Site Specific Verification Guidelines

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Prepared by
Steve Harding, P.E.
with
Fred Gordon
and
Mike Kennedy

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Bonneville Power Administration
Office of Energy Resources
Commercial Programs

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Introduction

The Bonneville Power Administration (Bonneville) and the Northwest region have moved from energy surplus to a time when demand for energy is likely to exceed available supplies. The Northwest Power Planning Council is calling for “a major push to acquire new resources.”

To meet anticipated loads in the next decade, Bonneville and the region must more than double the rate at which we acquire conservation resources. Bonneville hopes to achieve some of this doubling by programs independently designed and implemented by utilities and other parties without intensive Bonneville involvement.

Bonneville will accept proposals for programs using performance-based payments, in which Bonneville bases its reimbursement to the sponsor on measured energy savings rather than program costs.

To receive payment for conservation projects developed under performance-based programs, utilities and other project developers must propose verification plans to measure the amount of energy savings.

Bonneville has traditionally used analysis of billing histories, before and after measure installation, adjusted by a comparison group of non-participating customers to measure conservation savings. This approach does not work well for all conservation projects.

For large or unusual facilities the comparison group approach is not reliable due to the absence of enough comparable non-participants to allow appropriate statistical analysis. For these facilities, which include large commercial and institutional buildings, industrial projects, and complex combinations of building types served by a single utility meter, savings must be verified on a site-specific basis.

Bonneville is willing to accept proposals for programs using performance-based payments, in which Bonneville bases its reimbursement to the sponsor on *measured energy savings.*

These guidelines were written to help proposers understand what Bonneville considers the important issues in site specific verification of conservation performance. It also provides a toolbox of methods with guidance on their application and use.

Issues in Verification of Energy Savings

In pay-for-performance program designs, verification is the measurement of energy savings to determine payments due to a project sponsor.

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Verification methods naturally follow from the definition of energy savings. Bonneville defines energy savings as a reduction in energy consumption resulting from efficiency improvement beyond what would have occurred without the project.

To be consistent with this definition, the goal of verification is to demonstrate the following to a reasonable level of certainty:

1) a reduction in energy consumption from what it would have been,

2) an improvement in equipment efficiency, and

3) that the efficiency improvement would not have occurred in the absence of the project, that is; the program caused the efficiency improvement (attribution).

As a practical matter, it may not always be possible to demonstrate or measure in a meaningful way what would have happened in the absence of a project. As a result, attribution may need to be addressed prospectively as a program design issue rather than retrospectively as a verification issue.

Thoughtful program design can be used to minimize verification problems and vice versa.

Verification generally, but not exclusively, means measurement. However, a reduction in energy use may not be directly measurable separate from other changes in building energy use. In these cases, savings must be inferred from the most meaningful measurements available. In some cases, a reduction in energy use may need to be inferred from measured changes in energy efficiency. Verification has elements of art as well as science.

Distinctions Between Verification and Evaluation

Verification is significantly different from program *evaluation* that seeks to determine not only a program's impact, but also to understand how the impact occurred and how the program might be modified to improve performance.

Bonneville is interested in establishing verification methods that are fair to both buyer and seller, as inexpensive as possible to implement, and provide reasonable assurance that payments made are prudent and cost-effective.

Evaluation is a long term management tool aimed at improving our capability to acquire efficiency resources. Verification is a contractual tool to determine payments for energy savings. Bonneville is interested in establishing verification methods that are fair to both buyer and seller, as inexpensive as possible to implement, and provide reasonable assurance that payments made are prudent and cost-effective.

A verification plan is intended to be part of a contract. A good plan is clear and allows only one interpretation of its meaning.

Desirable Characteristics of Plans

Desirable characteristics of verification methods include the following:

- Simple and straightforward.
- Requires only data that are available.
- Measurements are objective and independent.
- Single measurements represent overall program results which may include the effects of many measures.
- Measures performance persistence over many years.
- Data used are easily verified.
- Data need not be normalized or can be normalized easily.
- Analysis is transparent enough for any interested party to understand.

