, as the apparent financial conflict of interest would render the results suspect, especially if they were positive.

1.6. Key Knowledge and Skills of Practitioner

Practitioners should fully understand the following:

- This best-practices guideline
- The emerging technology being assessed, including how it works and how it saves energy compared to the incumbent technology
- Appropriate safety procedures
- The test sites and the condition and operation of the affected systems and equipment at those sites

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[1] The incumbent technology defines the baseline of energy use and energy demand for the ET affected system. See ***2.2. Affected System*** for a discussion of how to define the affected system.

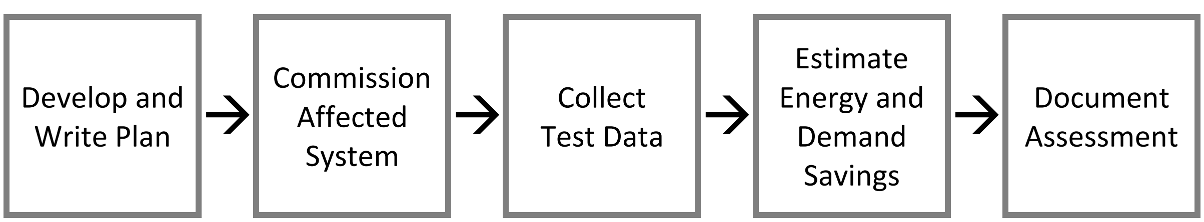
[2] In this context, “model” refers to any statistical or engineering calculations used to estimate ET energy and demand impacts or energy performance parameters. A model may be implemented through general-purpose software, e.g., the energy simulation model EnergyPlus, or in a custom spreadsheet.

Practitioners and their support teams must be able to perform the following tasks:

- Define the system affected by the ET, including substantial interactive components, e.g., those between refrigeration loads and HVAC loads.
- Identify the substantial determinants of system energy use, e.g., outside air temperature or cooling set point.
- Specify an energy-performance model (statistical or engineering) that reliably accounts for the substantial determinants, and which will be used to estimate energy and demand impacts of the ET on the affected system.
- Develop a technology-assessment plan for measuring incumbent and ET energy use and the substantial determinants of that use. This includes specifying appropriate measurement equipment, the associated installation and calibration procedures, and the required measurement intervals and duration.
- Verify the commissioning of the incumbent equipment and controls operating within the affected system, and verify the implementation and commissioning of the ET equipment and controls. See ***3. Commission the Affected*** System for more information.
- Collect measurements during the incumbent and ET periods, resolve problems with the measurement system, and process the data to make it ready for use in the energy-performance model.
- Use the energy-performance model to normalize energy use of the incumbent and ET measurements to typical operating conditions, e.g., normalize to CEC CTZ weather, and then use the normalized energy use in estimating typical ET impacts.
- Estimate the uncertainty of the impact estimate (see references in sections 8.2 and 8.3).
- Qualitatively describe the non-energy impacts of the ET.
- Follow appropriate safety rules and regulations during all site work.

1.7. Technology Assessment Tasks

This guideline focuses on five main tasks associated with a technology assessment, as shown in the figure below. The remainder of this document describes each task, using wording directed at practitioners.



Technology Assessment Tasks

2. Develop and Write an Assessment Plan

Conform to the following best practices when developing a technology-assessment plan. These best practices address five important topics within the technology-assessment plan:

1. How the ET saves energy
2. Systems and equipment that are affected by the ET
3. Experimental design used to estimate impact of the ET
4. Energy-performance model used to estimate impacts
5. ET testing plan

Each of these best practices is described below.

