Chapter 10: Peak Demand and Time-Differentiated Energy Savings Cross-Cutting Protocol

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

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Preface

This document was developed for the U.S. Department of Energy Uniform Methods Project (UMP). The UMP provides model protocols for determining energy and demand savings that result from specific energy-efficiency measures implemented through state and utility programs. In most cases, the measure protocols are based on a particular option identified by the International Performance Verification and Measurement Protocol; however, this work provides a more detailed approach to implementing that option. Each chapter is written by technical experts in collaboration with their peers, reviewed by industry experts, and subject to public review and comment. The protocols are updated on an as-needed basis.

The UMP protocols can be used by utilities, program administrators, public utility commissions, evaluators, and other stakeholders for both program planning and evaluation.

To learn more about the UMP, visit the website, https://energy.gov/eere/about-us/ump-home, or download the UMP introduction document at http://www.nrel.gov/docs/fy17osti/68557.pdf.

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Acronyms

AMI	automated metering infrastructure
CFL	compact fluorescent lamp
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
HVAC	heating, ventilating, and air conditioning
IPMVP	International Performance Measurement and Verification Protocol
ISO	independent system operator
kWh	kilowatt hour
LOLP	loss of load probability
MW	megawatt
MWh	megawatt hour
NEEP	Northeast Energy Efficiency Partnerships
NILM	non-intrusive load monitoring
NREL	National Renewable Energy Laboratory
RLF	rated load factor
RTO	regional transmission organization
SAE	statistically adjusted engineering
TRM	technical reference manual
UMP	Uniform Methods Project

Protocol Updates

The original version of this protocol was published in April 2013. This version has been updated to incorporate the following revisions:

- Expanded definition of coincidence and diversity factors
- Expanded interval metered data analysis discussion to include recent work related to non-intrusive load monitoring
- Added discussion of preferred applications and limitations
- Added recent relevant references.

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1 Introduction

Savings from electric energy efficiency measures and programs are often expressed in terms of annual energy and presented as kilowatt-hours per year (kWh/year). However, for a full assessment of the value of these savings, it is usually necessary to consider the measure or program's impact on peak demand as well as time-differentiated energy savings.[1]

This cross-cutting protocol describes methods for estimating the peak demand and time-differentiated energy impacts of measures implemented through energy efficiency programs.[2]

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[1] While natural gas peak demand impacts can be important in some situations, most utility programs do not attempt to generate peak demand impacts for natural gas or any other energy type except for electricity. As a result, this protocol focuses only on electricity peak demand and time-differentiated energy savings. The fundamental principles laid out in this chapter may be applied to peak demand and time-differentiated savings for other energy and water impacts.

[2] As discussed in the "Considering Resource Constraints" section of the Introduction chapter to this report, small utilities (as defined under U.S. Small Business Administration regulations) may face additional constraints in undertaking this protocol. Therefore, alternative methodologies should be considered for such utilities.

2 Purpose of Peak Demand and Time-Differentiated Energy Savings

Energy efficiency measures and programs frequently reduce peak demand and, consequently, the need for investment in new generation, transmission, and distribution systems. To estimate the value of these avoided costs—called "avoided capacity costs"—it is necessary to estimate peak demand savings. Peak demand savings are typically expressed as the average energy savings during a system's peak period. Avoided capacity costs can account for a substantial portion of the total value of an energy efficiency measure or program, particularly for those that produce savings coincident with the system peak.

The need to estimate peak demand savings is becoming more important as the value of avoided capacity costs increases, and as regional transmission organizations (RTOs, such as PJM and independent system operator [ISO]-New England) allow energy efficiency resources to be bid into the forward-capacity markets and be used to earn revenues.[3]

In addition to considering peak demand savings, evaluators often must calculate time-differentiated energy savings, or the energy savings that occur at different times of the day (e.g., morning or evening) or times of the year (e.g., summer or winter). This is because avoided energy costs are typically provided in terms of costing periods, which allocate the 8,760 hours of the year into periods with similar avoided capacity costs. These costing periods, which are utility/RTO/ISO-specific, tend to vary monthly, seasonally, and/or in terms of time of day (peak, off-peak, super-peak).[4]

When estimating the impacts of energy efficiency measures and programs, calculating load impacts on an hourly basis provides flexibility in applying the results to a variety of costing period definitions. The cost period used can significantly affect the value of the energy savings. For example, a measure that reduces energy mostly at night (typically a low-cost, off-peak costing period) is not as valuable as one that reduces energy mostly during the summer afternoon peak load periods, as shown in Figure 1.

