

Figure: 16 TAC §25.184(d)(2)



Measurement and Verification Guidelines

This section includes detailed information about the measurement and verification (M&V) requirements of the Commercial and Industrial Standard Offer Program, as well as guidance for Project Sponsors on how to prepare and execute an M&V plan.

1

Introduction to Measurement and Verification

Overview

In the Commercial and Industrial (C&I) Standard Offer Program, the demand and energy savings resulting from a project are determined through measurement and verification (M&V) activities. The M&V approach appropriate for a given measure will depend on the equipment type, operational predictability, and complexity involved in the retrofit. The M&V guidelines provided in the following sections vary in detail and rigor, but fall into two general categories:

- Simplified M&V approaches; and
- Full M&V approaches.

The M&V approaches presented in this section are intended for use by the Project Sponsor as a guideline for developing project-specific M&V plans. All M&V plans will necessarily be unique and based on project and site conditions, but may have the common elements discussed here. With the exception of lighting measures qualifying for the use of deemed savings, these M&V approaches adhere to the standards of the 1997 *International Performance Verification and Measurement Protocol* (IPMVP). The Project Sponsor is welcome to recommend alternate M&V methods. However, any alternate methods must be approved by the sponsoring utility and adhere to IPMVP standards.

Simplified M&V Approaches

Under the simplified M&V approach, savings values are based on engineering calculations using typical equipment characteristics and operating schedules developed for particular applications. Simplified methods can reduce the need for certain types of field monitoring by using stipulated values for data such as operating hours, equipment efficiencies, etc. Project measures must meet certain criteria in order to calculate their resulting savings using a simplified M&V approach; detailed criteria may be found in the M&V guidelines specific to each equipment type. Simplified M&V guidelines have been developed for the types of retrofits summarized in Table 1.1.

Table 1.1. Simplified M&V Guidelines

| Measure Type | Guideline Chapter |
|-------------------------------|--------------------------|
| Lighting efficiency upgrades* | 2 |
| Lighting controls* | 3 |
| Cooling efficiency projects | 4 |
| Motor efficiency upgrades | 5 |
| VSD motor retrofits | 6 |

* The simplified M&V approach can only be used for approved building types.

For lighting measures, stipulated savings values may be used for many building types. For other measures, some short-term testing or simple long-term metering will be needed to calculate demand and energy savings. For example, chiller energy and demand savings can be determined using the simple approach by comparing rated efficiencies of high-efficiency equipment to standard equipment, and using kW spot-metering and simple long-term kWh metering.

Full M&V Approaches

Full M&V approaches estimate demand and energy savings using a higher level of rigor than the simplified M&V approaches through the application of end-use metering, billing regression analysis, or computer simulation. All measures that do not meet the criteria for a simplified approach must use a full M&V approach. Refer to individual utility-approved full M&V procedures.

Steps in the M&V Process

Before a project's total incentive payment is made, the potential for the project measures to save demand and energy must be verified and the actual savings estimated. These activities will be conducted in accordance with the M&V plan developed for the project. Table 1 highlights the basic steps required during the M&V process for most retrofit projects under the C&I Standard Offer Program. Note that the Project Sponsor is responsible for conducting the majority of M&V activities.

Table 1.3. Steps in the M&V process

| Step | M&V Activity | Performed by: |
|-------------|--|----------------------|
| 1 | Develop a site-specific M&V plan | Sponsor |
| 2 | Conduct a pre-installation equipment survey (and pre-installation monitoring, if needed) | Sponsor |
| 3 | Conduct a pre-installation inspection | Sponsoring utility |
| 4 | Install retrofit equipment | Sponsor |
| 5 | Conduct a post-installation equipment survey | Sponsor |
| 6 | Conduct a post-installation inspection | Sponsoring utility |
| 7 | Determine operating hours (M&V activities if necessary) | Sponsor |
| 8 | Calculate savings | Sponsor |

The time required to complete M&V activities will range from less than a month up to 12 months, depending on the approach chosen.

Developing Project-Specific M&V Plans

This section defines the general guidelines for designing a project-specific M&V plan. Issues and requirements specific to each method are further described in the individual guidelines describing specific M&V methods for particular technologies.

The Project Sponsor should work with the sponsoring utility to identify an M&V methodology and develop an M&V plan that are appropriate for the retrofits being performed as part of each project. The M&V plan will be reviewed and must be approved by the sponsoring utility as part of the Final Application for the program.

A project-specific M&V plan should demonstrate that any proposed metering and analysis will be done in a consistent and logical manner and with a level of accuracy acceptable to all parties. An M&V plan should be prepared for each project defined in a contract agreement, as shown on the approved Final Application.

In general, a project-specific M&V plan should address the following (from the 1997 IPMVP):

1. Describe the project site and the project; include information on how the project saves energy and what key variables affect the realization of savings.
2. Describe the M&V method to be used.
3. Indicate who will conduct the M&V activities and prepare the M&V analyses and documentation.
4. Define the details of how calculations will be made. For instance: "List analysis tools, such as DOE-2 computer simulations, and/or show the equations to be used." A complete "path" should be defined indicating how collected survey and metering/monitoring data will be used to calculate savings. All equations should be shown.
5. Specify what metering equipment will be used, who will provide the equipment, its accuracy and calibration procedures. Include a metering schedule describing metering duration and when it will occur, and how data from the metering will be validated and reported. Include data formats. Electronic, formatted data read directly from a meter or data logger is recommended for any short- or long-term metering.
6. Define what key assumptions will be made about significant variables or unknowns. For instance: "actual weather data will be used, rather than typical-year data," or "fan power will be metered for one full year for two of the six supply air systems." Describe any stipulations that will be made and the source of data for the stipulations.
7. Define how any baseline adjustments will be made.
8. Describe any sampling that will be used, why it is included, sample sizes, documentation on how sample sizes were selected, and information on how random sample points will be selected.
9. Indicate how quality assurance will be maintained and replication confirmed. For instance: "The data being collected will be checked every month," or "to ensure sufficient accuracy, results will be subjected to third-party review by the ABC company."

