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End-Use Metering Absent Baseline Measurement: An M&V Protocol Application Guide

October 2018




End-Use Metering Absent Baseline Measurement: An M&V Protocol Application Guide

Version 2.0

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Prepared for

Bonneville Power Administration

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Table of Contents

1. Introduction

1.1. Purpose

End-Use Metering Absent Baseline Measurement: An M&V Protocol Application Guide (Absent Baseline Application Guide) is a complement to the Measurement & Verification (M&V) protocols used by the Bonneville Power Administration (BPA). It assists the engineer in applying the *Verification by Equipment or End-Use Metering Protocol (End-Use Metering Protocol)* to verify savings from energy-efficient equipment installed in situations where the baseline for the measure is not the equipment or processes in place prior to the measure's installation. This Guide applies to newly constructed facilities and major additions to an existing facility. The Guide can apply to replacement of failed equipment where the opportunity to measure the baseline has passed or the prior equipment is outdated and does not constitute the appropriate baseline. As is the case for the *End-Use Metering Protocol*, this application guide is intended for measures that change load or operating hours, or both load and hours. Savings can be large or small. The application guide accommodates non-interactive measures, and interactive measures within appropriate measurement boundaries in some circumstances.

The *Absent Baseline Application Guide* is adherent with *IPMVP Option A.*[1]

Originally developed in 2012, this *Absent Baseline Application Guide* is one of ten documents produced by BPA to direct M&V activities; an overview of the ten documents is given in the *Measurement and Verification (M&V) Protocol Selection Guide and Example M&V Plan (Selection Guide).*

Chapter 7 of this application guide provides full citations (and web locations, where applicable) of documents referenced. The document *Glossary for M&V: Reference Guide* defines terms used in the collection of BPA M&V protocols and guides.

1.2. Protocols Version 2.0

BPA revised the protocols described in this guide in 2018. BPA published the original documents in 2012 as Version 1.0. The current documents are Version 2.0.

1.3. How is M&V Defined?

BPA's *Implementation Manual* (the IM) defines measurement and verification as "the process for quantifying savings delivered by an energy conservation measure (ECM) to demonstrate how

[1] *International Performance Measurement and Verification Protocol.*

much energy use was avoided. It enables the savings to be isolated and fairly evaluated."[2] The IM describes how M&V fits into the various activities it undertakes to "ensure the reliability of its energy savings achievements." The IM also states:

> *The Power Act specifically calls on BPA to pursue cost-effective energy efficiency that is "reliable and available at the time it is needed."[3] […] Reliability varies by savings type: UES, custom projects and calculators.[4,5] Custom projects require site-specific Measurement and Verification (M&V) to support reliable estimates of savings. BPA M&V Protocols direct M&V activities and are the reference documents for reliable M&V. For UES measures and Savings Calculators, measure specification and savings estimates must be RTF approved or BPA-Qualified.[6]*

The *Selection Guide* includes a flow chart providing a decision tree for selecting the M&V protocol appropriate to a given custom project and addressing prescriptive projects using UES estimates and Savings Calculators.

M&V is site-specific and required for stand-alone custom projects. BPA's customers submit bundled custom projects (projects of similar measures conducted at multiple facilities) as either an M&V Custom Program or as an Evaluation Custom Program; the latter requires evaluation rather than the site-specific M&V that these protocols address.

1.4. Background

BPA contracted with a team led by kW Engineering, Inc. to assist the organization in revising the M&V protocols that were published in 2012 and used to assure reliable energy savings for the custom projects it accepts from its utility customers. The team conducted a detailed review and user assessment of the 2012 M&V Protocols and developed the revised version 2.0 under Contract Number 00077045.

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2 2017-2019 Implementation Manual, BPA, October 1, 2017. *https://www.bpa.gov/EE/Policy/IManual/Documents/IM_2017_10-11-17.pdf*

3 Power Act language summarized by BPA.

4 UES stands for Unit Energy Savings and is discussed subsequently. In brief, it is a stipulated savings value that region's program administrators have agreed to use for measures whose savings do not vary by site (for sites within a defined population). More specifically UES are specified by either the Regional Technical Forum – RTF (referred to as "RTF approved") or unilaterally by BPA (referred to as BPA-Qualified). Similarly, Savings Calculators are RTF approved or BPA-Qualified.

5 Calculators estimate savings that are a simple function of a single parameter, such as operating hours or run time.

6 https://www.bpa.gov/EE/Policy/IManual/Documents/IM_2017_10-11-17.pdf, page 1.

The kW Engineering team is comprised of:

- kW Engineering, Inc. (kW), led by David Jump, Ph.D., PE, CMVP
- Research into Action (RIA), led by Marjorie McRae, Ph.D.
- Demand Side Analytics (DSA), led by Jesse Smith

BPA's Todd Amundson, PE and CMVP, was project manager for the M&V protocol update work. The kW Engineering team compiled feedback from BPA and regional stakeholders, and the team's own review to revise and update this 2018 *Absent Baseline Application Guide*.[7]

[7] Kevin Warren, of Warren Energy Engineering, was the primary author of Version 1.0 of the Absent Baseline Application Guide, under Todd Amundson's direction and supported by other members of the protocol development team.

2. Overview of Method

2.1. Description

The BPA *End-Use Metering Protocol* provides guidance to verify energy savings for energy conservation measures (ECMs) in equipment or end uses. These methods are useful when the savings for an ECM are too small to be resolved with whole-building or facility energy meters, or for stand-alone equipment as may be found in the commercial, industrial, and agricultural sectors. It may also be applied to some new construction ECMs affecting equipment or end uses. Verifying savings from ECMs that involve multiple pieces of equipment with interactions among multiple or complex energy flow paths is not a good application of the protocol.

This *Absent Baseline Application Guide* has been written to illustrate how the methods in the *End-Use Metering Protocol* can be applied to the problem of verifying savings of energy-efficient equipment installed under one of the following conditions:

- ➡ There is no facility pre-installation period to serve as a baseline, such as for newly constructed facilities, major additions to an existing facility, or a new process at an existing facility.
- ➡ The pre-installation-period energy use is not relevant to regional definitions of measure savings, such as when the efficient equipment replaces either operating or failed equipment that had exceeded its useful life.[8]

Briefly, instead of using baseline measurements, the engineer must use information from sources such as Energy Code minimum efficiencies, Energy Code required features, and manufacturer data presenting equipment performance curves, characteristics, or tables. The appropriate method depends on whether the equipment draws constant load or variable load and whether it operates with a constant schedule or variable schedule.

Note that M&V practitioners may choose to address new construction projects with building simulation modeling . Modeling is not included in this application guide; the processes in the application guide are alternative approaches to modeling.[9]

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8 Replacement of failed equipment is sometimes referred to as replace-on-burnout.