The key concept behind Bonneville's guidelines for verification is that Bonneville wants a "fair count" of energy savings.

Unacceptable Characteristics

Consistent with Bonneville's position that all programs are verifiable and that verification means measurement, methods which 1) derive savings totals solely from engineering estimates or 2) extrapolate today's measured savings into future years are generally unacceptable.

In some cases, where the duty cycle of the measure is well known and invariable and where the change in connected load is clear, savings can be deemed; e.g., exit sign lighting or street lighting controlled by photocell.

In site specific cases, direct application of previous results or engineering estimates is unreliable, since measure performance will depend on conditions at a unique site that is not directly comparable to other locations. Site specific verification ideally determines actual conditions existing over the lifetime of measures as-installed and as-operated.

Depending on the specifics of a project, each of the following issues must be addressed, either directly or indirectly, to verify energy savings.

Facility Energy Use Characteristics

An important first step in developing a verification plan is to consider what variables influence energy use in the participating facility. Each of these factors may introduce changes in use that confound the observation of changes due to the sponsor's efficiency improvements. Explicitly identifying these factors and deciding whether they need to b e accounted for helps establish which verification method will work best. It also improves confidence that unforeseen variables won't mask project performance.

The key concept behind Bonneville's guidelines for verification is that Bonneville wants a "fair count" of energy savings.

Baseline Establishment

Energy savings are measured as a difference from some baseline condition. Verification methods require that an estimate of what would have happened without the project be clearly identified as a basis for comparison. This "baseline" data must be established not only for energy use, but for any factors that will be used to adjust or normalize energy use data, such as weather, building occupancy, or production levels.

Methods to establish baseline conditions should generally meet the following criteria to represent a "fair count":

1. The baseline must be pre-specified and agreed upon before the implementation of the project. In cases where baseline modifications may be necessary, the circumstances under which the baseline will be changed and the methodology by which changes will be calculated must be pre-specified.

Any baseline modification methodology must specify all data and calculations that will be used to determine whether modifications are required and, if so, what they will be. Data used should be developed by a third party or auditable by Bonneville. For example, if occupancy data are used to justify a change in baseline, the data should be provided by someone other than the project developer.

Baseline development using billing data

When billing data are being used and adjustments need to be made for non-programmatic influences, such as weather, a baseline for these other influences must also be developed. The baseline for energy use and the baseline for extra-program factors should be consistent with one another. For example, if an average of three years billing data is used to establish baseline energy use, baseline weather data should be averaged over the same three years.

Methods using sub-metering

Sub-metering to establish energy use of affected equipment must be performed in a manner that fairly represents all equipment operating modes. For example, in a building HVAC system metering for baseline data should cover both winter and summer operation if the savings are influenced by outside temperature and different heating and cooling operation.

Sub-metering periods should also be of sufficient length to make manipulation of the baseline data impractical. As a minimum, sub-metering for baseline data should be done for one month with longer metering strongly preferred.

Confidence in the validity of sub-metered data can be enhanced by comparing metered results with estimates from calculations or billing data.

Persistence

Bonneville is concerned with possible declines in energy-saving performance that may take place during a measure's useful life.[1] Such declines may take place because the measure is removed or not adequately maintained, because the operating conditions of the facility change, making the measureless effective, or the measure may deteriorate.

Bonneville wishes to continue paying only for measures that continue to provide savings. This does not mean that elaborate performance testing must be performed in all cases. A minimum standard is to inventory the installed measures to demonstrate that they are still in place and still operating on approximately the same schedule.

The more sensitive a measure's savings are to maintenance or operating procedures, the more important it is to verify continued performance. For example, savings persistence is a much greater concern with an energy management control system than it is with building envelope insulation. Where persistence is a concern, any condition that exerts a strong influence on a measure's performance should be checked on a

[1] This concern arises from program experience. Bonneville's evaluation of the Commercial Incentives Pilot Program found that 40% of the program participants had removed or altered energy conservation measures within two years after installation.

scheduled basis over the period in which payments are justified.

An alternative approach for measures less sensitive to operating conditions is to repeat measurements for a shorter period (e.g., two or three years) and agree on a pre-specified rate of savings decay and measure life for remaining payments. This method is not considered as reliable as continued measurement.