2

Simplified M&V Guidelines for Lighting Efficiency Measures

Overview

This measurement and verification (M&V) procedure is appropriate for projects that involve the replacement of existing fixtures, lamps, and/or ballasts with a similar number of new energy efficient fixtures, lamps, and/or ballasts. This procedure can also be used for projects involving delamping with or without the use of reflectors. This stipulated hours method requires the use of the appropriate values listed in Table 2.1. If these tables do not accurately characterize the building type, then the Project Sponsor should refer to the applicable individual utility-approved full M&V procedures. Any alternate M&V methods must be approved by the sponsoring utility and adhere to the 1997 *International Performance Verification and Measurement Protocol* (IPMVP) available at the organization's Web site (www.ipmvp.org).

Table 2.1 Stipulated Annual Operating Hours and Interactive Savings

| Building Type | Stipulated Annual Operating Hours | Coincidence Factor During Hour of Maximum Demand Savings | Interactive HVAC Demand Savings | Interactive HVAC Energy Savings |
|--|--|---|--|--|
| Office | 3,760 | 80% | 10% | 5% |
| Non-24-Hour Supermarket/ Retail/ Restaurant | 4,250 | 95% | 10% | 5% |
| Education (K-12; no summer session) | 2,150 | 85% | 10% | 5% |
| 24-Hour Supermarket/ Retail | 6,900 | 95% | 10% | 5% |
| In-Patient Health Care | 3,750 | 60% | 10% | 5% |
| Higher education (college/university) | 2,085 | 67% | 10% | 5% |
| Parking structure | 7,884 | 100% | 0% | 0% |
| Multi-family housing common areas | 4,772 | 85% | 10% | 5% |

Pre-Installation M&V Activities

Prior to installing lighting retrofit, the Project Sponsor conducts a pre-installation equipment survey. This survey should provide the following information about all the fixtures involved in the lighting retrofit: room location, fixture, lamp, and ballast types; lighting controls; area designations; counts of operating and non-operating fixtures; and type of control device. If Interactive factors are claimed the survey must also indicated if the space is air-conditioned with electricity consuming equipment, and if the space is electrically heated.

Fixture wattages in both the pre and post case should be based on the *Standardized Lighting Fixture Wattage Table*. For example, the baseline for a standard 4-foot

fluorescent fixture is a combination of 34-watt Energy Saver lamps with an energy efficient ballast.

Post-Installation M&V Activities

After the lighting retrofit has been completed, the Project Sponsor conducts a post-installation equipment survey. The proposed equipment provided in the pre-installation equipment survey information should be updated to reflect the equipment installed or modified.

Calculation of Demand and Energy Savings

The peak demand savings and energy savings are calculated according to Equations (a) through (f). Demand savings are only allowed for lighting fixtures that will be in operation on weekdays between the hours of 1 p.m. and 7 p.m. during the months of May through September. Interactive HVAC demand and energy savings may be calculated *only* for lighting retrofits taking place in air-conditioned spaces. Lighting retrofits in unconditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments. Total demand savings are calculated using a coincidence factor to account for the average number of lights on during the hour of maximum demand reduction.

Peak demand savings

Equation (a)

Lighting Demand Savings [kW] = Pre Lighting Demand [kW] – Post Lighting Demand [kW]

Equation (b)

Interactive HVAC Demand Savings [kW] = Lighting Demand Savings [kW]*Stipulated Interactive HVAC Demand Savings [%]

Equation (c)

Total Demand Savings [kW] = (Lighting Demand Savings [kW] + Interactive HVAC Demand Savings [kW]) * Coincidence Factor

Energy savings

Equation (d)

Lighting Energy Savings [kWh] = Lighting Demand Savings [kW]*Stipulated Annual Hours of Operation [hrs]

Equation (e)

Interactive HVAC Energy Savings [kWh] = Lighting Energy Savings [kWh]*Stipulated Interactive HVAC Energy Savings [%]

Equation (f)

Total Energy Savings [kWh] = Lighting Energy Savings [kWh] + Interactive HVAC Energy Savings [kWh]

Example¹

A lighting efficiency project is proposed for a typical small office building in Longview, Texas. The Sponsor submits the lighting survey forms as part of the Final Application detailing the existing and proposed equipment. The table below summarizes the existing and proposed connected lighting Load for each usage group in the project.

| Area Description | Survey Lines | Connected Lighting Load (kW) | | | Stipulated Operating Hours | Annual kWh Savings |
|---------------------|--------------|------------------------------|-------------|-------------|----------------------------|--------------------|
| | | Existing | Proposed | Saved | | |
| Hallways and Stairs | 5 | 0.9 | 0.5 | 0.4 | 3,760 | 1,504 |
| Common Offices | 18 | 16.5 | 3.6 | 12.9 | 3,760 | 48,504 |
| Conference Rooms | 5 | 3.9 | 2.4 | 1.5 | 3,760 | 5,640 |
| Misc Facilities | 6 | 1.5 | 1.2 | 0.3 | 3,760 | 1,128 |
| Private Offices | 11 | 14.8 | 10.3 | 4.5 | 3,760 | 16,920 |
| Restrooms | 5 | 1.0 | 0.7 | 0.3 | 3,760 | 1,128 |
| Total | 50 | 38.6 | 18.7 | 19.9 | | 74,824 |

¹ Projects that consist of only lighting measures receive 65% of the total incentive.