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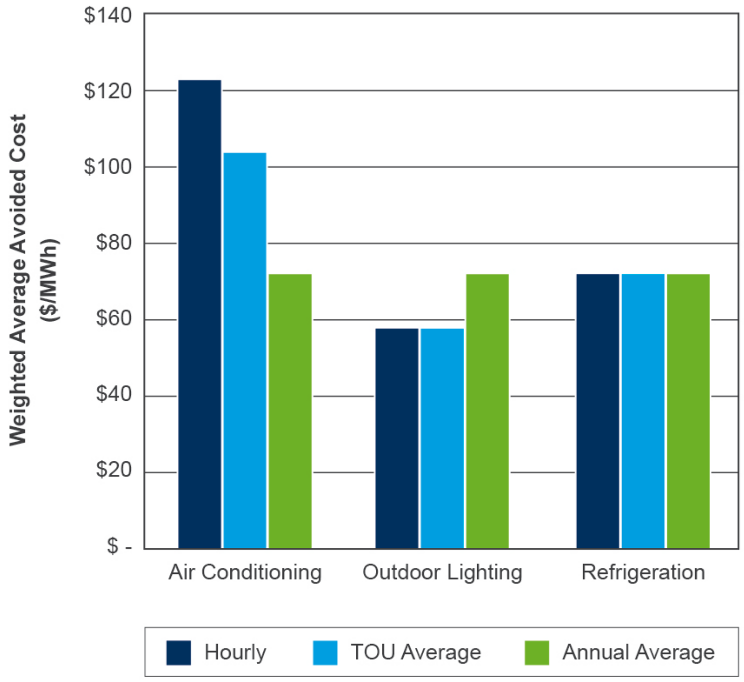
[3] Regional transmission markets obtain the capacity resources for ensuring system reliability. In some regions, energy efficiency is considered to be a resource comparable to traditional generating resources and can be included into these markets on an equivalent basis to supply-side resources. Bids must be supported by measurement and verification.

[4] Avoided energy costs tend to be more expensive during periods of higher demand because generating units available during those times tends to have lower efficiency and higher operating costs.



Source:

Figure 1. Consideration of time-differentiation in energy savings significantly affects estimates of the value of savings (EPA and DOE 2006)

In this example, the air conditioning efficiency measure has a higher value when considering hourly savings and costs because usage is higher when avoided costs are more expensive. Conversely, an outdoor lighting measure will have a lower value when considering hourly savings and costs as those savings typically occur during off-peak nighttime hours.

Peak periods typically relate to capacity limitations on physical equipment within the grid and may vary by location (e.g., a specific overloaded feeder may have a different peak than the overall grid). The load will approach the available capacity as a result of a combination of weather and behavior, causing the load to increase or some other impact causing the available capacity to decrease (such as a shortage of natural gas). A peak period can range from one 5-minute burst at a random time, driven by an irregular high-usage event,[5] to one hour per year or several hours per day during a season. When transmission and distribution operators define peaks, they frequently use a combination of time of day and weather as peaks tend to occur during extreme hot or cold temperatures.

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[5] In the UK, short bursts of electricity peak demand have correlated with the end of events, such as popular TV shows, World Cup matches, or solar eclipses.

3 Key Concepts

Understanding demand savings requires understanding the relationship between several factors—some of which have conflicting definitions. Figure 2 shows one such construct.