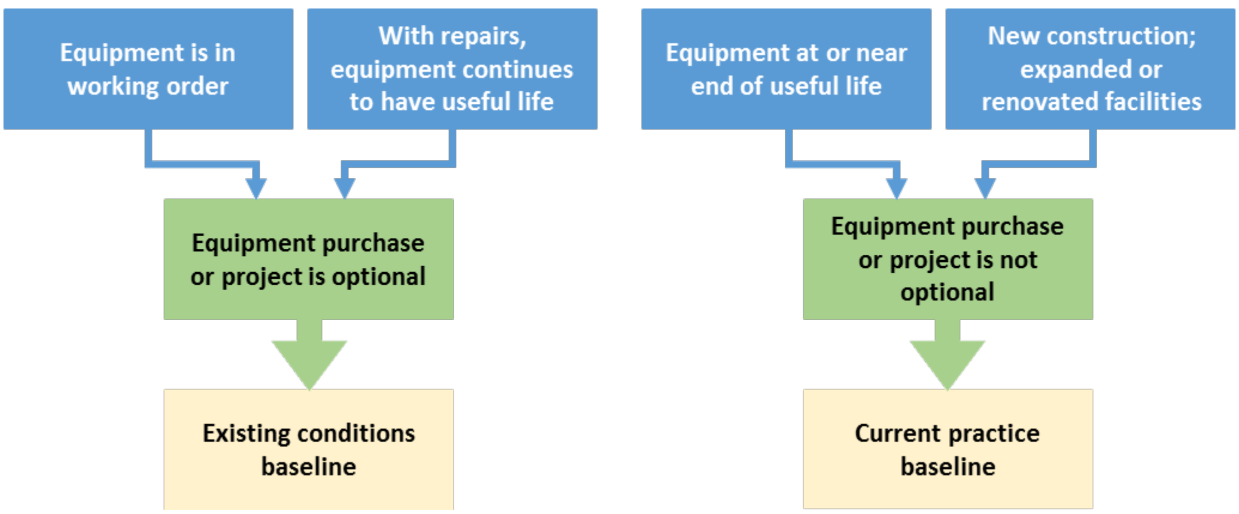
9 Building simulation modeling is an IPMVP Option D approach and requires that the simulation model be calibrated to prescribed random and bias error criteria, a process that requires time and effort. The calibration scope and process can be very detailed and some uncertainty and potential for error remains. Because actual building data from the post-construction occupied building is required, it will typically take up to a year to collect utility bill information sufficient to calibrate the models. This delays the incentive payment process.

2.2. Applicability

This application guide is applicable to measures with *current practice* baselines. When the practitioner uses a *current practice baseline*, the efficiency level of the baseline equipment must be consistent with any state or local mandates for new equipment, which may vary from city to city and state to state.[10]

The equipment or project is not optional for the owner when the equipment is at or near (within one year of) the end of its useful life, or when the equipment or project is necessitated by new construction, including expanded or renovated facilities. In this situation, the M&V practitioner typically should use the current practice efficiency level for the baseline. Figure 2-1 illustrates this guidance for selecting the appropriate baseline.

Figure 2-1: Guidance for Selecting Appropriate Baseline



Source: Research Into Action

The *End-Use Metering Protocol* defines the energy use characteristics of equipment or end uses according to their load and hours-of-use components, and whether they are constant or variable. Four load and hours-of-use categories are defined. This guide is applicable to all four categories – equipment with: *constant load, timed schedule* (CLTS); *variable load, timed schedule* (VLTS); *constant load, variable schedule* (CLVS); and *variable load, variable schedule* (VLVS).

Normally, a single baseline is determined for a project and a single annual verified savings estimate is determined. However, in some jurisdictions, two baselines may be assigned to a

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[10] The following websites hosted by Washington State University's Energy Program, the Northwest Energy Efficiency Council, and the Northwest Energy Efficiency Alliance provide information on mandates for new equipment among jurisdictions in the region:
(1) *http://www.energy.wsu.edu/BuildingEfficiency/EnergyCode.aspx*,
(2) *https://www.neec.net/energy-codes/*, and
(3) http://neea.org/initiatives/codes-standards/codes.

project. Consider a measure that is expected to have a useful life of 15 years that replaces an existing unit that is 10 years old. When estimating the lifetime savings of the project, a *pre-condition* baseline is assumed for the first 5 years and a *current practice* baseline for the remaining 10 years.

2.3. Additional Considerations

Safety

The *Absent Baseline Application Guide* may require that energy data is collected after installation of the energy efficiency project. While most efficiency projects are on systems and equipment that operate in the low voltage range,[11] the voltage levels are still high enough to cause severe injury or worse if proper safety precautions are not taken before making electric power measurements. It is of primary importance that personnel follow their organization's safety procedures and equipment whenever the situation warrants it. Practitioners using this application guide will need to make decisions about collecting the necessary data based on several factors including: the type and location of measurements, the ability to safely make measurements, and the resources available to make safe measurements. These factors can ultimately determine whether the *End-Use Metering Protocol* may be applied on the project.

Data Collection Techniques and Devices

This application guide characterizes equipment operation as constant and variable loads and schedules, based on which the practitioner will develop data collection plans. The plans will describe the data collection techniques to be used, including the specification of data collection devices. Generally, data collection devices are either hand-held instruments or data loggers that are left in place to store collected data. BPA and its efficiency program partners maintain inventories of data collection instruments and devices. Please consult your organization's resources for data collection tools. The techniques used to collect data fall into these categories:

1. **Constant loads.** When loads are constant, a single measurement (often referred to as a 'spot' measurement) may suffice to determine the load value. Practitioners may use a hand-held power meter measuring volts and amps. A device that measures amperage alone may also be used, with power estimates derived from the amperage measurement and the equipment voltage ratings. To increase measurement accuracy, the practitioner should use the average of multiple readings taken on the equipment.
    a. Alternatively, it may be necessary to confirm the load is constant by making multiple measurements over time and analyzing the data to assure its variation is low. This approach requires a data logger or a trend file from a building control system.
2. **Variable loads.** Variable loads require that data be collected over the time period of the load variation cycle, and often over multiple cycles and operating conditions to ensure

[11] There are multiple classifications of voltage levels. The low voltage range is 0 to 600V for three-phase power distribution circuits according to ANSI C84.1-1989.

enough data is collected to properly characterize equipment operation in analysis. The duration of the cycle and operating conditions are factors in deciding the duration of the monitoring period as well as the data collection interval (that is, how often measurements are made). The practitioner should be mindful that the data storage capacity of commercially available monitoring devices may limit data collection. It is often preferable to use a facility's own control system, if it has relevant control points on the project equipment, because the data easier and safer to obtain than from M&V monitoring and avoids costly trips back and forth to project sites. Control systems may be set up to collect data over time, a process known as trending.

3. **Schedules.** Control system trends provide reliable data that the practitioner may use to define schedules. If trending capability is unavailable, data loggers can be used both to collect schedule information and to measure loads on variable equipment. If equipment loads (and thus power or current) do not need to be measured, often schedule can be measured with only equipment status sensors, which do not require the use of safety equipment.