Based on the collected data, the demand and energy savings are calculated:

- (a) Lighting Demand Savings = $38.6 \text{ [kW]} - 18.7 \text{ [kW]}$
= 19.9 kW.
- (b) Interactive HVAC Demand Savings = $19.9 \text{ [kW]} * 0.10$
= 2.0 kW.
- (c) Total Demand Savings = $(19.9 \text{ [kW]} + 2.0 \text{ [kW]}) * .80$
= 17.5 kW.
- (d) Lighting Energy Savings = $19.9 \text{ [kW]} * 3,760 \text{ [hrs]}$
= 74,824 kWh.
- (e) Interactive HVAC Energy Savings = $74,824 \text{ [kWh]} * 0.05$
= 3,741 kWh.
- (f) Total Energy Savings = $74,824 \text{ [kWh]} + 3,741 \text{ [kWh]}$
= 78,565 kWh.

PLEASE REFER TO CI RETROFIT WATTAGE TABLE

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3

Simplified M&V Guidelines for Lighting Efficiency with Controls Measures

Overview

This Measurement and Verification (M&V) procedure is appropriate for lighting efficiency measures in combination with lighting controls retrofit measures. Lighting efficiency measures may include the replacement of existing fixtures, lamps, and/or ballasts with new energy efficient fixtures, lamps, and/or ballasts, as well as delamping with or without the use of reflectors. Controls measures may be occupancy sensors or daylighting controls.

This method requires the use of the appropriate stipulated hours from Table 3.1 and a Power Adjustment Factor (PAF) from Table 3.2. If values from these tables do not accurately characterize the building type and operation, then the Project Sponsor should refer to the applicable individual utility-approved full M&V procedures. Any alternate M&V methods must be approved by the sponsoring utility and adhere to the 1997 *International Performance Verification and Measurement Protocol* (IPMVP) available at the organization's Web site (www.ipmvp.org).

Table 3.1. Stipulated Annual Operating Hours and Interactive Savings

| Building Type | Stipulated Annual Operating Hours | Coincidence Factor During Hour of Maximum Demand Savings | Interactive HVAC Demand Savings | Interactive HVAC Energy Savings |
|---|--|---|--|--|
| Office | 3,760 | 80% | 10% | 5% |
| Non-24-Hour Supermarket/Retail/ Restaurant | 4,250 | 95% | 10% | 5% |
| Education (K-12; no summer session) | 2,150 | 85% | 10% | 5% |
| 24-Hour Supermarket/ Retail | 6,900 | 95% | 10% | 5% |
| In-Patient Health Care | 3,750 | 60% | 10% | 5% |
| Higher education (college/university) | 2,085 | 67% | 10% | 5% |
| Parking structure | 7,884 | 100% | 0% | 0% |
| Multi-family housing common areas | 4,772 | 85% | 10% | 5% |

Table 3.2. Power Adjustment Factors (PAFs)*

| Control Type | Power Adjustment Factor |
|---|--------------------------------|
| Daylight controls (DC) – continuous dimming | 0.70 |
| DC – multiple-step dimming | 0.80 |
| DC – ON/OFF | 0.90 |
| Occupancy sensor (OS) | 0.70 |
| OS w/ DC – continuous dimming | 0.60 |
| OS w/ DC – multiple-step dimming | 0.65 |
| OS w/ DC – ON/OFF | 0.65 |

*PAFs are adapted from ASHRAE Standard 90.1-1989, Table 6-3.

Pre-Installation M&V Activities

Prior to installing lighting retrofit, the Project Sponsor conducts a pre-installation equipment survey. This survey should provide the following information about all the fixtures involved in the lighting retrofit: room location, fixture, lamp, and ballast types; lighting controls; area designations; counts of operating and non-operating fixtures; and type of control device.

If Interactive factors are claimed the survey must also indicated if the space is air-conditioned with electricity consuming equipment, and if the space is electrically heated. Fixture wattages in both the pre and post case should be based on the *Standardized Lighting Fixture Wattage Table*. For example, the baseline for a standard 4-foot fluorescent fixture is a combination of 34 watt Energy Saver lamps with an energy-efficient ballast.

Post-Installation M&V Activities

After the lighting retrofit has been completed, the Project Sponsor conducts a post-installation equipment survey. The proposed equipment provided in the pre-installation equipment survey information should be updated to reflect the equipment installed or modified.

Calculation of Demand and Energy Savings

The peak demand savings and energy savings are calculated according to Equations (a) through (f). Demand savings are only allowed for lighting fixtures that will be in operation on weekdays between the hours of 1 p.m. and 7 p.m. during the months of May through September. Interactive HVAC demand and energy savings may be calculated *only* for lighting retrofits taking place in conditioned spaces. Lighting retrofits in non air conditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments. Total demand savings are calculated using a Coincidence factor to account for the average number of lights on during the hour of maximum demand reduction. No demand savings are credited to the controls.