2.1. How the Emerging Technology Saves Energy

The plan should describe the ET, including:

- Physical principles that are the basis of the energy savings
- Substantial determinants of energy savings including:
  - Interactive effects between components
  - Hours and modes of operation
  - Equipment efficiency at full- and part-load operation
  - Equipment load profile
  - Control sequence and settings
  - Outside air temperature or other weather parameters
  - Production rate and schedule
- Applicability and adaptability including:
  - Types of facilities or systems that could successfully use the ET
  - Adaptability of the ET to other conditions such as different climate zones

2.2. Affected System

Identify the equipment (e.g., lighting fixtures or air-handling units) or components (e.g., window assemblies or duct insulation) whose operation or performance characteristics will be modified by the ET (i.e., the system/measure). The boundary of the ET system encompasses all of the significantly affected equipment and components. Equipment or components are considered insignificant if their combined effect on energy or demand savings is presumably less than 10%. The boundary may also need to include equipment whose operation is modified by interactive effects, e.g., interaction of lighting changes with heating/cooling loads and the resulting changes in HVAC energy consumption.

Prepare a diagram that shows the significantly affected equipment and components (and connections among them) that constitute the incumbent and ET configurations of the affected system. Name each piece of equipment on the drawing, and use these names when documenting measurement points for the incumbent and ET monitoring periods. Use this sketch later when preparing the instrumentation plan (see ***2.5.1 Instrumentation Plan***), which will show the location and type of each instrument used to collect measurements for the test.

2.3. Experimental Design

There are three possible experimental designs for technology assessments.

- The **pre/post design** involves collecting data on the incumbent configuration of the affected system for a period that captures the likely variations in the significant determinants of the system's energy use (the pre period). Following this period, the ET is delivered and commissioned and the data collection continues for a post period similar in duration to the pre period. This design requires that the test site be carefully managed to avoid any changes other than delivery of the ET during the pre and post periods.
- Consider the **on/off design** if the enabling technology for the ET can be easily disabled and when it is disabled the system can still satisfy its operational intent. For example, certain advanced unitary HVAC controls can be turned on and off. In this design, data is collected for a single calendar period during which the ET is cycled on and off in an appropriate pattern.
- The **post-only design** is least desirable. Use it if the pre energy use and demand is very clearly defined. Such a design might be used for a laboratory bench test of an ET unit in which the incumbent technology has previously been laboratory tested with clearly defined test protocols and published results. This design may also include the use of an approved simulation tool to estimate baseline energy usage.

Whichever design you select, carefully consider the duration of the experiment to provide adequate data for estimating annual energy savings. Document the experimental design completely so that an independent party can repeat the experiment with similar results under similar conditions.

2.4. Energy-Performance Model

Select an energy-performance model that can account for the substantial determinants of savings, and reliably estimate the savings of the ET relative to the incumbent technology. For electric technologies, the model must be able to estimate both energy and demand savings. For gas technologies, the model only needs to estimate energy. You may use a single model or adopt separate models suited to estimating either energy or demand. Demand models must be able to analyze appropriate demand periods, as defined by the IOU, for which the ET is being assessed.

2.4.1. Possible Models

Two types of energy-performance models may be applicable.

- **Statistical Models** fit a change-point model or a polynomial function to the relationship between energy use for affected systems and significant determinants, such as outdoor air temperature. An example of equipment that is affected by the ET would be a variable-flow heating hot-water pump. The flow rate is dependent on the space-heating load. The model would be based on a correlation between pump kW demand and outside air temperature. If it was a process heating load, the pump kW demand might be correlated to a production variable.
    - The model is fit (see references in sections 8.2 and 8.3) to measurements taken during both the incumbent and ET test periods.
    - The model is then used to estimate energy use for a typical year under the incumbent and ET conditions, based on a full year of data for determinants, e.g., production logs or typical outside air temperature.
    - The energy savings from the ET is equal to the difference between these two estimates of typical annual use
    - The electric model must also be able to distinguish savings during appropriate demand periods

  Several publications with detailed guidance on how to formulate statistical models are cited in section 8.2.

- **Engineering Models** rely on thermodynamic, heat transfer, and other physical principles to estimate energy use for systems and equipment. There are two important subcategories of these models.
    - **General Purpose Software**. Examples include DOE 2.1R, Trane Trace, eQUEST, EnergyPlus, and AIRMaster+.
        - The algorithms and available data input options used by the software should be well documented.
        - The person using the software should understand it fully.
    - **Custom Spreadsheets**. You may also consider using an engineering model built specifically for the technology assessment.
        - It should be based on engineering equations that represent the affected system.
        - It may be a bin model, e.g., loads averaged by 2°F outdoor-temperature bins.