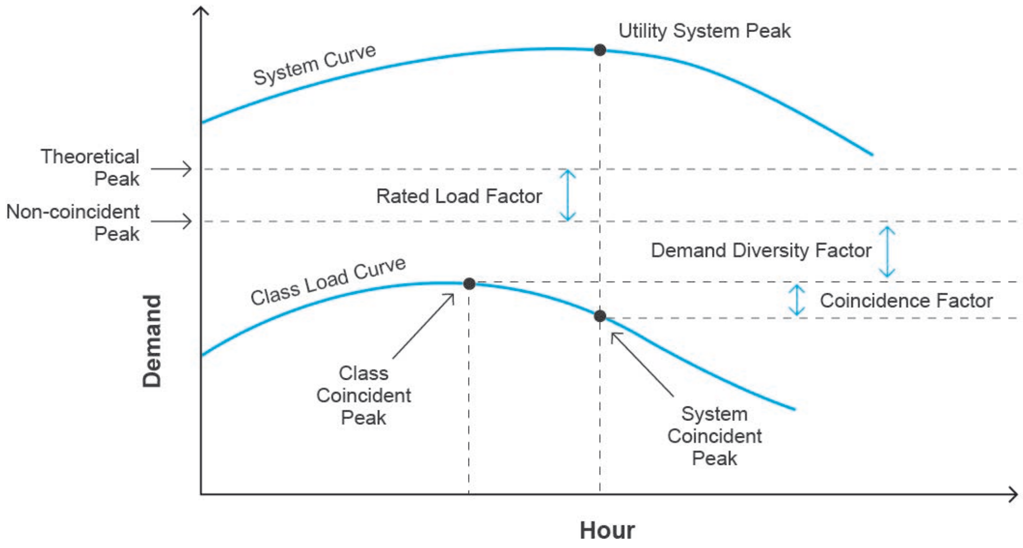

Figure 2. Demand savings relationships[6] (Jacobs 1993)

These brief definitions describe the key factors within this construct:

- **Peak period** is the period during which peak demand savings are estimated. Some utilities have a winter and summer peak period. The peak period definition may also include weather conditions.
- **Theoretical peak** is the usage of a population of equipment if all operate at nameplate capacity.
- **Non-coincident peak** is the sum of the individual maximum demands, regardless of time of occurrence within a specified period.
- **Rated load factor (RLF)** is the ratio of maximum operating demand of a population of equipment to the nameplate power/capacity. It is the ratio of non-coincident peak to theoretical peak. For example, a building that dims its lamps to 90% of their output has a RLF of 0.9.
- **Demand diversity factor** is the ratio of the peak demand of a population of units to the sum of the non-coincident peak demands of all individual units. While an individual efficiency technology may save a certain amount of demand, those technologies do not all operate at the same time across all buildings throughout the

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[6] Rated load factor, demand diversity factor, and coincidence factor are sometimes combined and referred to as "coincidence factor."

region. For example, if a maximum of 7 of 10 installed compact fluorescent lamps (CFLs) are on at any given time, the diversity factor is 0.7.

- **Coincidence factor** is the fraction of peak demand of a population in operation at the time of system peak. Thus, it equals the ratio of the population's demand at the time of the system peak to its non-coincident peak demand. The peak demand use for a given building and end use typically do not align exactly with the utility system peak, which is how avoided peak demand is defined. For example, if at the time of system peak, only 3 of the 7 CFLs mentioned above are on, then the coincidence factor is 3/7.

The Northeast Energy Efficiency Partnerships (NEEP) defines a coincidence factor as, “The ratio of the average hourly demand during a specified period of a group of electrical appliances, or consumers to the sum of their individual maximum demands (or connected loads) within the same period.” (NEEP 2011). This corresponds to the product of rated load factors, demand diversity factors, and coincidence factors, as defined above.

IEC60050—International Electrotechnical Vocabulary (International Electrotechnical Commission 2016) defines coincidence and diversity as:

- **Coincidence factor** is the ratio, expressed as a numerical value or as a percentage, of the simultaneous maximum demand of a group of electrical appliances or consumers within a specified period to the sum of their individual maximum demands within the same period. Per this definition, the value always remains less than or equal to 1 and can be expressed as a percentage.

- **Diversity factor** is the reciprocal of the coincidence factor, which means it will always be greater than or equal to 1.

The following terms are also important in understanding peak demand:

- **Average (or Annual Average) megawatt (MWa or aMW).** One megawatt of capacity produced continuously over a period of one year.

  $$1 \text{ aMW} = 1 \text{ MW} \times 8{,}760 \text{ hours/year} = 8{,}760 \text{ MWh}$$

- **Load factor.** The ratio of average energy savings to peak energy savings. This is also known as “peak coincidence factor” (NYSERDA 2008).

  $$Load\ factor = \frac{Energy\ savings}{Peak\ demand\ savings \times 8760\ hours}$$

- **Loss of load probability (LOLP).** The likelihood that a system will be unable to meet demand requirements during a certain period. LOLP can be used to distribute avoided capacity costs to each hour of the year.

4 Methods of Determining Peak Demand and Time-Differentiated Energy Impacts

Estimating peak demand and time-differentiated energy savings may require different techniques than estimating annual energy savings. For example, the method used to estimate demand savings may not be the most appropriate method to estimate energy savings—and vice versa (Fels 1993).