2.4. Advantages of this Approach

Use of the *Absent Baseline Application Guide* has several advantages:

- ➡ The guide enables verification of ECMs on specific equipment using data and information used to develop the original savings estimates.
- ➡ The guide allows for use of the abundant technical information from manufacturers, such as equipment performance curves, design and nameplate information, and so on.
- ➡ Many of the measurements required by the guide can be achieved in a relatively short time period.
- ➡ The methods may be applied to more complicated systems as long as the systems' operational characteristics fall into the categories identified above.
- ➡ The methods allow uncertainty in the savings estimates to be estimated, should that be a project requirement.

2.5. Disadvantages of this Approach

The *Absent Baseline Application Guide* is not appropriate for multiple ECMs installed throughout a building; a whole-building approach is more appropriate for that situation. The methods described in this guide do not account for energy interactions, such as heating savings from a lighting retrofit project. Projects with highly randomized load and schedule characteristics may not be appropriate for the methodology.

3. Algorithms

3.1. Basic Procedure

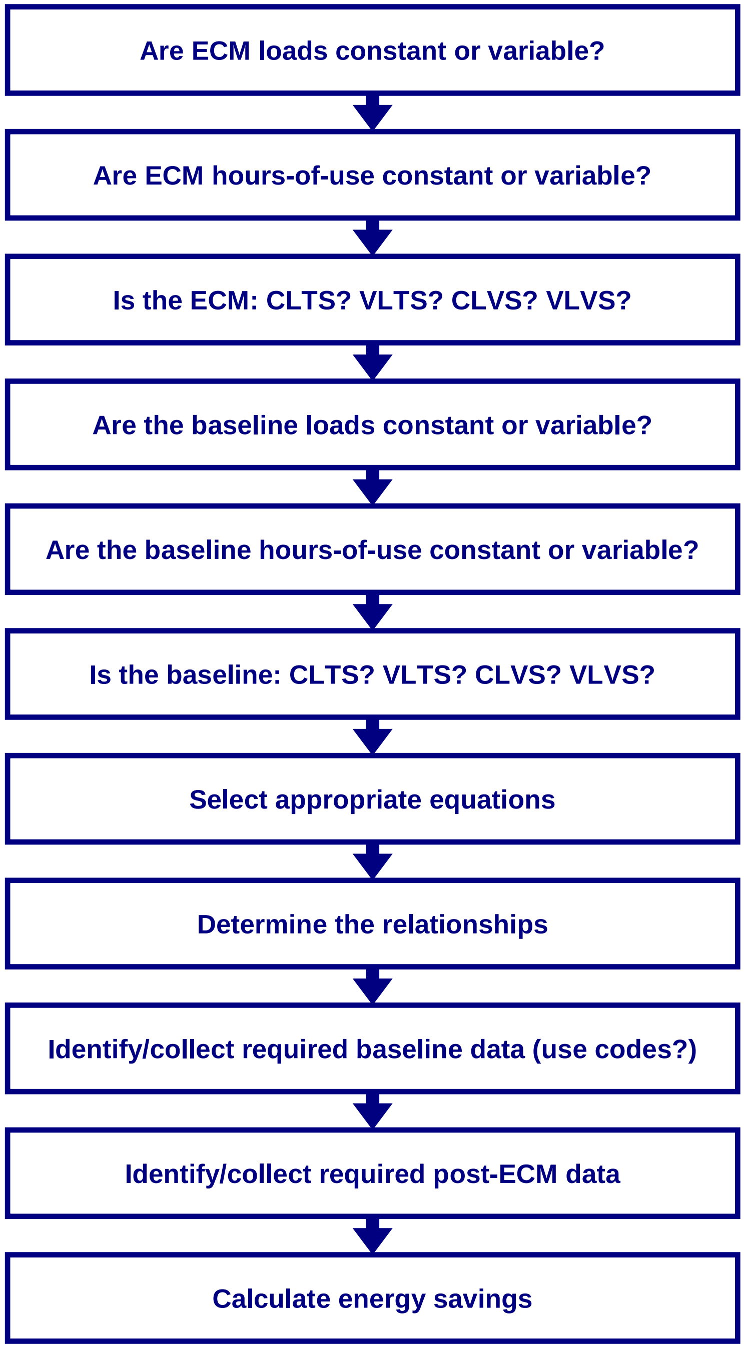
The basic procedure for applying the method is described in the *End-Use Metering Protocol*. Below, it is customized for projects where the baseline cannot be directly measured. Characterizing the equipment's energy use properties into constant or variable load and hours-of-use facilitates development of the M&V Plan for each project. The baseline load and schedule characteristics must also be defined. The fundamental procedure is as follows (see Figure 3-1 for a flow chart of this procedure).

1. Identify which of the four categories described in the *End-Use Metering Protocol* and summarized in its Section 2.2 best represents the anticipated post-installation equipment's load and hours-of-use characteristics.
2. By comparing the ECM to the post-installation load and schedule characteristics, determine the impact the ECM would have on the equipment's baseline load or hours-of-use. Determine if it would have changed the load or hours-of-use, or would have changed them from constant to variable.
3. Identify which of the four categories described in the *End-Use Metering Protocol* and summarized in its Section 2.2 best represents the equipment's baseline load and hours-of-use characteristics.
4. Identify the most appropriate equations to be used to determine energy savings.
5. Determine the relationships between load and hours-of-use terms in the energy savings equation and other parameters (such as, temperature, air or water flow, pressure, and so on).
6. Identify and collect the required data in the post-implementation period.
7. Identify and collect the required baseline data (from sources such as codes, rather than from metering).
8. Calculate energy savings using the equations in the *End-Use Metering Protocol*.

The *End-Use Metering Protocol* provides guidance on measuring and estimating parameters. Under *IPMVP Option A*, either the load or the hours-of-use must be measured; the other parameter may be estimated. Option A does <u>not</u> allow both load and hours-of-use parameters (including all of their sub-parameters) to be estimated; key parameters must be identified and *measured*.

Under Option A, key parameters for measurement are identified and the other parameters to the savings calculation may be estimated based on reliable sources. The key parameters to be measured are normally the most uncertain or unknown parameters. Reliable sources include past measurements, manufacturer specifications and performance curves, lighting wattage tables, and so on. When applying this protocol to new construction ECMs where there is no baseline equipment for measurement, the relevant building code or standard may be used to define estimated parameters.

Figure 3-1: Customized Basic Procedure Flowchart



Refer to the *End-Use Metering Protocol* for additional guidance on selecting the duration of metering and extrapolating results to an annual basis.

3.2. Equations

The *End-Use Metering Protocol* states that it is often not necessary to repeat baseline data collection activities in the post-implementation period. One parameter (either load or hours) is often not affected by the ECM. In the *End-Use Metering Protocol*, the recommended approach is to measure the unchanged parameter in the baseline period and apply it to both baseline and post-installation scenarios. The same logic can be applied to measures covered by this Guide, except that the unchanged parameter will have to be measured in the post-implementation period.

Tables 3-2 through 3-5 of the *End-Use Metering Protocol* contain energy savings equations that may be used for each combination of load and schedule category. Within each table, the impact of the ECM on the load, hours-of-use, or both, determines the potential energy savings equations that may be used. These equations apply equally well to projects of the type addressed by this application guide.