  Use time-series measurements of energy use and significant determinants to calibrate any type of engineering model. More specific guidance on the selection, development, and use of engineering models is provided in several publications cited in sections 8.2 and 8.3.

2.4.2. Model Inputs

Describe all inputs to the selected energy model for both the incumbent and ET systems. Possible parameters include:

- Loads, e.g., air or water flow, Btu/h, cooling tons, and conveyance delivery rates
- Equipment performance, e.g., sizing, machine curves, part-load efficiency curves
- Control sequence and set points
- Envelope thermal properties, e.g., glazing U-values, infiltration rate, and insulation levels
- Distribution system properties, e.g., leakage, pressure drop, and insulation levels
- Operation-and-maintenance practices

Model inputs may be different for the incumbent and ET systems.

Also, normalize the model results to typical conditions. Weather conditions are often a significant determinant. The selected model may require actual weather for the test period, but use typical weather conditions to estimate the final impact. For typical weather, use the most recent CEC CTZ weather file for the location where the ET is implemented.

2.4.3. Model Specification

The specifications of the model will depend, in part, on what equipment and components constitute the affected system, and where the energy is saved. Here are some examples of challenges and solutions that you might encounter when developing a reliable specification for an energy-performance model.

- The performance of a variable-frequency drive on a heating hot-water pump may be affected by changes to valves controlling heating coils scattered throughout the facility. The ET may involve valve changes needed to implement variable flow control. Changes to the valves will change the heating coil loads and will affect the operation of the distant pump where the energy is saved. In this case, it makes sense to meter the pump kW demand and create a statistical model that correlates pump demand to the heating load or a proxy of the heating load such as outside air temperature or level of production. After the statistical model is specified, typical conditions can be input to the model to extrapolate to annual energy consumption.
- Some isolated equipment components may be better modeled with specialty software. For example, an air compressor might be modeled with AIRMaster+ software.
- When the affected system comprises more than one piece of equipment, multiple variables may affect the energy use of the system. An example is the conversion of a constant-volume HVAC system to a variable-air-volume system. In these cases, a more complex engineering model is needed to describe the relationship of the loads on the system to energy use. Several end uses may be affected, including fans and primary heating and cooling. It is even more complex if the heating and cooling loads are met by central-plant

chillers and boilers. If the HVAC system is only one of several in the facility, it would make more sense to create a bin model for the isolated single system and supporting equipment than to develop a whole-building model, especially if the energy savings is a small part of the total building energy use. However, if it is a small building with only one HVAC system, it may make more sense to use a whole-building model.

2.4.4. Best Practical Reliability

Each assessment should result in estimates of impacts with the best practical reliability. “Reliable” means that the method includes tests of the model that demonstrate it is free of substantial measurement bias.

- For statistical models, this requires at least achieving a good fit with the test metering.
- For engineering models, use the test metering either directly, such as in a spreadsheet bin model, or indirectly to calibrate a simulation model.
- The model (statistical or engineering) should accurately extrapolate short-term metering (if that is all that is practical) to estimate annual use.

“Practical” means that you can use proven techniques and resources deemed reasonable by the IOU manager to collect required data and perform the required analysis. Other factors may constrain what is practical to accomplish in an assessment, especially those conducted in situ. For example, the managers and occupants may only be willing to tolerate baseline measurements for a short period. Find strategies for minimizing constraints that limit the quality and quantity of the data collected and the analyses performed with that data.