Peak demand and time-differentiated energy impacts are typically more difficult to measure than annual energy savings impacts (York 2007), and may require additional metering or simulation analysis to estimate these impacts accurately.

Peak demand savings and time-differentiated energy savings can be estimated with:

- Engineering algorithms
- Calibrated hourly building simulation modeling
- Billing data analysis
- Interval metered data analysis
- Non-intrusive load monitoring
- End-use metered data analysis
- Survey data on hours of use.

Approaches can also be combined to leverage available information. For example, a method used to estimate annual energy savings that does not directly provide peak demand savings (such as monthly billing data analysis) can be used with load shapes to estimate peak or hourly impacts.

The more closely the time-based impacts of a device or measure can be calculated, the more accurate and supportable the results will likely be. This means that directly measuring an end use of interest will generally provide the most accurate results. Other methods are generally used to provide a lower-cost means of estimating measure-level peak demand impacts or, in rare cases, are used where direct measurement does not work.

The following sections examine the various methods for estimating peak demand and time-differentiated energy savings, and discuss the preferred applications and limitations for each method. Table 1 presents a summary of all approaches.

4.1 Engineering Algorithms

Algorithms can be used to estimate peak demand savings. The demand algorithm in Equation 1 is similar to the energy algorithm in Equation 2 (used to estimate annual energy savings), except that the demand equation has the diversity factor and the coincidence factor in place of the full load hours.

Equation 1

$$\Delta kW_{gross} = units\ \times RLF \times \left[\left(\frac{kW}{unit}\right)_{base} - \left(\frac{kW}{unit}\right)_{ee}\right] \times \boldsymbol{DF}\ \times \boldsymbol{CF} \times (1 + HVAC_d)$$

Where:

ΔkW_{gross} = gross demand savings
Units = units of measure installed in the program
RLF = rated load factor
kW/unit = unit demand of measure
DF = diversity factor
CF = coincidence factor
$HVAC_d$ = HVAC system interaction factor for demand

Source: (TecMarket Works 2004)

Equation 2

$$\Delta kWh_{gross} = units\ \times RLF \times \left[\left(\frac{kW}{unit}\right)_{base} - \left(\frac{kW}{unit}\right)_{ee}\right] \times \boldsymbol{FLH} \times (1 + HVAC_c)$$

Source: (TecMarket Works 2004)

Preferred Applications: Engineering algorithms are most useful for quickly and inexpensively estimating prescriptive program impacts for measures or programs with accurate and stable parameter estimates from previous studies. This approach is common for residential and commercial lighting measures where confidence and diversity factors have been previously measured.

Limitations: To acquire good estimates for an alogrithm's time-based parameters, results from another method must be extrapolated from another place or a previous study. Differences in the installation context may cause biased results. For example, the residential lighting consumption patterns of retirees in Arizona may be very different than the residential lighting consumption patterns of young apartment-dwellers in Brooklyn.

4.2 Calibrated Hourly Building Simulation Modeling

Hourly building simulation modeling (International Performance Measurement and Verification Protocol [IPMVP] Option D) can produce hourly savings estimates for whole buildings as well as for specific end uses. It is an excellent means of estimating peak demand and time-differentiated energy savings. A building energy simulation model combines building characteristic data and weather data to calculate energy flows. While hourly models calculate energy consumption at a high frequency, non-hourly models may use simplified monthly- or annual-degree-day or degree-hour methods with limited applications to calculating time-differentiated impacts. Hundreds of building energy simulation programs have been developed over the past 50 years (Crawley 2005). This chapter differentiates between calibrated building simulations, which calibrate models to the primary usage data from the group studied, and uncalibrated building simulation, as described in Section 5.3. Calibrated building simulation is generally much more accurate than uncalibrated building simulation.

Preferred Applications: Building simulation models serve as an ideal method for extrapolating observable data to unobservable scenarios, or for capturing interactive effects that may be difficult or impossible to measure directly. They prove most applicable for heating, ventilating, and air conditioning (HVAC) and shell measure impacts. Preferred applications include estimating savings for new construction applications that have unobservable code-baseline buildings, extrapolating measured weather-sensitive data to extreme weather conditions, and calculating HVAC's interactive effects on lighting and equipment measures.