3.3. Uncertainty

The guidance provided in the *End-Use Metering Protocol* regarding uncertainty should be followed. Where baseline values are fully determined from code, the value is known with statistical certainty. However, often the baseline load or schedule is only partly known with certainty.

For example, the baseline load for a new construction lighting project is typically determined by:

- kW = lighting density (watts/sq.ft.) x floor area (sq.ft.)

The lighting density is known with statistical certainty, since it is taken from a table in the applicable energy code. As long as the correct code version and the correct facility or space type are used, the lighting density value is known. There could be uncertainty around the estimate of floor area. The uncertainty for an equation where two variables are multiplied is:

- $x = a \cdot b$; $(\Delta x / x)^2 = (\Delta a / a)^2 + (\Delta b / b)^2$

Thus, if the one variable is known with certainty, the relative error in the product is equal to the relative error in the one variable.

4. Issues Specific to a New Construction Application of the End-Use Metering Protocol

4.1. Baseline

BPA Custom Project program rules define new construction savings relative to "code" standards without defining what those standards are. The following websites hosted by Washington State University's Energy Program, the Northwest Energy Efficiency Council, and the Northwest Energy Efficiency Alliance provide information on mandates for new equipment among jurisdictions in the region:

- *http://www.energy.wsu.edu/BuildingEfficiency/EnergyCode.aspx*
- *https://www.neec.net/energy-codes/*
- *http://neea.org/initiatives/codes-standards/codes*

The code in effect during the design phase is the relevant code during periods of code transition. Where local energy codes are more stringent than state codes, the local code establishes the baseline. The applicable code defines *what would have been built* in the absence of energy-efficient design.

A baseline must also be defined for measures that replace failed equipment or are installed in a new process in non-building applications. In such cases, there is typically no energy code that applies. The baseline should reflect the conditions that *would have occurred* in the absence of the project. For non-building applications, this is typically defined as the industry standard practice (equivalently, current practice).

Industry standard practice can be difficult to define. Publications can be useful for determining the practices that are common for an industry or system. Note, however, that articles tend to focus on new or innovative approaches. The standard practice is less likely to be highlighted. The practices of the customer at other locations can be considered. If the customer uses different practices in jurisdictions that have incentives for energy efficiency than in other jurisdictions, this presents a strong basis for the standard practice. However, the customer may consistently exceed standard practice and, if so, the practitioner will need to look elsewhere to ascertain the industry standard. The practices of the customer's competitors can be considered, but this information can be difficult to obtain. The practitioner may be able to make a case for standard practices as represented by the characteristics of commonly sold equipment, with the equipment identified or inferred from an investigation of manufacturer, distributor, and installer websites.

4.2. Post-Installation

Guidance on the data to be collected in the post-implementation period is provided in the *End-Use Metering Protocol*.

4.3. ASHRAE 90.1 Appendix G

Some new construction programs make use of *ASHRAE Standard 90.1 Appendix G* to define the baseline. Appendix G defines baseline HVAC system types based on the size of the building. For example, the baseline system type for a large (>150,000 square feet) nonresidential building is a variable air volume fan system with reheat at the terminal boxes (VAVRH). The baseline system type may be a different type than the system installed in the building. If a high efficiency heat pump system was installed, and the baseline was defined as a VAVRH system, then the savings cannot be easily determined by the methods in the *End-Use Metering Protocol*. A modeling approach is generally required for a case where the entire system type is changed.

If Appendix G is not used to define the baseline, the baseline for the high efficiency heat pump ECM would be code-compliant heat pumps. For this case, the methods in the *End-Use Metering Protocol* can be used to determine the savings.

Appendix G also defines baseline characteristics for some parameters for which no minimum efficiency is specified in the main code. For example, the 2007 version specifies baseline pump power for systems with hot water pumps as 19 watts per GPM. Such values may provide a defensible baseline for a highly efficient hot water pumping and distribution system.

5. Minimum Reporting Requirements

5.1. Measurement and Verification Plan

5.1.1. Essential Elements of the Measurement and Verification Plan

Proper savings verification requires planning and preparation. The IPMVP lists several requirements for a fully-adherent M&V plan.[12] The *Absent Baseline Application Guide* describes methods for verifying savings in equipment and end uses. This Guide describes planning requirements, as well as specific measurement and analysis activities. Documenting in an M&V Plan how these requirements will be met is important so that others who subsequently become involved in the project can obtain a full understanding of the project's history and progress.

The following are the essential items in documenting a savings verification plan.

- **Measurement Boundary:** Define the boundary around the equipment or end use within which the savings will be verified. This boundary can be around a specific piece of equipment, such as a pump and its motor, or a combination of equipment comprising a building subsystem, such as an air-handling system or chilled-water system.
- **Baseline Equipment and Conditions:** Document the end-use baseline systems affected by the ECMs. Document equipment configurations, operational characteristics (operating practices or operation schedules that characterize its hours-of-use), and equipment inventories, sizes, types, and conditions.
- **Energy and Independent Variable Data:**
  - Include all energy data from spot measurements and short- or long-term monitoring from each source. Describe:
    - The parameters needed to characterize equipment load,
    - The sources of the energy and independent variable data and the time interval at which they are monitored,
    - The start and duration of monitoring for both the baseline and post-installation periods, and
    - Any needed corrections to the data.
- **Reporting Period:** Describe the length of the reporting period and the activities that will be conducted, including data collection and sources.
- **Analysis Procedure:** Describe how the baseline and post-installation energy use or demand will be adjusted to a common set of conditions. Describe the procedures used to

[12] *Chapter 5, IPMVP Volume I – 2010*.

prepare the data. Describe the procedures used for analyzing the data and determining savings. Describe any extrapolations of energy use or savings beyond the reporting period. Describe how savings uncertainty (if required) will be estimated. Document all assumptions.

- ➡ **Option A Requirements:** For each non-key parameter including energy code or standard practice, specify the basis for the estimated values used. Describe their source or sources. Describe the impact of any significant variation in the values used and what otherwise would be measured on the calculated savings.
- ➡ **Savings Verification Reports:** Describe what results will be included in the savings reports. Describe what data and calculations will be provided. Describe when savings will be reported for the project. Indicate the reporting format to be used. See the section below regarding the *Savings Verification* Report for the minimum requirements.

5.1.2. M&V Plan Additional Elements

The IPMVP describes several other elements of a good M&V plan. These items are good practice in general, but not necessary for every project. Many of them are provided here for reference and consideration for inclusion in M&V Plans written under this guide.

- ➡ **Energy Prices:** Document the relevant energy prices to be used to value the savings. This can be a blended electric rate or a schedule of rates based on time-of-use. Note that the latter will add significant complexity to the calculations.
- ➡ **Measurement Instrument Specifications:** Document the instruments used to obtain the data used in the calculations, including their rated accuracy and range. Identify the last instrument calibration date.
- ➡ **Budget:** Estimate the budget required for the savings verification activity. Estimate labor and material (such as meters and instruments, and associated safety equipment) costs and provide an approximate schedule for when activities will occur.
- ➡ **Quality Assurance:** Describe any quality assurance activities that will be conducted as part of this M&V project. This may include how data is validated, how *IPMVP Option A* estimates are checked, identifying other parties who will review the work, and so on.