2.5. Test Plan

Develop a plan for a test that will produce the data needed by the selected energy-performance model to reliably estimate ET savings. The plan should describe a fair comparison between the ET and the incumbent technology that it replaces. For example, existing lamps and ballasts will be replaced with new lamps and ballasts so that both technologies provide the same illumination levels and lighting quality. Another example is to add carbon-dioxide sensors to control outside air fraction, where the incumbent technology is an economizer control with minimum outside air per ventilation codes. The results would not be reliable if the incumbent system was set at minimum outside air other than the appropriate minimum, or have broken economizer controls that are fixed by adding the ET. The test plan should assume that both the incumbent and ET configuration of the system are commissioned as discussed in ***3. Commission the Affected System***.

The plan should also specify the following for both the incumbent and ET systems:

- **Energy Use**. Describe how the energy use of the effected system will be measured. This may involve one or more measurements of power and natural-gas use to isolate the energy use of the affected system.

- **Model Inputs**. Describe each of the inputs to the energy-performance model and the source of the input values. Input values might come from several sources and they may be derived from one or more primary data elements. For example, a simulation model might need the U-values of window assemblies. These might be derived from window-component specifications, building plans, and manufacturer specifications. Possible sources of model inputs include, but are not limited to:
  - **Test measurements**. All test plans will include collecting time-series measurements from one or more instruments, e.g., a poly-phase true-power transducer installed on an affected chiller. The plan should detail all necessary measurements as specified in ***2.5.1 Instrumentation Plan***.
  - **In-situ performance**. Metering to develop part-load performance curves is desirable as an alternative or an adjunct to the manufacturer's part-load performance data. For example, developing the part-load performance of a chiller based on metering data will account for in-situ conditions different from the conditions used in the manufacturer's tests.
  - **Testing Standards**. If applicable, use industry test standards, such as ARI or ASTM, that are appropriate for testing the ET equipment. This might be the case if a laboratory test is made on a more efficient version of an equipment item that currently has an associated test standard, such as for a new efficient refrigerator.
  - **Design documents**. These will show the location, connections, and specifications of affected equipment. Be wary of deviations between these documents and actual conditions, even if the documents are recent and labeled "as-built." Spot verification is always a good idea. Including photographs or videos of the equipment during the pre- and post-test periods could complement the design documents.
  - **Manufacturer specifications**. These include results from standardized tests and performance curves, nameplates, and other data. These are particularly critical when using engineering models to estimate savings. It is best to get this information from the contractor or trade ally most directly involved in the ET's delivery.
  - **Equipment databases**. These include equipment performance data or specifications. An example is MotorMaster+, which contains useful data on the efficiency curves for motors of many types and sizes.
  - **Weather data**. It is often necessary to use site-specific weather data. The National Weather Service maintains data from many measurement sites that can often meet the needs of the energy-performance model.
  - **Commissioning**. Tests performed to commission the affected system may provide inputs to the model.
- **Test Standards**. Specify any test standards that you will apply in the test. For example, ARI Standard 210/240 applies to tests of unitary air-conditioning and air-source heat-pump equipment. Reference each test standard and explain why it will be used and how the results of the test will be used in specifying the energy-performance model.

- **Data Frequency and Duration**. Describe the frequency and duration of data collection that is required to reliably specify the selected model. For example, 1-minute data might be needed to specify a statistical model for high-performance unitary HVAC equipment. You could use this high-resolution data to identify when the unit is in heating, cooling, or ventilating modes. The model might need data for periods that include both hot and cold weather conditions, and all the operating modes of the system. These periods should be sufficient to capture data over the necessary parameter ranges for both the incumbent technology and the ET conditions.

2.5.1. Instrumentation Plan

Most ET tests will require installing instruments to take various one-time and time-series measurements, e.g., air-leakage rate, true power, flow, temperature, humidity, and pressure. If such measurements are required, develop an instrumentation plan and include it in the ET test plan. The instrumentation plan should include:

- **Measurement Points**. List all measurement points. For each point, specify the expected range of measurement and the sensors selected for the measurement (manufacturer, model number, and individual and full-scale accuracies). Identify the locations of each sensor on the incumbent or ET system diagram (prepared as described in ***2.2. Affected System***). Sensors must be the appropriate type and size to ensure acceptable accuracy, which means that modeled energy impacts will not change by more than 5% over the range of expected measurement error.
- **Control System Points**. Some measurement points may be part of existing control systems operated at the test sites. Document these in the same way as measurement points that will be added specifically for the assessment. Use them only if they can provide acceptably accurate data, which means that modeled energy impacts will not change by more than 5% over the range of expected measurement error.
- **Data recording**. Specify the instrument(s) used with the sensors to record the measurements. Specify the data-scanning rate, unit conversion, and recording intervals for each sensor. Describe how the data are acquired, e.g., cellular modem, customer Ethernet, or manual download. Specify how often the data are downloaded. The frequency of downloads will be dictated by the storage capacity, number of data points, size of the data, and the frequency of measurements. Data download procedures may also be dictated by the capabilities of customer control systems, if these are used to capture test data.
- **Measurement Methods**. Specify the standard methods used for each measurement. For example, *ANSI/ASHRAE 41.7, Standard Method for Measurement of Flow of Gas*, *ANSI/ASHRAE 41.1, Standard Method for Temperature Measurement*, or *IEEE 1159, Recommended Practice for Monitoring Electric Power Qualify*. For an explanation of possible metering technologies, and guidance on how to select the appropriate technology for each measurement, see *Metering Best Practices: A Guide to Achieving Utility Resource Efficiency*, U.S. Department of Energy, August 2011.

2.5.2. Instrument Installation and Calibration

Describe the installation and calibration of all measurement instruments. Some of these may already be in place as part of the control systems operated at the test sites. Whether they are installed under your supervision or are already in place, make sure the sensors are installed and calibrated properly.

- **Installation**. Make sure sensors are installed at points in the system that will provide accurate measurements. For example, flow measurement in ducts must be a sufficient distance from bends and flow restrictions. The test plan should require that sensors be installed by a qualified installer (electrician, plumber, steam fitter, etc.) under your direct supervision. Take photographs of the sensor installations and archive them with the assessment data.
- **Calibration**. Where possible, require the use of recently calibrated sensors. If this is not possible, take redundant short-term measurements with high-quality calibrated instruments to confirm that critical sensors are transmitting reasonable values. In some instances, it will not be practical to take either redundant measurements or to have sensors calibrated. In that case, use data analysis to determine whether the measurements are usable and to adjust the energy-performance model.

  If it is not possible to remove an instrument (e.g., it belongs to the customer and is permanently installed in the system) for calibration, and if short-term measurements by calibrated instruments indicate that the in-situ instrument is more than 5% out of calibration, then measure and record values under the full range of anticipated system operation, and develop a calibration curve, so that you can correct data from the in-situ, long-term measurement system.

See section 10.3 in the 2012 version of the *International Performance Measurement and Verification Protocol (IPMVP)* for references related to instrument calibration.

3. COMMISSION THE AFFECTED SYSTEM

The goal of commissioning is to ensure the affected system is operating as intended. If possible, the operational intent should be the same for the incumbent and ET configurations of the system. The amount of energy required to satisfy this intent may change significantly when the ET is delivered, but the intent should not change. If there are unavoidable changes in intent, (e.g., more comfortable temperatures in conditioned spaces), the energy modeling, (see ***5. Estimate Energy and Demand Impacts***), should account for these changes in order to fairly compare the incumbent and ET configurations of the affected system.

It is important to commission the equipment in the incumbent system so that it is operating as intended and its performance is consistent with new equipment. This provides a better assessment of the ET and prevents poorly operating incumbent equipment from biasing the impact estimate. Likewise, the ET configuration of the affected system must be commissioned to ensure that it also conforms to the system's operational intent.

To achieve these commission goals:

- Establish the operational intent of the affected system.
- Examine equipment-installation documentation and functional-performance-test results.
- Perform additional tests, if needed.
- Resolve any performance issues.

If the incumbent technology does not need to be or cannot be commissioned (such as an electric motor), or the uncommissioned equipment is clearly representative of the typical incumbent technology, then no commissioning is required. Clearly document the basis of any decision not to commission any incumbent technology.