Ongoing verification of measure performance has been shown to improve the savings performance and cost-effectiveness of measures in many studies. Persistence verification serves the region's interest to ensure payments for savings are reasonable and prudent. It also serves the participating customer's interest in maximizing the energy efficient performance of buildings.

Independence

All verification plans need to provide for means to independently check the accuracy of savings calculations. The key concept is that Bonneville wants a "fair count." This interest is served by having data collection or calculations performed or checked by a party who does not have a direct financial interest in the result. Independence is needed to avoid situations where "the fox is guarding the hen house."

When methods use independently measured data, such as utility billing history, allowing Bonneville to audit the data and its analysis will generally provide sufficient independence.

In cases where the project sponsor is responsible for data collection, possible strategies to address independence include:

• prespecifying the method and timing of all data collection, including where readings will be taken, what instruments will be used, etc.;

• providing copies of all meter readings, other data, and calculations used to arrive at estimated savings;

• allowing Bonneville or some other independent party acceptable to BPA to jointly read and/or calibrate meters periodically.

Attribution

There must be some reason to believe that the energy savings that project proposers wish to be paid for are the result of the proposer's efforts. Just as proposers wish to avoid uncontrollable risks, Bonneville does not wish to make windfall payments for changes in energy use that would have occurred in any case. In some cases this may simply be verified by documenting that the energy savings claimed are within the theoretical potential of the measures installed by the proposer and understanding what confounding factors are at work.

Measure Interaction

Many efficiency measures cause changes in more than one end-use or interact with other efficiency measures. Verification proposals that rely on spot measurements or end-use metering should document all end-uses that are likely to be affected. Proposers should describe how measurement or calculations will account for each of these impacts in the measurement of savings.

This does not mean in every case that elaborate efforts are required to measure or model interactions. All that is required is to account credibly and reasonably for significant interactions in overall savings estimates.

"Outlier" Measurements

Measurement may produce estimates or data that are substantially different from expectations. In many cases, these "outlier" values may indicate that some nonprogrammaric change in site conditions is masking the effect of energy saving measures. Verification plans should address how outlier data points will be considered.

The key principles guiding Bonneville's approach to outliers are that:

i) what constitutes an outlier measurement must be pre-specified;

ii) any methods for adjusting outlier measurements must be pre-specified, and

iii) the method should be symmetrical. That is, outliers thatincrease or decrease verified savings will be addressed in the same manner.

Key Aspects to Planning and Budgeting

The following steps may be used to develop a verification plan.

1. Identify and collect available information including:

• energy use characteristics of the facility or process, and

• planned or anticipated energy efficiency measures.

2. Identify non-program variables that cause variation in energy use and may cloud measurement of savings such as:

• weather,

• occupancy levels,

• hours of operation,

• production levels,

•changes in production mix or input.

3. Decide whether data already available will allow direct measurement or inference of savings. This might be billing data or existing metering on production processes. If so, questions to focus on include:

• What analysis method will be used to calculate savings from data?

• How will a baseline be established?

• How long will measurements be made to verify persistence?

• What steps might be taken to assure independence of data?

• How will existing measurement devices be calibrated and tested to insure acceptable data quality?

4. If data are not already available, develop a measurement plan. Give especially careful attention to identifying all uncontrolled variables that affect the measured energy usage. Each of these should be identified and explicitly determined to be negligible or measured so that savings can be normalized.

In preparing a measurement plan, proposers should attempt to get specific information about existing facility conditions. The practicality of end-use measurement, for example, may depend on whether end-uses are on isolated circuits.

Steps in developing a measurement plan include:

• determine variables to be measured,

• perform analysis to identify sources of error and appropriate metering accuracy (see Appendix I),

• determine possible steps to provide independence,

• determine how measurement devices will be calibrated and tested to insure acceptable data quality,

•decide when measurements will be taken and for how long (before and after implementing the measure), and

• establish analysis method showing how measured data will be used to calculate savings.