5.1.3. Documentation for BPA Database

The documentation should also include the following information to support review and inclusion of the project and measure in the BPA energy efficiency reporting system*:*

- ➡ Utility name
- ➡ Utility program
- ➡ Sector (commercial/industrial/residential)
- ➡ Existing building or new construction

- ➡ Site address (this will be used to establish the climate zone)
- ➡ Building type (examples: office, school, hospital)
- ➡ Building size, square feet
- ➡ Affected end uses (examples: HVAC, interior lights, exterior lights, receptacle plugs, DHW)
- ➡ Affected system (examples under HVAC: cooling plant, heating plant, HVAC fans, terminal units, controls)
- ➡ Affected equipment type (examples under cooling plant: chiller, packaged unit, cooling tower, pumps)
- ➡ Measure type (broad category)
- ➡ Measure name (specific category)

5.2. Savings Verification Report

5.2.1. General Verification Report Requirements Based on IPMVP

After the M&V calculations have been completed, the savings and actual M&V process used need to be documented.

Per the IPMVP, the *Savings Verification Report* should follow the savings verification report requirements described in the project's M&V Plan. Any deviations from the M&V Plan must be clearly described. If the M&V method followed the M&V Plan, then the information in the M&V Plan does not need to be repeated but can just reference the Plan. However, deviations from the planned method, measurement boundary, baseline characteristics, etc. necessitate new descriptions.

IPMVP Chapter 6, M&V Reporting, generally requires the following:

- ➡ Report both energy and cost savings.
- ➡ Report the data relevant to the reporting period, including the measurement period and the associated energy data and independent variables. Any changes to the observed data must be described and justified.
- ➡ Describe any non-routine baseline adjustments, including the details of how the adjustments were calculated.
- ➡ Report the energy prices or rates used in the cost-savings calculations.

In addition, actual data for baseline and post-period energy use should both be reported.

5.2.2. Additional Savings Verification Report Requirements

Load and Schedule Relationships

Determine the relationships between load and hours-of-use terms in the energy savings equation and other parameters, such as temperature, air or water flow, pressure, and so on. This includes the relationships of daytypes and seasons to load and hours-of-use.

The savings verification report should clearly define loads and schedules, and their relationship to other variables:

- ➡ **For a constant load**, the load value and units should be provided, as well as how the load value was obtained. If any proxies are used to define the load, the proxies should be justified and their development described.
- ➡ **For variable load**, the load frequency distribution should be provided, along with a description of how it was obtained. For loads that can be any value, they should generally be grouped into 5 to 10 bins, but this is dependent upon how much the load varies. For example, if the load varies from 0% to 100%, 10 bins might be appropriate, but if the load only varies from 80% to 100%, then 2 to 4 bins might be appropriate.
- ➡ **For a timed schedule**, report the source for the schedule and the total annual hours.
- ➡ **For a variable schedule**, report the source for the estimate of the hours during the measurement period and the total annual hours.

Variable load information, energy models, and load correlations for engineering calculations are all similar and should be shown graphically in an x-y (scatter chart), as well as an equation or table. Load frequency distributions should be shown in both a bar chart and a table.

Savings Verification Report Information

The report should include the following information in most cases. It may be organized in this order with a separate section for each of these items, or in another order or organization that makes sense for a program or project.

1. The data for the baseline period, including the period, monitoring intervals, and data points should be described.
2. The load and schedule for the baseline period, and any relationships associated with variable loads or schedules, should be clearly defined.
3. The impact of the ECM on the load or hours-of-use in the reporting period should be described.
4. The data for the reporting period, including the time period, monitoring intervals, and data points should be described.
5. The load and schedule, and any relationships associated with variable loads or schedules, should be clearly defined for the reporting period.

6. The equations used to estimate baseline consumption, reporting period consumption, and savings should be listed and explained.

7. Report consumption (and where relevant, demand), as well as savings, since this facilitates review and reasonableness checks.

8. As required by IPMVP, report the energy prices or rates used in the cost savings calculations.

9. Also, as required by IPMVP, report both energy and cost savings.

10. Provide verification of potential to generate savings.

Post Installation Verification of Potential to Generate Savings

IPMVP Section 4.3 requires that, "After the ECM is installed, inspect the installed equipment and revised operating procedures to ensure that they conform to the design intent of the ECM." Therefore, an IPMVP-adherent process requires evidence that the efficiency measures have the potential to generate savings. BPA may require short-term monitoring, spot measurements, production data, or other forms of verification to confirm potential.

Verification includes notation of any changes to the project subsequent to the M&V plan. If the project changed, the energy and demand savings should be recalculated based on as-installed conditions. Data and analysis from metering performed before or after installation should be included with the calculations.

In general, verification of potential to generate savings can take either of two forms:

➡ Installation verification

➡ Operational verification

Installation Verification

Installation verification is the less rigorous of the two verification methods. It demonstrates the measures were installed as planned. This demonstration may vary by measure. Project developers are required to describe the evidence and documentation they plan to provide to demonstrate that the measures were installed, and this evidence and documentation belongs in the savings verification report.

Examples of installation verification include:

➡ Photographs of new equipment

➡ Photographs of new control set-points

➡ Screen captures from EMCS

➡ Invoices from service contractors (invoices should not be the sole form of evidence but may supplement other verification documentation).

Operational Verification

Operational verification demonstrates that in the post-installation period, the system is operating (or not operating) as modeled in the calculations. It is based on visualization of *operational* data (as opposed to *energy* data) collected during one or more site visits after the measures have been installed.

Operational verification is in addition to installation verification and documentation should include the same types of evidence as for installation verification. In addition, the data logging, control system trending, or functional tests used to establish baseline shall be repeated to demonstrate that operations have been improved. Documentation of the commissioning of the new systems or equipment can be used for operational verification.

If the collected post-installation data, test results, and/or commissioning indicate less than predicted performance, or that the measures were not installed as assumed in the savings calculations (for example, due to incorrect or partial installation, or other circumstance), either:

- ➡ Act to help the customer fully install the measure properly and then re-verify it using these procedures; or
- ➡ Use the same calculation methodology with the post-installation data to calculate a revised measure savings estimate.

Choice of Verification Method

Common, well-known measures, measures with low expected savings, and measures whose savings estimates have considerable certainty, may need only installation verification. Measures with large savings and measures with less certain savings (whose savings can vary greatly dependent upon application) typically require operational verification.

Thus, there is no hard-and-fast rule for this choice. The analyst should recommend a verification method and the evidence expected to be presented for verification when submitting calculations or simulations. The final choice of verification method and evidence will be made by the reviewer.

6. Examples

6.1. Example 1 – New Construction Lighting

A new wing is being added to a building. The design team chooses to install high efficiency lighting. The electrical load of the installed lighting is less than the maximum lighting load allowed by local code. The lighting will be controlled by manual switches. An Option A approach will be used. The following outlines the M&V activities for this project.