Peak demand savings

Equation (a)

Lighting Demand Savings [kW] = Pre Lighting Demand [kW] – Post Lighting Demand [kW]

Equation (b)

Interactive HVAC Demand Savings [kW] = Lighting Demand Savings [kW]*Stipulated Interactive HVAC Demand Savings [%]

Equation (c)

Total Demand Savings [kW] = (Lighting Demand Savings [kW] + Interactive HVAC Demand Savings [kW]) * Coincidence Factor

Energy savings

Equation (d)

Lighting Energy Savings [kWh] = {Pre Lighting Demand [kW] – Post Lighting Demand [kW] *Power Adjustment Factor [%]}*Stipulated Annual Hours of Operation [hrs]

Equation (e)

Interactive HVAC Energy Savings [kWh] = Lighting Energy Savings [kWh]*Stipulated Interactive HVAC Energy Savings [%]

Equation (f)

Total Energy Savings [kWh] = Lighting Energy Savings [kWh] + Interactive HVAC Energy Savings [kWh]

Example²

A lighting efficiency and controls projects is proposed for a typical small office building in Longview, TX. Controls are to be installed in some common offices, private offices and restrooms. The Project Sponsor submits the lighting survey detailing the existing and proposed equipment inventory (example Form LE1 is attached). The following table summarizes the existing and proposed connected lighting load and operating hours for each usage group in the project.

| Area Description | Connected Load (kW) | | New control type | PAF Table 2.2 | Pre-retrofit hours Table 2.1 |
|----------------------------|---------------------|----------|-------------------------------------|---------------|------------------------------|
| | Existing | Proposed | | | |
| Common Offices w/ controls | 9.0 | 4.3 | Daylight control—multi-step dimming | 0.8 | 3,760 |
| Common Offices | 10.1 | 4.1 | | | 3,760 |
| Private Offices | 5.2 | 2.1 | | | 3,760 |
| Private Offices w/controls | 4.3 | 2.0 | Occupancy sensor | 0.7 | 3,760 |
| Conference Rooms | 3.9 | 1.5 | | | 3,760 |
| Restrooms | 0.3 | 0.1 | | | 3,760 |

² Projects that consist of only lighting measures receive 65% of the total incentive.

Pre-retrofit operating hours are determined using the Stipulated Hours Method. The stipulated annual operating hours for office buildings is 3,760 hours/year. Usage groups that are being retrofitted with controls are divided into control and non-control usage groups. The post-retrofit hours for the control usage groups are multiplied by the PAF corresponding to the type of control being utilized. The post-retrofit hours for the non-control usage groups remain unchanged from the pre-retrofit hours. Using equations (a) through (f), the energy savings for the *Common Offices With Controls* will be

$$(a) \text{ Lightng Demand Savings [kW]} = 9.0 \text{ [kW]} - 4.3 \text{ [kW]} \\ = \mathbf{4.7 \text{ [kW]}}$$

$$(b) \text{ Interactive HVAC Demand Savings [kW]} = 4.7 \text{ [kW]} * 0.10 \\ = \mathbf{0.5 \text{ [kW]}}$$

$$(c) \text{ Total Demand Savings [kW]} = (4.7 \text{ [kW]} + 0.5 \text{ [kW]}) * 0.80 \\ = \mathbf{4.2 \text{ [kW]}}$$

$$(d) \text{ Lighting Energy Savings [kWh]} = \{9.0 \text{ [kW]} - 4.3 \text{ [kW]} * 0.8\} * 3760 \text{ [hrs]} \\ = \mathbf{20,906 \text{ [kWh]}}$$

$$(e) \text{ Interactive HVAC Energy Savings [kWh]} = 20,906 \text{ [kWh]} * 0.05 \\ = \mathbf{1,045 \text{ [kWh]}}$$

$$(f) \text{ Total Energy Savings [kWh]} = 20,906 \text{ [kWh]} + 1,045 \text{ [kWh]} \\ = \mathbf{21,951 \text{ [kWh]}}$$

The energy savings is then calculated for each usage group.

| Area Description | Results | | | | | |
|-----------------------------|---------|-----|-------------|--------|-------|---------------|
| | (a) | (b) | (c) | (d) | (e) | (f) |
| Common Offices w/ Controls | 4.7 | 0.5 | 4.2 | 20,906 | 1,045 | 21,951 |
| Common Offices | 6 | 0.6 | 5.3 | 22,560 | 1,128 | 23,688 |
| Private Offices | 3.1 | 0.3 | 2.7 | 11,656 | 583 | 12,239 |
| Private Offices w/ Controls | 2.3 | 0.2 | 2.0 | 10,904 | 545 | 11,449 |
| Conference Rooms | 2.4 | 0.2 | 2.1 | 9,024 | 451 | 9,475 |
| Restrooms | 0.3 | 0 | 0.2 | 1,128 | 56 | 1,184 |
| Total | | | 16.5 | | | 79,986 |

4

Simplified M&V Guidelines for Cooling Efficiency Projects

Introduction

The following calculations and coefficient tables are for use with utility-approved cooling efficiency project measurement and verification guidelines.

Cooling Efficiency Calculations

The simplified calculation involves the application of two mathematical formulas shown in Equations 1 and 2.

$$kW_{\text{savings}} = \text{Tons} * (a \cdot \eta_{\text{baseline}} - b \cdot \eta_{\text{post-installation}}) \quad \text{Equation 1}$$

$$kWh_{\text{savings}} = \text{Tons} * (c \cdot \eta_{\text{baseline}} - d \cdot \eta_{\text{post-installation}}) \quad \text{Equation 2}$$

Where:

- kW_{savings} is the calculated demand savings
- kWh_{savings} is the calculated energy savings
- η_{baseline} is the baseline efficiency of the equipment
- $\eta_{\text{post installation}}$ is the rated efficiency of the installed equipment
- a, b, c and d are the simplified M&V calculation coefficients that are provided in the tables in Appendix A
- Tons is the rated equipment cooling capacity at standard conditions, set by the American Refrigeration Institute (ARI).