4. Collect Test Data

This section provides guidance for collecting data. When data should be collected is dictated by the experimental design and the data requirements of the selected energy-performance model, which are discussed in ***2. Develop and Write an Assessment Plan***.

4.1. Inspection and Interview

Gather data during one or more visits to the test site. Data are obtained by inspecting the affected system and by interviewing site staff or vendors who are familiar with operation, maintenance, and performance of the affected system. Conduct an initial inspection to gather the information needed to formulate the assessment plan. Other inspections may be needed for the following purposes:

- Supervising or confirming the commissioning of the incumbent or ET system configuration
- Implementing the incumbent or ET instrumentation plan
- Resolving problems with test instrumentation during the incumbent or ET data-collection periods

During all inspections, take photographs to document the configuration of the system and the test instrumentation.

4.2. Test Metering

Install and operate the instrumentation, including both one-time measurements or metering over time, during the periods and under the conditions specified in the test plan. Safety is paramount. Potential hazards include falls, electric shock, and damaging interactions with moving parts. Make sure you are familiar with the relevant safety procedures, as stated in ***1.6. Key Knowledge and Skills of Practitioner***. Also, take precautions to prevent any unintended interruption to the end user's equipment or systems. If ET testing will interrupt work schedules or production at the facility, get the end user's approval in advance.

Some end users may want "outside staff" working on critical equipment and systems. In those cases, enlist the assistance of end-user staff or their trusted vendors in completing the installation and configuring the trend-metering equipment.

4.2.1. Data Acquisition

You can acquire data either by installing instruments specifically for the assessment or by obtaining data from the monitoring and control system at the site. In either case, confirm at the beginning of any data-collection period that the data are being acquired and are usable and reliable. Where possible, compare redundant measurements made with high-quality calibrated instruments to output from the data loggers or trend logs at the beginning of the data-collection period. If you need to collect data over extended periods, routinely confirm that the collected data usable, and if not, take remedial action. This is especially important for data from the incumbent system, because the window of opportunity for collecting data may be limited, and acquisition failures may be impossible to remediate.

4.2.2. Preparing Analysis-Ready Trends

Even when applying best practices for selecting, installing, and calibrating sensors, and acquiring data, it is still likely that some of the data acquired will be defective. Examine all data that fall outside the expected range of any measurement. Small calibration errors commonly appear as negative values in trend logs. Check for unexpected sequences of identical values that do not correspond to known modes of operation for the equipment being measured. Also, identify any unexpected relationships between measurements and their primary determinants, such as power to a chiller and outside air temperature.

Inspecting collected data may reveal that certain intervals of measurements are unusable. Ignore these when estimating savings. It is good practice to automate data editing, e.g., using formulae in a spreadsheet to document how the data has been modified. If data must be edited manually, do so on a copy of the primary data, and document how the data were modified.

5. Estimate Energy and Demand Impacts

Estimate the energy and demand impacts for each test site using the selected energy-performance model (see ***2.4. Energy-Performance Model***) and the data collected according to the test plan. Energy savings should be the difference between the energy use of the incumbent technology and the ET under typical conditions. Similarly, demand savings should be the difference between the peak demand, for demand periods defined by the IOU, of the incumbent technology and the ET.

5.1. Calibrate Engineering Models

As discussed in ***2.4. Energy-Performance Model***, engineering models rely on thermodynamic, heat-transfer, and other physical principles to estimate energy use for systems and equipment. If practical, measure the energy use of the modeled system for the ET and incumbent periods. Compare the estimated energy use, derived from the model, to the measured use. If appropriate, adjust the model inputs or specification to calibrate the model to the measured use. The objective of the calibration is to reduce the difference between the modeled and measured use so that it is within the limits defined by the IPMVP Option D protocol summarized in the table below. Bin models and statistical models can also be specified to achieve these limits by applying the model to hourly data and comparing monthly and hourly values of metered data.