1. Identify load and schedule category for the post-installation equipment.
   - Post-Installation Load and Schedule Category*:* CLVS
2. Determine impact of ECM on baseline equipment.
   - Reduces lighting load from code required level to high efficiency lighting level.
3. Identify load and schedule category for the baseline equipment.
   - Baseline Load and Schedule Category: CLVS
4. Identify equations for energy savings.
   - The correct savings formula is selected from the *End-Use Metering Protocol*. In this case, for a CLVS project where the ECM has an impact on the load, but not the hours, savings is calculated by:
     - $kWh_{saved} = \left(kW_{base} - kW_{post}\right) \cdot HRS_{post}$
5. Determine relationships between load and hours of use in terms of other parameters.
   a. The baseline load for a new construction lighting project is determined by:
      - kW_{base} = lighting power density (watts/sq.ft.) x floor area (sq.ft.)

      Where the lighting power density (LPD) is prescribed by the local jurisdiction's code requirement, which may describe LPD requirements based on space use type and floor area.

   b. The post-installation lighting load is determined by:
      - $kW_{post} = \Sigma_{,i}$ (watts/fixture$_i$ x fixture quantity$_i$)

      where: *i* = each fixture type installed
6. Identify and collect the required data in the post-implementation period.
   a. Baseline period measurements: Record the floor area of the expansion from the architectural drawings for the project. Determine the baseline lighting power density from the local energy code.

   b. Post-installation period measurements: Light loggers on a sample of fixtures for one month (annual hours based on extrapolation of hours of operation for all weekdays, weekends, and holidays). Verify the type and quantity of installed fixtures. The fixture wattage (load) may be estimated based on a lighting wattage table

7. Calculate energy savings using the above savings equation.

6.2. Example 2 – Chiller Replacing a Failed Chiller

A facility has two chillers, but one is incapable of meeting the entire cooling load of the facility and functions as a backup only. The main chiller runs year-round to meet the cooling load of the facility. Some of the facility's air handlers run continuously, so there is no time-of-day scheduling of the chiller. An outside air lockout is used to disable the chilled water pumps and chiller when the outside air temperature is less than 55°. The main chiller is old and suffers a major failure. The site must install a new chiller. They elect to install a chiller that is more efficient than is required by the local energy code. An Option A approach will be used. The following outlines the M&V activities for this project.

1. Identify load and schedule category for the post-installation equipment.
   - Post-Installation Load and Schedule Category*:* VLTS
2. Determine impact of ECM on baseline equipment
   - This is a chiller upgrade project where a new chiller that exceeds local code efficiency requirements will be installed. The ECM effects the efficiency only, the building's cooling requirements do not change, nor do the hours of operation.
3. Identify load and schedule category for the baseline equipment.
   - Baseline Load and Schedule Category: VLTS
4. Identify equations for energy savings.
   - This case is a VLTS project where the ECM has an impact on the load through the change in chiller efficiency, but not the cooling requirements or hours of operation. The savings are calculated by:
     - $kWh_{saved} = \sum_{i=1}^{n}\left[\left(Eff_{base,i} - Eff_{post,i}\right) \cdot HRS_{post,i} \cdot Q_{post,i}\right]$
     - where:
       - $HRS_{post,i}$ = hours in ambient temperature bins as determined from typical weather files. The chiller will operate continuously, but only for hours above 55° F dry-bulb.
       - $Q_{post,i}$ = average cooling load (tons) at each temperature bin as determined from the post-installation metering of cooling plant load
       - $Eff_{base,i}$ = minimum chiller efficiency required by code (kW/ton)

- $Eff_{post,i}$ = chiller efficiency at each cooling load, as determined from a performance curve provided by the manufacturer
- i = temperature bin number

5. Determine relationships between load and hours of use in terms of other parameters.

- A typical meteorological year of dry-bulb temperature data is collected from a website. The hours that dry-bulb temperature are in 5 degree temperature bins is determined.
- The relationship between the building load Q and ambient dry-bulb temperatures will be determined via a regression relationship.
- Cooling load Q is determined by the formula:
  - $Q = 500\ GPM(T_R - T_S)$ (tons)
  - Where:
    - GPM is the chilled water flow rate
    - T_R is the chilled water return temperature
    - T_S is the chilled water supply temperature
- The baseline and post-installation load (kW) for a chiller is determined by $Eff \cdot Q$.

6. Identify and collect the required data in the post-implementation period.
   a. Baseline period measurements: Determine the baseline chiller efficiency from the local energy code.
   b. Post-installation period measurements: Cooling plant load Q is monitored for several months by measuring chilled water GPM, chilled water supply temperature T_S, and chilled water return temperature T_R. Note that in some facilities, this data is available from existing energy management systems or industrial SCADA systems. Ambient dry-bulb temperatures are also measured concurrently.

7. Calculate energy savings using savings equation above.
   a. Cooling load Q over the monitoring period is determined using the above formula for each measurement of flow and temperatures.
   b. A relationship between ambient dry-bulb temperature and cooling load is determined with a regression relationship
   c. The number of hours that TMY temperatures are within each 5-degree F bin are determined, using only the hours when temperatures are above 55 F.
   d. The regression relationship between cooling load and ambient temperature is used to determine the cooling load for each temperature bin.
   e. Savings are calculated for each temperature bin using the above equation.

6.3. Example 3 – New Construction High Efficiency Pump

In a new construction scenario, a design team chooses to design and install a more efficient pump motor than the local applicable codes require. The pump will be constant speed and operate a known number of hours per year. The savings will be based on the increased efficiency of the pump motor over that required by the building code. An Option A approach will be used. The following outlines the M&V activities for this project.

1. Baseline
   a. *Load and Schedule Category*: CLTS (new construction)

Measurements: None, however, record the local code's minimum pump motor efficiency.

2. Post-Installation
   a. *Load and Schedule Category*: CLTS (new construction)

Post-Installation Measurements: pump motor power (average of multiple measurements); motor status logging for one month (annual hours based on extrapolation of hours of operation for all weekdays, weekends, and holidays)

3. The known baseline value is the efficiency of the motor. The baseline kW is determined assuming that the motor load (brake horsepower) is the same as in the post-installation case.
   - $kWh_{base} = \left(Eff_{base} / Eff_{post} - 1\right) \cdot kW_{post}$
4. Savings calculated by:
   - $kWh_{saved} = \left(kW_{base(code)} - kW_{post}\right) \cdot HRS_{post}$
5. Identify load and schedule category for the post-installation equipment.
   - Post-Installation Load and Schedule Category*:* CLTS
6. Determine impact of ECM on baseline equipment.
   - Reduces pump motor load from code required level to high efficiency pump motor level.
7. Identify load and schedule category for the baseline equipment.
   - Baseline Load and Schedule Category: CLTS

8. Identify equations for energy savings.

   - The correct savings formula is selected from the *End-Use Metering Protocol*. In this case, for a CLTS project where the ECM has an impact on the load, but not the hours, savings may be calculated by:
     – $kWh_{saved} = \left(kW_{base} - kW_{post}\right) \cdot HRS_{post}$
     – Where:
       - kW_{base} = baseline motor power consumption
       - kW_{post} = post-installation power consumption
       - HRS_{post} = post-installation operation hours

9. Determine relationships between load and hours of use in terms of other parameters.

   a. The baseline power consumption kW_{base} is determined by:
      – $kW_{base} = HP \ \cdot 0.7457/\eta_{fl}$
      – Where:
        - kW_{base} is the input power at full-rated load
        - *HP* is the nameplate baseline motor horsepower
        - η_{fl} is the baseline motor efficiency at full load

10. Identify and collect the required data in the post-implementation period.

    a. Baseline period measurements: Determine the baseline motor efficiency η_{fl} from the local energy code for the same size motor (same horsepower) as installed.

    b. Post-installation period measurements: Measure pump motor power (average of multiple measurements when pump operating); apply a motor status logger for one month to determine hours of use.