5. Document the savings calculation method developed using the outline on pages 11 and 12.

Sample Verification Outline

Appropriate methods for savings verification are a function of the technology applied and the energy use characteristics of the facility in which they are implemented. Verification planning is much easier when a plan is being written for specific measures in a specific facility. In this case, key information on the facility's energy systems and the planned measures is available and can be used to specify an appropriate verification approach in detail.

In other cases, a project sponsor may be proposing a program design and a target market without detailed information about specific facilities or measures. In this case the verification plan should outline the verification approaches that will be used for different situations and specify the circumstances that will be used to determine which verification approach will be applied. Specifics on metering locations, sampling, and so forth will not be stated in detail, but general rules describing a process to establish these in each case should be clearly set forth.

Verification proposals should address the issues outlined below for each verification method proposed.

1. Basis of Comparison

Describe the comparison that will be the basis of claimed energy savings for pay-ment. The description should explicitly address whether a reduction in use will be directly measured (as by billing analysis) or inferred (calculated) from a measured improvement in efficiency.

2. Facility Energy Use Characteristics

Describe factors such as weather, occupancy, or production levels that may cause significant changes in energy use independent of the sponsor's project. Indicate whether these factors will be normalized in the proposed method.

3. Data Required

The data required to make the comparison must be described with the proposed method for measuring or collecting the data. State whether data are already available or will have to be gathered by the project sponsor or another party.

4. Data Quality

Describe how the quality of measured or collected data will be assured. Special attention should be paid to situations where a sample of data will be collected to represent the performance of a larger population. Propose methods for ensuring that samples will present a fair count of the overall performance.

5. Independence

Describe how independence of data will be assured. Where data are collected by a party with a financial interest in the measurements, propose methods to ensure that the data are independently tested and confirmed.

6. Baseline Establishment

Describe the method for establishing a baseline to measure savings against. In the case of a plan for a specific facility, propose an actual baseline with an explanation of how it was derived.

7. Baseline Modification

If, in response to facility changes or other events that may have a significant impact on energy savings, the sponsor wishes to allow for modifications to the baseline, the circumstances under which the baseline will be modified should be pre-specified in detail. How the modification will be calculated and when it will take effect should also be specified. Baseline modification provisions should be symmetrical. That is, they should allow for adjustments that increase or decrease verified savings, whichever is appropriate, on an equal basis.

8. Outlier Data

If measurements or data outside a specified range (“outlierdata”) will be adjusted or modified in any way, or their application in the verification method will be changed in any way, specify the definition of outlier data and their treatment in energy savings calculations.

9. Persistence

Propose a method for verifying persistence of savings. This may involve a description of how long measurements will be taken, periodic inspections of measures to check their proper operation, or other means to ensure that efficiency improvements continue to produce energy savings.

10. Reporting

Propose the form and content that will be used to report energy savings calculations to Bonneville. All relevant data should be included in reports so that calculations are transparent and can be understood by any interested party. Where sampling is used, the report must include the logical and mathematical basis for extrapolation from the sampled measurements to the entire savings.

11. Application

If the verification plan is based on multiple methods to be applied in different cases, the sponsor’s preferred method should be indicated, with a description of what circumstances will be used to dictate application of an alternate method. The rules for determining which method will be used in each case should be as prescriptive as possible and not depend simply on “judgment.”

Site Specific Verification Methods

In the following sections a variety of verification methods are described in detail. This section lists different ECM load characteristics and outlines recommended approaches.

I. Constant loads with fixed duty cycle.

Example: Incandescent exit sign lamps are replaced with higher efficiency lamps. Preand post- measure connected loads are well identified and operating schedule is known and constant.

Problem/Opportunity: The opportunity is to verify savings for this measure with very low cost using engineering estimates (deeming).

Suggested Method: **Deeming** may be used as follows:

a) Inventory pre-installation connected load (kW).

b) Inventory post-installation connected load (kW).

c) Savings = (calculated reduction in kW load) x (known operating hours).

Limitations: This method does not address interactions with other end-uses (e.g., space conditioning) or persistence. Interactions may not be significant. Persistence verification could be accomplished by periodic equipment inventories to verify continued operation.