Data Interval	Maximum Root Mean Square (RMS) Error	Maximum Mean Bias Error
Monthly	$\pm$ 15%	$\pm$ 5%
Hourly	$\pm$ 30%	$\pm$ 10%

5.2. Estimate Typical Impacts

Specify and calibrate models using data from the incumbent and ET data-collection periods. But also estimate savings for typical conditions. For models of weather-dependent technologies, use the CEC CTZ weather data to estimate typical savings. Develop customized, site-specific methods to account for factors other than weather. For example, at an industrial site, multiyear records of seasonal production levels might be needed to adjust for typical production levels in modeling both the incumbent and ET periods.

5.3. Estimate Uncertainty

For statistical models, compute uncertainty in the estimates of energy and demand savings and report it according to ASHRAE Guideline 14. You can use models such as ECAM to compute these uncertainty values. Consult various references in sections 8.2 and 8.3 for other techniques that may apply to estimating uncertainty from complex engineering models.

6. Document the Assessment

Document the assessment completely. Include the assessment plan, the test results, and all associated electronic data, model, and analytical files. The information should be consistent with the statewide ETP report template (to be developed and based on the IOU templates and modified to be consistent with this guideline).

Some of the report components are described below.

6.1. Plan Document

Include the original plan for the assessment as an appendix.

6.2. Document the Model, Data, and Analysis

Document the model, data, and impact analysis with sufficient detail to allow an appropriately skilled analyst to review it for quality control. The documentation should allow the reviewer to reproduce the savings results, assuming that they have access to the software used for the assessment. If the analysis involved custom spreadsheet models, include those files in the final documentation. Those spreadsheets should adhere to the following practices:

- Organize sheets into sections for each savings calculation:
  - Summary of Results – along with an estimate of uncertainty (to the extent possible)
  - General Fixed Inputs – baseline and post
  - Curve Fits – baseline and expected post
  - Equations – list and explanation
  - Calculations – by category (occupancy, equipment status, day type, etc.)
- Do not bury literal constants inside formulas.
- Explain any uncommon constants.
- List equations including explanations of variables.
- Use names for variables instead of cell references as much as practical.
- Break long calculations into multiple steps where it will enhance clarity.
- If breaking up a long calculation will increase clutter, thereby reducing clarity, explain the calculation in a cell comment or on a separate worksheet.

If the analysis used general-purpose software, such as DOE 2.1R, eQUEST, or AIRMaster+, include all input data and files needed to run the model (such as weather data) and all output files with the documentation. The documentation should clearly state what runs were performed with which version of the software and how the outputs were used in estimating savings.

If the software used in the analysis is not inherently transparent, document it fully. Describe completely the exact algorithms for all calculations in a document accessible to all practitioners, or document the analysis method along with the results of a validation process similar to ASHRAE Standard 140, which demonstrates the comparability of the method to other accepted calculation methods.

6.3. Identify Non-Energy Impacts

Identify and document the non-energy impacts of the ET to the extent feasible. This can be anecdotal, but quantify the impacts whenever possible. Examples of these impacts are:

- Improved quality, such as a process change that improves the purity of the final product from 98% to 99.5% pure.
- Greater productivity and/or comfort, such as a lighting system that provides better color rendering for the specific task, thus reducing eye fatigue and increasing worker productivity.
- Longer lifetime, such as an LED light source that has a longer lifetime than a fluorescent light source
- Reduced or increased maintenance cost, such as long-life light sources that reduce the maintenance cost to replace them, or specialized equipment that requires additional staff training to maintain, or that requires maintenance by the manufacturer
- Reduction of waste products, such as more efficient dewatering equipment for a waste-water treatment plant that reduced the volume and weight of solid waste requiring disposal.
- Environmental/air-quality benefits (listed or quantified, if data is available)

7. GLOSSARY

Term	Definition
ANSI	American National Standards Institute
ARI	American Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CEC	California Energy Commission
CEC CTZ	California Energy Commission California Thermal Zones, typical weather data for 16 zones
CPUC	California Public Utilities Commission
ECAM	Energy Charting and Metrics tool
ET	Emerging Technology
ETP	Emerging Technology Program
IEEE	Institute of Electrical and Electronic Engineers
Incumbent technology	defines the baseline of energy use and energy demand for the ET affected system (see ***2.2 Affected System*** for a discussion of how to define the affected system)
IOU	Investor Owned Utility
IPMVP	International Performance Measurement and Verification Protocol

8. References

The following documents provide specific guidance relevant to designing and conducting ET assessments.