Limitations: Simulation modeling requires an experienced modeler who understands energy engineering. Using this method does not necessarily provide an estimate of diversified demand. If using a single, typical building, demand savings would be overstated due to a lack of consideration of diversity, which tends to smooth out the usage spikes seen in individual buildings. Consideration of diversity requires either using average schedules in an aggregate building simulation model[7] or simulating a sample of buildings with different sizes, climates, and schedules. A building simulation model, however, can be only as good as the data it calibrates to. Deriving accurate hourly load shape results from a building simulation model requires—at a minimum—calibrating the model to hourly whole-facility load shape data.

4.3 Billing Data Analysis with Load Shapes

Billing data analysis (IPMVP Option C) is a common evaluation method for many common energy efficiency measures and programs and has been used traditionally to develop monthly and annual estimates of energy savings (Agnew 2017). Such analysis entails statistical comparison of pre- and post-participation and/or participant and nonparticipant billing data and may require control for non-programmatic influences, such as weather and economic conditions, to estimate savings.

Billing data analysis does not directly estimate peak demand or hourly energy savings, but can be combined with other tools to estimate these impacts.

Preferred Applications: Billing data analysis can be used to derive a realization rate using an engineering algorithm for energy savings from *in situ* baseline measures, which also may be applied to a demand savings algorithm by using a previously calculated load shape. In this case, the billing analysis would not determine the shape of savings, which derive from the previously defined shape or demand parameters, but it would prove useful for determining the savings' amplitude.

Limitations: As addressed in UMP *Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol*, billing analysis does not work with non-retrofit baseline measures. Further, monthly building peak demand typically does not prove useful for estimating peak demand savings, given that billing peak demand typically is not coincident with utility system

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[7] An aggregate building simulation model uses all empirical relationships included in a building simulation model; however, it is calibrated to match the load shape and characteristics of a large group of buildings (e.g., program participants in a given sector) rather than an individual building. Aggregate building simulation models can look more abstract than engineers prefer, while lacking the mathematical purity desired by econometricians accustomed to abstraction.

peak. Isolating the impacts of a specific measure can be difficult because the meter measures usage for an entire building.

4.4 Interval Metered Data Analysis

Utility revenue interval meters, including automated metering infrastructure (AMI) meters, can measure usage at the whole-building level in increments of 15 minutes or less. Because consumption during different periods may be billed at different rates, these meters provide a means for analyzing a customer's load pattern. Interval meter data analysis is essentially the billing data analysis discussed above but with a finer time resolution. As with billing analysis, isolating a specific measure's impacts can be difficult, and statistical analysis may be required to control for non-programmatic influences. With the advent of AMI and increased access to hourly information, additional statistical approaches (such as conditional demand type analysis on hourly data) can be used to help develop estimates of demand savings.

Preferred Applications: Use of interval metered data for calculating demand savings is preferred for measures with energy savings calculated using billing analysis. This includes retrofit measure baselines with sufficient savings and participants to produce statistically significant results. Large home performance programs with insulation and air sealing measures are a good example application.

Limitations: Isolating a specific measure's impacts can be difficult, and statistical analysis may be required to control for non-programmatic influences.

4.5 Non-Intrusive Load Monitoring (NILM)

Numerous hardware and software vendors have made varying claims regarding the ability to disaggregate whole-premise interval data into individual end use load shapes—a process known as non-intrusive load monitoring (NILM). NILM combines software and hardware in many different configurations, such as (Mass Save 2016):

1. Software-based solutions that disaggregate data from third-party software
2. Utility smart meters providing data transmission via a Wi-Fi-connected gateway
3. Current transformer-based devices that monitor voltage and current at the home electrical panel or meter
4. Utility meter-reading devices—devices installed at the meter and using meter/optical sensors.

The applications range from devices that record and process data at rates higher than 1 hertz to software working with large volumes of hourly AMI data. The former might cost around $1,000 or more per site, while the latter might cost less than $1 per site.

Preferred Applications: NILM works better for disaggregating larger and more unique loads within smaller facilities,[8] and for loads correlating with other observable data (e.g., weather-sensitive loads such as central air conditioners). Given further NILM advances and declining costs for interval metered data, evaluators should consider using NILM in combination with end-use metering data, if requiring high accuracy. Future NILM improvements may eventually supplant the need for end-use metered data. Example applications can be seen in Decker (2017) and Elszasz (2017).