The simplified calculation can be applied to both equipment replacements and changes from one type of equipment to another, e.g. changing from packaged direct expansion (DX) units to a water-cooled chiller. The simplified calculation also can also be applied to cooling equipment installed in new construction projects.

The steps to perform the proposed simplified calculation is as follows:

1. Determine the applicable baseline efficiency for the existing equipment in kW/ton (η_{baseline}). Select either the minimum baseline efficiency from the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1-1989, or the actual full load rated efficiency if it is better than ASHRAE 90.1-1989. For new construction projects, the baseline efficiency is from ASHRAE 90.1-1999.
2. Determine the efficiency of the retrofit or new construction equipment in kW/ton ($\eta_{\text{post installation}}$).
3. Determine the equipment capacity in tons (*Tons*). Record the lesser of the existing unit tonnage or the replacement unit tonnage.
4. Determine the applicable demand and energy coefficients (*a, b, c, and d*) from the location-specific tables in Appendix A. Select the kW and kWh coefficients for the appropriate building and equipment type.
5. Use Equations #1 and #2 to calculate the savings.

The following equations should be used to convert equipment efficiencies, which are often stated in units such as Energy Efficiency Ratings (EERs), Coefficients of Performance (COPs) and Seasonal Energy Efficiency Ratios (SEERs), to kW/ton:

$$\text{kW/ton} = 12 / \text{EER} \quad \text{Equation 3}$$

$$\text{kW/ton} = 3.516 / \text{COP} \quad \text{Equation 4}$$

$$\text{kW/ton} = 12 / (\text{SEER} * 0.697 + 2.0394) \quad \text{Equation 5}$$

For example, a 150-ton air-cooled packaged unit in a retail application is being replaced with a more efficient unit (of similar size and type) in Brownsville, TX.

1. The applicable baseline efficiency (η_{baseline}) from ASHRAE 90.1-1989 is 8.2 EER, which is the equivalent of 1.46 kW/ton.
2. The applicable efficiency for the retrofit equipment ($\eta_{\text{post installation}}$) is 9.5 EER, which is the equivalent of 1.26 kW/ton.
3. Equipment capacity (*Tons*): 150.
4. Demand and energy coefficients (*a, b, c, and d*). From Appendix A: $a = b = 0.84$, $c = d = 2,917$.
5. $kW_{\text{savings}} = 150 * (0.84 * 1.46 - 0.84 * 1.26) = 25.2kW$
6. $kWh_{\text{savings}} = 150 * (2,917 * 1.46 - 2,917 * 1.26) = 87,510kWh$

Coefficients

Building type/cooling equipment combinations for which there are no coefficients are shaded gray in the tables.

Table 4.1 Simplified Calculation Coefficients for Cooling Equipment Projects in Fort Worth, Texas.

| FORT WORTH, TX | | | | | | |
|-------------------|--------------------|----------------------|------------------------|--------------------|----------------------|------------------------|
| Building Type | Demand Coefficient | | | Energy Coefficient | | |
| | Air Cooled Chiller | Water Cooled Chiller | Packaged DX Air Cooled | Air Cooled Chiller | Water Cooled Chiller | Packaged DX Air Cooled |
| College | 0.89 | 0.81 | 0.91 | 1,587 | 1,761 | 1,955 |
| Convenience | | | 0.92 | | | 3,831 |
| Fast Food | | | 0.92 | | | 3,106 |
| Grocery | | 0.87 | 0.92 | | 2,708 | 2,815 |
| Hospital | 1.15 | 0.83 | | 2,453 | 2,733 | |
| Hotel | 0.89 | 0.84 | 0.92 | 1,633 | 1,698 | 2,137 |
| Motel | | | 0.92 | | | 2,211 |
| Nursing Home | 0.90 | 0.82 | 0.92 | 1,744 | 1,854 | 2,218 |
| Large Office | 0.88 | 0.80 | 0.92 | 2,232 | 2,406 | 2,493 |
| Small Office | 0.90 | 0.80 | 0.92 | 1,598 | 1,649 | 1,970 |
| Public Assembly | 0.90 | 0.84 | 0.92 | 2,005 | 2,116 | 2,385 |
| Restaurant | | | 0.92 | | | 2,405 |
| Religious Worship | 0.88 | 0.83 | 0.90 | 1,355 | 1,396 | 1,946 |
| Retail | 0.90 | 0.83 | 0.92 | 1,770 | 1,828 | 2,225 |
| School | 0.88 | 0.81 | 0.91 | 1,136 | 1,273 | 1,569 |
| Service | | | 0.92 | | | 2,262 |
| Warehouse | 0.90 | 0.86 | 0.92 | 1,378 | 1,435 | 2,110 |

Table 4.2 Simplified Calculation Coefficients for Cooling Equipment Projects in Amarillo, Texas.