11. Calculate energy savings using the above savings equation.

    a. Average the multiple measurements of motor power consumption during operation to get an accurate measurement of kW_{post}.

    b. Extrapolate the measured hours of use during one month to annual hours of use.

    c. Calculate kW_{base} from above equation using motor *HP* and η_{fl}.

6.4. Example 4 – Wastewater Treatment Plant Aeration Blower

The following example illustrates how to apply the M&V approach in the *End Use Metering Absent Baseline Application Guide (Absent Baseline Guide)* to a project. The project is a new construction project in which a City's wastewater treatment facility is expanding treatment capacity by adding an aeration basin and blower system to the existing system. In this project, the City reviewed the benefits of a more advanced blower technology and decided to install the advanced blowers in place of the standard blower technology it was originally considering. The City expected significantly reduced energy and operating costs with the selection of this blower. Because this was not a replacement or retrofit project, there was no opportunity to make energy measurements on an existing system, therefore the *Absent Baseline Guide's* M&V methodology was used.

6.4.1. Introduction

The following is a simplification of the project to demonstrate how the M&V was applied. In 2010, the City worked with its design-build team to specify its treatment plant's additional basin's dimensions, capacity, and blower system requirements. The new aeration and clarifier basins would expand the treatment process to 20 million gallons per day (MGD) of influent. Original plans included a 300 hp multi-stage centrifugal blower with inlet vanes, however the City decided to go with a more expensive turbo blower in the design stage, as this blower type was much more efficient than other types. A neighboring city had installed a turbo blower in its treatment facility, and operations personnel from the City had visited and were impressed by its performance, minimal maintenance requirements, and savings.

Efficiency Measure

According to the literature, energy consumption of aeration blowers in wastewater treatment facilities accounts for about 75% of their lifecycle costs. While multi-stage centrifugal blowers have a decent turn-down ratio when using inlet guide vanes or variable frequency drives, they are not as efficient as turbo blowers. Turbo blowers are variable speed and are more efficient over a wide range of air flows and have the same or better turn-down ratios as multi-stage centrifugal blowers, often making them the superior choice in many applications. In addition, they have fewer moving parts and therefore lower maintenance requirements.

Preliminary energy savings calculations were based on data obtained from performance curves for the multi-stage centrifugal and turbo blowers. These calculations made many assumptions about the influent flow profile for the aeration pond, and estimated pressure and air flow requirements from both blowers. Estimated savings was over 600,000 kWh annually.

Assessment

The *Absent Baseline Guide* was selected for this project, as there was not a baseline system in existence upon which measurements could be made. Following the basic procedure in the *Absent Baseline Guide*, the measurement and verification (M&V) approach was developed. These steps are shown below.

1. Identify which of the four categories described in the End-Use Metering Protocol best represents the anticipated post-installation equipment's load and hours-of-use characteristics.

The turbo blower operated as variable load equipment. It modulated its load to meet air flow requirements, which were in turn controlled by the amount of dissolved oxygen (DO) in the aeration pond. A DO sensor in the pond monitored the amount of dissolved oxygen and controlled the blower to increase or decrease speed and air flow.

The wastewater facility operated continuously day and night all year.

The post-installation load characteristic was variable load and the hours-of-use were constant.

2. By comparing the ECM to the post-installation load and schedule characteristics, determine the impact the ECM would have on the equipment's baseline load or hours-of-use. Determine if it would have changed the load or hours-of-use or would have changed them from constant to variable.

The selection of the turbo blower over the multi-stage centrifugal blower was a reduction in equipment load due to the more efficient turbo blower. In both cases, the equipment was variable load.

Hours of use did not change.

3. Identify which of the four categories described in the End-Use Metering Protocol best represents the equipment's baseline load and hours-of-use characteristics.

The multi-stage centrifugal blower originally considered for the design was a variable load piece of equipment.

The design of the new aeration pond was anticipated to be continuous throughout the year, as it was for the post-installation case. Baseline hours of use were constant.

4. Identify the most appropriate equations to be used to determine energy savings.

Since the load changed from baseline to post-installation periods, but total hours and hours at each load level did not, the fundamental equation was:

$$kWh_{saved} = \sum_{i} \left(kW_{base,i} - kW_{post,i}\right) \cdot HRS_{post,i}$$

5. Determine the relationships between load and hours-of-use terms in the energy savings equation and other parameters (such as, temperature, air or water flow, pressure, and so on).

The multistage centrifugal blower's power consumption was dependent on the air flow and head pressure to be delivered at any particular time. Similarly, the turbo blower's power consumption was also dependent on the air flow and head pressure in the system.

The air flow requirement was governed by the amount and dissolved oxygen content of the wastewater flowing through the pond. The discharge pressure was governed by the design of the aeration system.

6. Identify and collect the required data in the post-implementation period.

After construction, the air flow, head pressure and power consumed by the turbo blower was measured through monitoring of these parameters over a representative time period.

7. Identify and collect the required baseline data (from sources such as codes, rather than from metering).

Power consumed by the multi-stage centrifugal blower was obtained from manufacturer performance curves.

8. Calculate energy savings using the equation identified above.

6.4.2. Baseline Period

Data Collected

The performance specifications for the originally planned multi-stage centrifugal blower was obtained from the design team. The data included tables of inlet and discharge pressure, air flow, and power.

Analysis

A relationship between flow and power at a constant discharge pressure was developed from the multi-stage centrifugal blower performance data. This relationship was used to estimate baseline power and energy use under the flow and pressure conditions in the post-installation period. Energy savings were determined for post-installation conditions.

Project Documentation and M&V Plan

The M&V Plan developed for this project described the as-built wastewater treatment facility, and its aeration blower system. Based on the *Absent Baseline Guide* and using the BPA M&V Custom Project Calculator, it described the baseline aeration blower system considered in the original design and its energy performance. The increase in efficiency of the turbo blower over the baseline blower, and the planned data collection and analysis activities to determine actual energy savings was also described. The M&V plan described the equations to be used to quantify savings, what data would be measured and monitored in the post-installation period, how the data would be analyzed to quantify the parameters in the savings equations, and the resulting savings. The M&V Plan addressed important considerations that influenced savings, such as what adjustments should be made if plant inflow rates deviated from expected operations.