II. Constant loads, varying duty cycle.

Example: Conventional F40 fluorescent lamps with magnetic ballasts are replaced with more efficient lamps and electronic ballasts.

Problem/Opportunity: The opportunity is to verify savings for this measure with simple metering and low cost.

Suggested Method: **Connected load measurement** (see page 21) may be used as follows:

a) Measure pre-installation connected load (kW).

b) Measure post-installation connected load (kW).

c) Install elapsed time meters to record post-installation operating hours.

d) Savings =(reductionin kW load) x(post-installation operating hours).

III. Conversion of a constant load to a varying load (varying duty cycle).[2]

Example: Photocell dimming controls are installed to control indoor light fixtures or a constant volume reheat air conditioning system is converted to a variable volume system with variable speed drives (VSD) for fans.

Problem/Opportunity: The measure converts what was a simple, constant load to a continuously varying load. How can this be measured?

Suggested Method: Equipment or end-use metering (see page 23) can be used in the following manner:

a) Measure pre-installation kW of the affected equipment or circuit.

b) Install a kWh meter on the line side of the dimmer or VSD.

c) Install a run-time meter on the affected equipment or circuit.

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[2] Source for Method III is a paper by Peregrine White, Jr., P.E. (see References)

d) Savings are calculated by (measured circuit full-load kW) x (operating hours from run-time meter) minus (kWh measured at dimmer or VSD).

IV. Variable load changed to higher efficiency variable load.

Example: A variable air volume system using inlet dampers is converted to a VSD.

Problem/Opportunity: Thereductionin energy use changes with demand for heating and cooling, which varies for both the existing and new system based on occupancy, weather, etc.

Suggested Method: Energy use indexing (see page 29) can be used in the following manner:

a) Measure pre-installation kW of the fan at several flow rates in cubic feet per minute (cfm) to determine the power/flow relationship.

b) Measure VSD kW at the same flow rates to determine the new power/flow relationship. (To demonstrate persistence, this measurement should be repeated periodically.)

c) After installation, a data acquisition system or EMS trending capability is used to monitor and store a record of runtimes and flow levels.

d) Calculate savings as a function of flow by the difference in kW/cfin: savings = {(inlet vane kW)-(VSD kW)} at each flow rate measured multiplied by the hours at that flow rate.

V. Verification of combinations of measures with different load characteristics.

Example: A comprehensive package of energy conservation measures is installed in a building.

Problem/Opportunity: The opportunity is to capture the effects of all measures in a single, low-cost, straightforward measurement.

Suggested Method: **Billing analysis** (see page 15) may be used in the following manner:

a) Establish a baseline utility billing history based on one or more years before installation.

b) Compare post installation utility bills with baseline energy use.

c) Savings equals the difference between baseline and post installation energy use.

Limitations: This method is unreliable when savings are small compared to total building use, when facility construction or operation change frequently, and in major remodel situations.

Alternate Methods: A mosaic of measure-specific verification methods can be used when whole-building verification is not feasible.

Verification by Billing Analysis

Description

Billing comparison uses past utility, bills to develop a baseline energy use for the facility. Energy savings are verified by gross changes in energy use at the utility meter. When electricity is used for space heating or cooling, energy use is normalized for weather changes. Controlling for site changes in use or equipment may also be necessary.

Application

Billing comparison is best used in buildings with several years' history of predictable energy use and a likelihood that building use and schedule are likely to remain relatively unchanged. The anticipated effect of ECMs must be large compared to normal billing variations.

If energy savings are not large compared to normal bill variations, they may not be observable over the "noise" of other fluctuations in use. Studies of institutional buildings have shown annual energy use variations of 8% to 14% are typical[3]. To reliably use billing comparisons, savings should be at least l5-20% on an annual basis (the larger the savings percentage the better).

Because of the requirement that building use and major equipment remain relatively constant or at least that changes can be clearly adjusted for, this method may be most useful in institutional buildings such as schools and dedicated-use buildings, such as large retail stores, where building operations are relatively predictable.