| AMARILLO, TX | | | | | | |
|-------------------|--------------------|----------------------|------------------------|--------------------|----------------------|------------------------|
| Building Type | Demand Coefficient | | | Energy Coefficient | | |
| | Air Cooled Chiller | Water Cooled Chiller | Packaged DX Air Cooled | Air Cooled Chiller | Water Cooled Chiller | Packaged DX Air Cooled |
| College | 0.87 | 0.68 | 0.92 | 1,115 | 1,243 | 1,721 |
| Convenience | | | 0.92 | | | 3,452 |
| Fast Food | | | 0.92 | | | 2,632 |
| Grocery | | 0.67 | 0.92 | | 1,892 | 2,252 |
| Hospital | 1.10 | 0.68 | | 1,910 | 2,115 | |
| Hotel | 0.85 | 0.66 | 0.92 | 1,124 | 1,138 | 1,791 |
| Motel | | | 0.92 | | | 1,887 |
| Nursing Home | 0.87 | 0.65 | 0.92 | 1,230 | 1,260 | 1,873 |
| Large Office | 0.86 | 0.68 | 0.92 | 1,736 | 1,874 | 2,062 |
| Small Office | 0.87 | 0.66 | 0.92 | 1,106 | 1,117 | 1,705 |
| Public Assembly | 0.87 | 0.65 | 0.92 | 1,404 | 1,444 | 1,979 |
| Restaurant | | | 0.92 | | | 1,928 |
| Religious Worship | 0.82 | 0.67 | 0.90 | 848 | 856 | 1,585 |
| Retail | 0.87 | 0.65 | 0.92 | 1,193 | 1,185 | 1,838 |
| School | 0.87 | 0.69 | 0.92 | 755 | 806 | 1,462 |
| Service | | | 0.92 | | | 1,848 |
| Warehouse | 0.87 | 0.66 | 0.92 | 802 | 783 | 1,639 |

Table 4.3 Simplified Calculation Coefficients for Cooling Equipment Projects in Houston, Texas.

| HOUSTON, TX | | | | | | |
|-------------------|--------------------|----------------------|------------------------|--------------------|----------------------|------------------------|
| Building Type | Demand Coefficient | | | Energy Coefficient | | |
| | Air Cooled Chiller | Water Cooled Chiller | Packaged DX Air Cooled | Air Cooled Chiller | Water Cooled Chiller | Packaged DX Air Cooled |
| College | 0.80 | 0.84 | 0.85 | 1,858 | 2,099 | 2,175 |
| Convenience | | | 0.88 | | | 4,168 |
| Fast Food | | | 0.87 | | | 3,365 |
| Grocery | | 0.88 | 0.87 | | 3,012 | 2,935 |
| Hospital | 1.05 | 0.85 | | 2,781 | 3,172 | |
| Hotel | 0.80 | 0.88 | 0.84 | 1,831 | 1,981 | 2,266 |
| Motel | | | 0.84 | | | 2,404 |
| Nursing Home | 0.80 | 0.84 | 0.84 | 1,960 | 2,172 | 2,368 |
| Large Office | 0.81 | 0.90 | 0.85 | 2,501 | 2,786 | 2,750 |
| Small Office | 0.81 | 0.87 | 0.85 | 1,860 | 1,990 | 2,158 |
| Public Assembly | 0.81 | 0.86 | 0.86 | 2,264 | 2,482 | 2,559 |
| Restaurant | | | 0.86 | | | 2,548 |
| Religious Worship | 0.83 | 0.84 | 0.87 | 1,474 | 1,594 | 2,028 |
| Retail | 0.80 | 0.84 | 0.84 | 2,003 | 2,162 | 2,381 |
| School | 0.80 | 0.84 | 0.85 | 1,280 | 1,489 | 1,639 |
| Service | | | 0.87 | | | 2,429 |
| Warehouse | 0.84 | 0.87 | 0.88 | 1,534 | 1,673 | 2,248 |

Table 4.4 Simplified Calculation Coefficients for Cooling Equipment Projects in Brownsville, Texas.

BROWNSVILLE, TX

| Building Type | Demand Coefficient | | | Energy Coefficient | | |
|-------------------|--------------------|----------------------|------------------------|--------------------|----------------------|------------------------|
| | Air Cooled Chiller | Water Cooled Chiller | Packaged DX Air Cooled | Air Cooled Chiller | Water Cooled Chiller | Packaged DX Air Cooled |
| College | 0.80 | 0.87 | 0.83 | 2,340 | 2,583 | 2,547 |
| Convenience | | | 0.85 | | | 4,647 |
| Fast Food | | | 0.85 | | | 3,933 |
| Grocery | | 0.85 | 0.85 | | 3,603 | 3,489 |
| Hospital | 0.98 | 0.92 | | 3,379 | 3,755 | |
| Hotel | 0.79 | 0.84 | 0.84 | 2,482 | 2,673 | 2,799 |
| Motel | | | 0.84 | | | 2,973 |
| Nursing Home | 0.80 | 0.85 | 0.85 | 2,634 | 2,890 | 2,953 |
| Large Office | 0.77 | 0.88 | 0.82 | 2,907 | 3,181 | 3,153 |
| Small Office | 0.74 | 0.77 | 0.80 | 2,213 | 2,323 | 2,370 |
| Public Assembly | 0.80 | 0.85 | 0.85 | 2,857 | 3,085 | 3,077 |
| Restaurant | | | 0.84 | | | 2,993 |
| Religious Worship | 0.81 | 0.85 | 0.84 | 1,754 | 1,907 | 2,181 |
| Retail | 0.80 | 0.85 | 0.84 | 2,662 | 2,872 | 2,917 |
| School | 0.79 | 0.85 | 0.83 | 1,537 | 1,753 | 1,778 |
| Service | | | 0.85 | | | 2,684 |
| Warehouse | 0.80 | 0.85 | 0.84 | 1,876 | 2,014 | 2,568 |

5

Simplified M&V Guidelines for Constant Load Motor Efficiency Retrofits

Overview

This measurement and verification (M&V) method is appropriate for projects in which existing motors serving a constant load will be replaced with higher efficiency motors of equal or lesser capacity (horsepower). The rated efficiency of the new motor must exceed the minimum efficiency standard defined by ASHRAE 90.1m (see the *Minimum Standard Motor Table*) in order to be eligible for the program. Potential retrofit equipment includes:

- Constant load chilled water, hot water, or condenser water pumps;
- Constant speed exhaust, return, and supply fans without dampers or pressure controls;
- Single-speed cooling tower fans; and/or
- Constant load industrial processes.