6.4.3. Post-Implementation Period

Verification Activities

A site visit was made to verify that all the specified equipment was installed and operating per the manufacturer's specifications. Copies of the construction contractor's commissioning reports were collected to verify that the new equipment was installed correctly and operational.

Data Collected

Data trends on the SCADA system had been initiated soon after the facility was operational. A trend period was set to begin a month after the facility started up, to avoid initial start-up changes and adjustments, and to capture a period of normal operations typical for a year. The trend period was six weeks in duration. One-hour interval trends were collected for blower power consumption, discharge pressure, and air flow. A Fluke power meter was used to collect independent power readings and validate trended power data.

Analysis

The baseline blower performance specifications were used to determine the relationship between the baseline blower power consumption and flowrate. As the discharge pressure recorded over the monitoring period averaged 7.0 psi without significant deviation, blower power for various flow rates were obtained from the baseline performance specifications. A cubic relationship between baseline blower power and flow was developed. This relationship is shown as Equation 1.

Eqn. 1.

$$kW_{base} = -5.91 + 0.032 \cdot FLOW_{post} + 6.0 \times 10^{-6} \cdot FLOW_{post}^{2} - 7.0 \times 10^{-10} \cdot FLOW_{post}^{3}$$

A spreadsheet was used to analyze the data. In the spreadsheet, the baseline blower power was estimated based on the post-installation air flow readings using Equation 1. The energy use of the turbo blower and the multi-stage centrifugal blower were calculated by multiplying their kW values by one hour, as the readings were made for each hour. The difference between the monitored turbo blower energy use and the calculated multi-stage centrifugal blower energy use were determined for the monitoring period. The energy savings was determined from the difference between the baseline and post-installation energy use values for each hour in a separate column, and the total energy savings for the monitoring period was determined by summing the hourly savings values. The monitoring period was assumed to represent typical operating conditions, meaning the daily wastewater influent was consistent, and the air flow requirements the same in the monitoring period as for the entire year. The annual savings was then determined by multiplying the monitoring period savings by the ratio of days in the full year to that of the monitoring period.

Savings Results

A chart of the turbo blower and multi-stage centrifugal blower power and discharge pressure over a range of flow rates is shown in Figure 6-1. A portion of the savings estimation spreadsheet is shown in Figure 6-2. The annual savings was estimated to be 775,760 kWh.

Figure 6-1: Baseline and post-installation blower power consumption versus air flow rate.

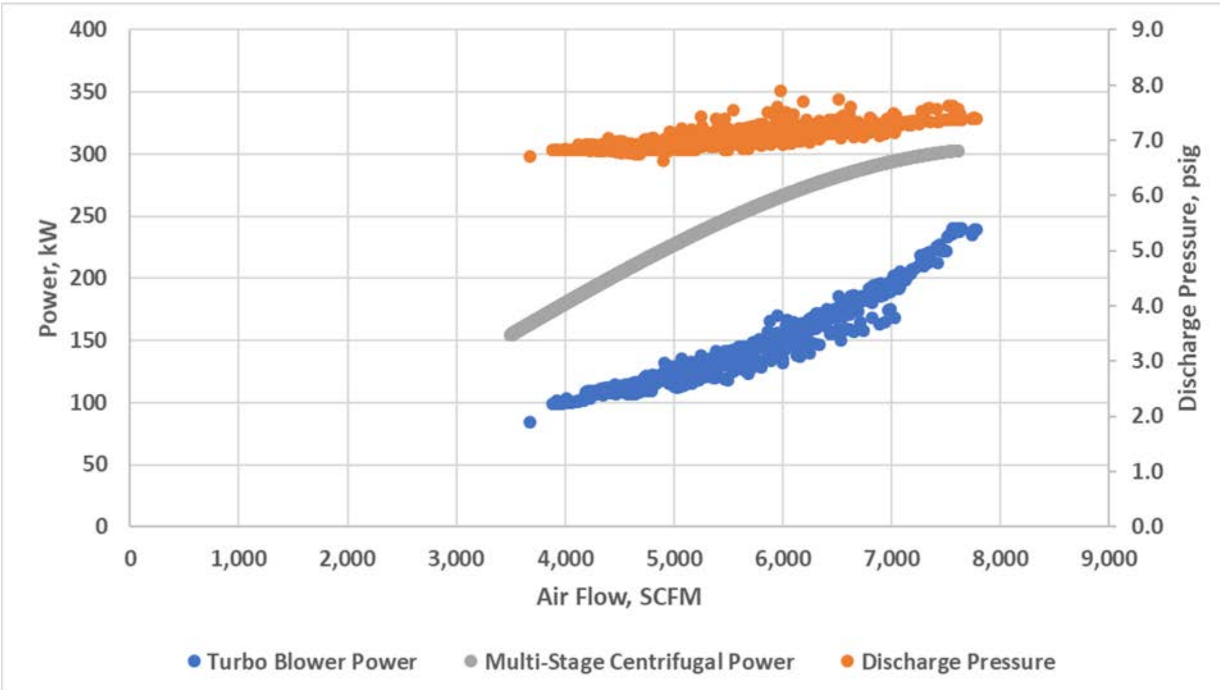


Figure 6-2: Savings estimation spreadsheet (partial).

Turbo Blower Control System Data - Monitoring Period 3/1/2010 - 4/12/2010									
							Annual Savings		**775,760**
Min	2,820.7	7,483.8	70.9	3.4	3.3				365 days
Max	7,781.4	16,724.8	240.3	7.9	7.7		kWh savings (mon. period)		**90,417**
Average	5,404.9	14,388.4	136.5	7.0	6.8		monitoring per. days		**42.5**
Date time	**Flow, SCFM**	**Speed, RPM**	**Power, kW**	**Discharge Pressure, psi**	**Header Press, psi**		**Baseline Power, kW**		**Energy Savings, kWh (=kW * 1 hr)**
3/1/11 1:00	6,650	15,048	157	7.1	6.8		268		111
3/1/11 2:00	6,340	14,777	146	7.0	6.8		261		115
3/1/11 3:00	6,004	14,490	135	6.9	6.8		252		117
3/1/11 4:00	5,710	14,292	127	6.9	6.7		243		116
3/1/11 5:00	5,687	14,269	127	6.9	6.7		243		116
3/1/11 6:00	5,679	14,265	127	6.9	6.7		242		116
3/1/11 8:00	5,676	14,264	126	6.9	6.7		242		116
3/1/11 9:00	5,675	14,267	126	6.9	6.7		242		116
3/1/11 10:00	5,673	14,276	126	6.9	6.7		242		116
3/1/11 11:00	5,662	14,293	126	6.9	6.7		242		115
3/1/11 12:00	5,659	14,297	126	6.9	6.7		242		115
3/1/11 13:00	5,662	14,294	126	6.9	6.7		242		115
3/1/11 14:00	5,660	14,301	126	6.9	6.7		242		116
3/1/11 15:00	5,659	14,308	126	6.9	6.7		242		116

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