Limitations: Given the rigorous testing results thus far, NILM should be considered significantly less accurate than direct end-use metering, presenting some of the same accuracy issues encountered through survey data, engineering assumptions, or uncalibrated building simulations (Baker et al. 2016). NILM methods based on data collected at a higher frequency and/or with real and reactive power tend to have a greater capability for disaggregation. Ultimately, to be considered accurate, the results of NILM analysis for most measures still require calibration to end-use metered data for a reasonable proxy set of facilities. Due to the high degree of diversity among facility equipment and load sizes, NILM calibrated for one set of facilities may not provide high-accuracy results with another set of facilities in a different region.

4.6 End-Use Metered Data Analysis

End-use metering data analysis (IPMVP Option A and Option B) can provide a highly accurate means of estimating peak demand or time-differentiated energy savings. As with billing and interval data analysis, end-use metering data analysis entails a statistical comparison of pre- and post-participation and/or participant and nonparticipant billing data. However, end-use metering eliminates most—if not all—of the difficulty in isolating the impacts of specific measures. As a result, end-use metering is considered the gold standard for providing measure-level peak demand or time-differentiated energy savings estimates. ASHRAE has developed a methodology to derive diversity factors and to provide typical load shapes of office buildings' lighting and receptacle loads using end-use metered data (Abushakra 2001). An example of end-use metered data analysis can be seen in the recent Northeast residential lighting and Maryland commercial lighting studies (NMR 2014, Powanda et al. 2015).

Preferred Applications: For most high-impact measures where the baseline need not be observed (e.g., prescriptive measures), end-use metering provides the preferred approach to developing hourly impacts.

Limitations: Evaluators should consider the following when using end-use meter data:

- End-use metering cannot be used easily for measuring small load changes. While the likelihood of picking up a useful signal at the end-use level is higher than at the whole-premise level, fundamental limitations remain on the size of the signal that can be detected when measuring a change in usage. Interactive effects of lighting measures on HVAC systems generally fit in this category.
- Savings should be normalized for weather and other confounding factors.

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[8] NILM efforts have focused on residential applications and small commercial applications to a lesser extent. As the facility (and number of different loads) increases, the complexity increases accordingly.

- Pre-installation meter data are difficult to obtain because of the logistics entailed in coordinating with customers, though they may be recreated in some cases (e.g., turning off variable-speed drives). Without pre-installation data, baseline conditions must be estimated with engineering algorithms.
- Although costs have gone down, end-use metering is costly and should be conducted strategically.
- An impact load shape may be different than a post-participation load shape. For example, lighting control impact shapes differ from the shape of controlled lighting. (End uses have shapes with and without the efficiency measures in place, and the difference is the impact shape.) Determining energy efficiency shapes may require either pre-installation metering or reconstruction of the baseline shape.
- Sampling must be done carefully—see UMP *Chapter 11: Sample Design Cross-Cutting Protocol* (Khawaja et al. 2017). Sampling requirements for peak demand savings can significantly differ from requirements for energy savings due to higher coefficients of variation related to peak demand.
- The evaluator must consider the period over which to collect end-use meter data, including the time of year and duration of metering.

4.7 Survey Data on Hours of Use

Evaluators may conduct hours-of-use surveys to identify the times of day when equipment is used. For example, a survey might ask if residential CFLs are used during the summer from 3 p.m.–6 p.m., a typical period for system peak. If the results indicate that 5% of lights were in use at that time, then the combination of the coincidence and diversity factors would be 5%.

Preferred Applications: In populations with highly diverse usage patterns, surveys offer a cost-effective means of determining the range of usage patterns present in a population. Survey results may be combined with end-use metering in nested sampling designs. Surveys work better with more-informed respondents and with targeted questions. For example, asking facility managers what time the building ventilation systems are on should provide more accurate results than asking homeowners to describe their hot water usage patterns.

Limitations: The survey respondent must be knowledgeable about the operation of equipment in question. Relying on customer perceptions may result in significant inaccuracy and bias. Survey sampling should be done in conjunction with the techniques described in UMP *Chapter 11: Sample Design Cross-Cutting Protocol* (Khawaja et al. 2017).

4.8 Combined Approaches

Applying a combination of approaches facilitates using data from several sources to estimate peak demand or hourly energy savings. For example, billing data may be the best approach for estimating energy savings for a low-income program. Engineering algorithms can be used to develop energy and demand savings for each program participant, and these participant energy savings can serve as the independent variables in a statistically adjusted engineering (SAE) billing analysis (see Chapter 8: *Whole-Building Retrofit with Consumption Data Analysis*

Evaluation Protocol). The realization rate from the SAE analysis can be then applied to the population demand estimate from the engineering model.