If the proposed retrofit does not meet these requirements, the Project Sponsor should refer to the appropriate individual utility-approved full M&V procedures. Any alternate M&V methods must be approved by the sponsoring utility and adhere to the 1997 *International Performance Verification and Measurement Protocol* (IPMVP) available at the organization's Web site (www.ipmvp.org).

Pre-Installation M&V Activities

Spot measurements of the power draw (kW) of the existing motors must be conducted. If the constancy of the motor load cannot be verified by visual inspection (as determined by the utility administrator), then short-term metering of the power draw or current (amperes) of the existing motors may also required.¹

¹ A motor load is considered constant if at least 90% of all non-zero observations are within $\pm 10\%$ of the average. If the results of pre-installation short-term metering do not satisfy this criterion, then one of the M&V methods designated for variable-load, motor efficiency projects must be used.

The minimum efficiency standard for the existing motor type is listed in the *Standard Motor Efficiency Table*. If the efficiency of the existing motor is greater than or equal to the minimum efficiency standard, then the baseline demand is equal to the spot measured value; if not, then it is calculated according to Equation (a).

Equation (a)

$$\text{Baseline demand [kW]} = \frac{\text{efficiency of existing motor}}{\text{minimum efficiency standard}} \times \text{Spot measured demand of existing motor [kW]}$$

Post-Installation M&V Activities

The post-installation M&V consists of two activities:

1. Spot measurements of the power draw (one-hour average values) of the high-efficiency motors must be conducted in order to establish the post-installation demand.
2. Short-term metering of motor operating hours must be conducted for a minimum period of one week, or a sufficient amount of time to capture the full range of operation. The motor annual operating hours are calculated from the metering data according to Equation (b).

$$\text{Equation (b) Annual operating hours} = \frac{\text{motor on - time during metering period [hrs]}}{\text{length of metering period [hrs]}} \times 8760 \text{ hrs/yr.}$$

For projects in which a large number of equal-sized motors with the same application and operating schedule will be replaced, M&V may be conducted on a sample of the motors and the results extrapolated to the applicable population. If this approach is adopted, the sponsoring utility will select the motors to be metered. Please refer to the applicable individual utility-approved full M&V procedures to determine the appropriate sample size.

Calculation of Peak Demand and Energy Savings

Demand savings are only allowed for equipment that will be in operation on weekdays between the hours of 1 p.m. and 7 p.m. during the months of May through September. The peak demand savings and energy savings are calculated according to Equations (c) and (d), respectively.

Equation (c)

Peak demand savings [kW] = Baseline demand [kW] – Spot measured demand of new motor [kW]

Equation (d) Energy savings [kWh] = Peak demand savings [kW] × Annual operating hours [hrs]

Example

A constant-speed process motor at an agricultural processing plant will be replaced with a smaller, high-efficiency motor. As indicated on its nameplate, the existing motor is a 200 hp, 1800 RPM enclosed motor with a nominal efficiency of 0.91. This motor will be down-sized to a 150 hp motor with a nominal efficiency of 0.96.

As the first step in the M&V, a spot measurement of the existing motor was made and indicated a power draw of 165.3 kW.

The minimum efficiency standard for the existing motor is 0.95 (as given in the Minimum Standard Motor Table) which is greater than the efficiency of the existing motor; therefore, the baseline demand is calculated according to Equation (a).

$$(a) \quad \text{Baseline motor demand} = 165.3 \times (0.91/0.95) = 158.3 \text{ kW}$$

Following installation of the new motor, a spot measurement was made, and indicated an average, one hour, power draw of 117.9 kW.

Post-installation metering of operating hours was then conducted for a one-week period. The metering results show that the motor was operating for 81 hours out of the 168 hours in the metering period. The annual operating hours were calculated using Equation (b), as shown below.

$$(b) \quad \text{Annual operating hours} = (81/168) \times 8760 = 4224 \text{ hrs}$$

The peak demand savings and energy savings were then calculated using Equations (c) and (d), respectively, as shown in below.

$$(c) \quad \text{Peak demand savings} = 158.3 - 117.9 = 40.4 \text{ kW}$$

$$(d) \quad \text{Annual energy savings} = 40.4 \times 4224 = 170,650 \text{ kWh}$$

6

Simplified M&V Guidelines for Constant Baseline VSD Retrofits

Overview

This measurement and verification (M&V) method is appropriate for projects in which variable-speed drives (VSDs) or other load controls will be installed on motors with a constant existing (baseline) load. If the existing motors will be replaced as part of the measure, the capacity (horsepower) of the new motors must be equal to or less than that of the existing motors. Additionally, the rated efficiency of the new motors must exceed the minimum efficiency standard defined by ASHRAE 90.1m (see the *Minimum Standards Motor Table*) in order to be eligible for the program. Potential retrofit equipment includes:

- Conversion of a constant air volume system to variable air volume (VAV)
- Cooling tower or ventilation fans with no existing dampers or pressure controls
- Condenser water, hot water, or chilled water circulation pumps with no existing flow or pressure controls
- Industrial process motors with existing throttling valves or fixed bypass valves

If the proposed retrofit does not meet these requirements, the Project Sponsor should refer to the applicable individual utility-approved full M&V procedures. Any alternate M&V methods must be approved by the sponsoring utility and adhere to the 1997 *International Performance Verification and Measurement Protocol* (IPMVP) available at the organization's Web site (www.ipmvp.org).