8.1. ETP Reporting Documents

Evaluation of the California Statewide Emerging Technologies Program. Summit Blue Consulting. February 2010.

CA Energy Efficiency Strategic Plan. California Public Utilities Commission. January 2011 Update.

PG&E's Emerging Technologies (ET) Final Report Template. PG&E. 2012.

PG&E's Emerging Technologies (ET) Project Handbook, Version 1.0. PG&E. April 26, 2011.

Emerging Technologies Program – Operation and Procedures Guide. SCE. November 2011. [This document includes SCE's report template.]

8.2. Statistical and Engineering Modelling

NIST/SEMATECH e-Handbook of Statistical Methods, http://www.itl.nist.gov/div898/handbook/

Applied Data Analysis and Modeling for Energy Engineers and Scientists. Reddy, T. Agami. Springer, 2011.

Guideline 14-2002 – Measurement of Energy and Demand Savings. ASHRAE. 2002.

Regression for M&V: Reference Guide. Bonneville Power Administration. September 2011.

Applied Data Analysis and Modeling for Energy Engineers and Scientists, Reddy, T. Agami. Springer, 2011 edition.

8.3. Energy Savings Estimation

International Performance Measurement and Verification Protocol. Efficiency Valuation Organization. January 2012.

Evaluation of the 2010-2012 Custom Impact Energy Efficiency Programs for the California IOUs – Procedures for Site-Specific Impact Analysis. Itron, Inc. and KEMA, Inc. January 2012.

Guidelines for the Estimation of Energy Savings. Regional Technical Forum. April 2013.

Verification by Energy Modeling Protocol. Bonneville Power Administration. September 2011.

Verification by Equipment or End-Use Metering Protocol. Bonneville Power Administration. September 2011.

Uniform Methods Project, U.S. Department of Energy, April, 2013.

Energy Efficiency Program Impact Evaluation Guide, http://www1.eere.energy.gov/seeaction/pdfs/emv_ee_program_impact_guide.pdf. Evaluation, Measurement, and Verification Working Group. December 2012.

9. Appendix A: Public Comments

This appendix presents the written comments on the draft report that were submitted by the public and the formal responses to these comments. These comments have been taken into account in the preparation of the final report.

Source	IOU Comment	Response	Page #
SCE	Request an explanation in the document of how the term "best practices" differs from that of the energy efficiency industry. Please include clarification that these ET Assessment Guidelines have not been linked to any "superior results" as such.	Revision in Methodology section of report to acknowledge that there was some IOU disagreement that this guideline should be titled a "best practices." A sentence was added to note that following this guideline will produce superior TA results over currently described TA procedures.	Page 1
SCE, PG&E	Request that a statement be included that these Guidelines are a living document that will change and be updated as new information becomes available.	Sentence added in the Introduction section of report.	Page 1
SCE	Remove from the cover the statement that these guidelines were done in collaboration with IOU staff. Also, please add that that there was disagreement about using the term "best practices".	IOUs removed from the cover and disagreement about the term "best practices" was added to the Methodology section	Cover, Page 1
PG&E	Report would benefit from short Methodology section to help the reader better understand how the list was compiled and the criteria used to determine best practices.	Addition of Methodology section.	Page 1
PG&E	Suggest changing the title of Section 1.5 (now 1.6) to "Key Knowledge and Skills of Practitioner" and replace "must" with "should" in the first sentence.	Section title revised as well as replacing "must" with "should"	Page 2
PG&E	To maintain consistency with other reports, suggest that "In Collaboration with ETP Staff" is removed from the cover and the IOUs be recognized in the new Methodology report section.	IOU's removed from the cover and their role is described in the Methodology section.	Page 1