Combined approaches also include nested samples, where a smaller number of metered sites are used to calibrate surveys from a much larger population. For example, a sample of 30 metered sites may yield a combined coincidence and diversity factor of 6.1%, while the surveys produce an estimate of 5.0% for the metered sample and 5.5% for the entire survey sample. The ratio of 6.1% to 5.0% would be applied to the 5.5% survey sample estimate, resulting in an adjusted factor of 6.7%.

4.9 Summary of Approaches

Table 1 summarizes the approaches in terms of relative cost and relative potential accuracy. In all cases, the accuracy achieved depends on the quality of the analysis.

Table 1. Summary of Approaches

Approach	Relative Cost	Relative Potential Accuracy	Comments
Engineering Algorithms	Low	Low-Moderate	Accuracy depends on the quality of the input assumptions as well as the algorithm. Appropriate for prescriptive measures with good existing data.
Calibrated Hourly Simulation Modeling	Moderate	Moderate	Input assumptions are again important—garbage in, garbage out; appropriate for HVAC and shell measures and HVAC interaction
Billing Data Analysis with Load Shapes	Moderate	Moderate	Typically not directly useful for peak demand or on/off peak energy analysis, but it can be used to leverage other approaches
Interval Metered Data Analysis	Moderate	High	Interval metered data is not available for many customers; it is becoming more feasible with proliferation of advanced metering infrastructure (AMI). Appropriate for residential retrofit programs with HVAC and shell measures.
NILM	Moderate	Moderate	Considered significantly less accurate than direct end-use metering, but less expensive. Most applicable for residential cooling.
End-Use Metered Data Analysis	High	High	Requires careful sampling and consideration of period to be metered. Most applicable to high impact prescriptive measures.
Survey Data on Hours of Use	Low-Moderate	Low	Only applicable in the rare cases when customers can provide better estimates than other available data.

5 Secondary Sources

Evaluators may choose to rely on the following secondary sources rather than on the primary sources listed above because of budget or time constraints.

5.1 Technical Reference Manuals

Technical reference manuals (TRMs) specify savings or protocols for estimating savings for common energy efficiency measures. Typically, TRMs provide approved estimates of energy and demand savings. These deemed savings are based on a regional average for the population of participants rather than for a particular installation.

Although TRMs often provide industry-accepted values or algorithms for calculating savings, users should not assume that an algorithm is correct because it has been used elsewhere. Mistakes are common and should be expected. Values based on “engineering judgment” should be used cautiously.

5.2 Application of Standard Load Shapes

Load shapes provide information about the distribution of energy consumption or savings over time. For example, a savings or impact load shape will indicate the fraction of savings achieved during a specific time period. An hourly annual electricity load shape using fractions of the total annual energy consumption can be multiplied by the annual consumption to derive the consumption in each hour of the year.

Load shapes can be applied to allocate energy consumption into costing periods. Similarly, load shapes can be applied to estimate peak demand and time-differentiated energy savings from energy impacts.

Load shapes may be derived from metering or simulation. A key resource of load shape data is the California Database for Energy Efficiency Resources (CPUC 2011). NEEP has also catalogued load shape data and conducted primary research on several common energy efficiency measures to develop load shapes specific to the northeast region (NEEP 2016). As with any secondary data, the evaluator must consider the applicability of the shapes when climate-sensitive end uses are involved.

5.3 Uncalibrated Simulation Using Standard Building Reference Models

The U.S. Department of Energy (DOE) publishes standard commercial building reference models (Deru 2011) for 16 commercial buildings in 16 climates (for 256 prototypes in all). In addition, DOE publishes a Building America Benchmark definition (Hendron and Engebrecht 2011) that can be used to generate residential building prototypes. These prototypes may be run with an appropriate weather file and be used as a first guess at hourly consumption shapes in the absence of better data, though the results will likely have significant errors. As noted in Section 4.2, calibrating these models to whole-building interval data for building sectors provides much more accurate results.

6 Future Improvements

Best practices for developing time-based estimates of savings are advancing rapidly. Given further advances in NILM and the declining cost of interval metered data, evaluators should consider using NILM in combination with end-use metered data if high accuracy is needed. Future improvements in NILM and accessibility of interval metered data may eventually supplant the need for as much end-use metered data.

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