Pre-Installation M&V Activities

Spot measurements of the power draw (kW) of the existing motors must be conducted. If the constancy of the motor load cannot be verified by visual inspection (as determined by the utility administrator), then short-term metering of the power draw or current (amperes) of the existing motors may be required.²

The minimum efficiency standard for the existing motor type is listed in the *Minimum Standards Motor Table*. If the existing motor will be replaced as part of the measure and its efficiency is less than the minimum efficiency standard, then the baseline demand is calculated according to Equation (a); otherwise it is equal to the spot measured value.

Equation (a)

$$\text{Baseline demand [kW]} = \frac{\text{efficiency of existing motor}}{\text{minimum efficiency standard}} * \text{Spot measured demand of existing motor [kW]}$$

Post-Installation M&V Activities

Short-term metering of the power draw (kW) of the motors must be conducted and the data recorded at intervals of 15 minutes or less.³ However, one-hour values are used in the calculation of demand and energy savings. This information may be available from the VSD controller. For weather dependent applications, if peak demand savings will be claimed, then metering must occur between May 1 and September 30.

The duration of the metering period must be sufficient to capture the full range of operation. If the motor load varies only on a daily basis and not seasonally, then a metering period of one week is generally sufficient. If the motor load or operating hours vary with weather or other seasonal parameters (e.g., production schedules, school calendars), then at least two weeks of metering during each operating period is generally necessary. For example, if the motor serves cooling equipment, then the metering should occur for at least two weeks during the winter months and two weeks during the summer months.

² A motor load is considered constant if at least 90% of all non-zero observations are within $\pm 10\%$ of the average. If the results of pre-installation short-term metering do not satisfy this criterion, then one of the M&V methods designated for variable-load, motor efficiency projects must be used.

³ Long-term monitoring may be required for motors with non-uniform or unpredictable load patterns.

The metering data is used to determine three values:

1. Peak summer period demand (kW): Equal to the maximum recorded peak summer period demand (one hour values, where the summer peak period is defined as weekdays, between the hours of 1 p.m. and 7 p.m., from May 1 through September 30).
2. Average demand (kW): Equal to the average recorded demand. For motors with seasonal load patterns, the average demand should be weighted according to the relative length of each seasonal period. (See example).

Annual operating hours: Calculated from the metering data according to Equation (b). For motors with seasonal load patterns, the annual operating hours should be weighted according to the relative length of each seasonal period.

$$\text{Equation (b) Annual operating hours} = \frac{\text{Motor on - time during metering period [hrs]}}{\text{Length of metering period [hrs]}} * 8760 \text{ hrs/yr.}$$

For projects in which a large number of equal-sized motors with the same application and operating schedule will be replaced, M&V may be conducted on a sample of the motors and the results extrapolated to the applicable population. If this approach is adopted, the utility administrator will select the motors to be metered. Please refer to the applicable individual utility-approved full M&V procedures to determine the appropriate sample size.

Calculation of Peak Demand and Energy Savings

Demand savings are only allowed for equipment that will be in operation on weekdays between the hours of 1 p.m. and 7 p.m. during the months of May through September. The peak demand savings and energy savings are calculated according to Equations (c) and (d), respectively.

$$\text{Equation (c) Peak period demand savings [kW]} = \text{Baseline demand} - \text{Peak summer period demand}$$

$$\text{Equation (d) Energy Savings [kWh]} = (\text{Baseline demand} - \text{Average demand}) * \text{Annual operating hours}$$

Example

The constant air volume ventilation system at a commercial office building will be converted to a variable air volume (VAV) system by retrofitting four 50 hp supply fan motors with variable speed drives (VSDs). Additionally, the existing motors will be replaced with premium efficiency motors. The M&V procedures for a single motor are illustrated below. In general, the same procedure would be followed for all four motors.

A spot measurement of the power draw of the existing motor was made and gave a reading of 42.3 kW. The nameplate on the existing motor indicates that it is an 1800 RPM, enclosed motor with a nominal efficiency of 0.92. The minimum efficiency standard for this type of motor is 0.93, as given in the Minimum Standard Motor Table; therefore, the baseline demand is calculated according to Equation (a)

$$(a) \text{ Baseline demand} = (0.92/0.93) * 42.3 = 41.8 \text{ kW}$$

Because the motor load is weather dependent, short-term post-installation metering must be conducted during both summer and winter months. Thus, after the new motor and VSD are installed, short-term metering of the motor's power draw (kW) is conducted for two weeks in January (winter) and two weeks in July (summer).

The metering data indicates that the peak (one hour) summer period demand was 37.6 kW. The average demand during the January metering period was 5.3 kW, and the average demand during the July metering period was 19.8 kW. The summer and winter periods are assumed to account for equal portions of the year; therefore, the metering results are weighted evenly for the two periods. Thus, the average demand is 12.6 kW.

The metering data indicates that motor was operating for 88 hours during the 336-hour January metering period, and for 110 hours during the 336-hour July metering period. As discussed above, the results from the two metering periods are weighted evenly; thus, the annual operating hours are calculated as shown in Equation (b).

$$(b) \text{ Annual operating hours} = [(88/336 + 110/336) / 2] * 8760 = 2581 \text{ hours}$$

The peak demand savings and energy savings for this motor are calculated according Equations (c) and (d), respectively.

$$(c) \text{ Peak demand savings} = 41.8 - 37.6 = 4.2 \text{ kW}$$

$$(d) \text{ Energy savings} = (41.8 - 12.6) * 2581 = 73,367 \text{ kWh}$$