Pre/Post billing comparisons are not applicable in major renovation or remodel cases, since past energy use is not a fair representation of what would have happened absent an energy savings program. The likelihood of major renovation in the future should be considered before selecting this method.

Advantages/Disadvantages

Billing data comparisons are simple, easy to administer, and low cost to apply. They use objective, independent data that are already available, and account for the effects of many ECMs through a single measurement.

Disadvantages include limited applicability due to the need for stable building operations and the need to normalize for non-program effects, including weather (for electrically heated or cooled buildings) and changes in building equipment and use.

In some respects, representing the effects of many measures in one measurement is both the greatest strength and weakness of this method. Capturing all effects in one measurement makes the method simple, easy to understand, and low cost to apply. However, it means that non-program impacts are also represented in the measurement and these can confound estimates of savings.

Baseline Establishment

A baseline period must be established either by selecting a typical year as the base period, or by creating a baseline from an average of several years. If unusual operating conditions have occurred (such as unusually high or low use of the building) the baseline period should not incorporate these periods if possible. It is not necessary that the baseline period be an exact

[3] Schueler, *Measuring the Impacts of Energy Efficiency Measures In Institutional Buildings With Billing Data: A Review of Methodological Issues*, ACEEE 1990

model of typical use since there will always be some variation. The goal is simply to establish a reasonably representative history.

If substantial changes in building equipment, size, or use occur during the period of measurement, changes may need to be made to the baseline to fairly measure all savings. In the interest of a fair count, the following principles should apply for any baseline modification:

i) the circumstances under which the baseline may be modified should be pre-specified;

ii) the methodology for baseline modification should be prespecified. This might be a prorata adjustment (for changes in building size) or engineering estimates (including computer modeling) to estimate the effect of changes in equipment or use.

Persistence

Persistence of savings is considered by continuing measurement as long as Bonneville's paymentscontinue. Any decay in savings performance is included in the measurement using this method.

In some cases, it may be acceptable to perform billing comparisons for a limited number of years and use these results to establish future savings with a specified rate of decay.

Periodic surveys should be used to verify that the measures are still in place and operating as intended. Where agreeable to Bonneville, these surveys might be conducted by knowledgeable on-site staff to minimize costs.

Independence

Use of utility billing data and national weather service data for weather normalization reduces independence concerns with this method. Independence of data becomes more problematic when site changes in equipment or use are used in calculations. The source and method of data collection for any data of this type should be pre-specified to ensure the data is acceptable to all parties.

Measure Interactions

Because pre and post billing comparisons represent the effects of many measures in a single measurement, measure interactions are implicitly taken into account by this method. No additional analysis is necessary.

Data Requirements and Sources

Utility billing data (kilowatt-hours) are needed for at least one year and preferably for two to four years before implementation. These data are available from the building owner or the serving utility.

Weather data, commonly average daily temperature or heating degree days, is needed if weather normalization is required. These data are available from the National Weather Service or may be available from the serving utility.

If there are substantial changes in the building's operation (e.g., occupancy rates) in the baseline period, documentation of these changes is needed if energy use will be normalized to account for them. This information is generally available from the building owner.

Analysis Required

After measures are installed, savings are verified by comparing actual monthly energy use with the energy use during the same month of the baseline period.

In general, the formula for energy savings is as follows:

BL kWh - Actual kWh = Saved kWh

"BL" = baseline use for the period and

"Actual" = actual use for the comparable period.

Figure 1 shows an example of actual before and after energy use for an office building energy efficiency project. A variety of lighting, HVAC, and temperature control measures were installed in the building, making end-use or equipment metering impractical. Because pre-retrofit energy use was relatively stable and predicted savings were large, billing analysis was used to estimate savings. Pre-retrofit energy use variation (on an annual basis) was 14% without weather adjustment (variation is defined as the maximum year-to-year variation for a period divided by the average annual use for the same period) and expected savings were approximately 30%.

While there are no consensus procedures for weather normalization, certain basic principles should be followed. The most important is that energy use that is not weather-sensitive should not be normalized. For example, if energy use for an electrically heated building is being normalized, the portion of use thatis due to heating should be identified and only that portion should be adjusted for varying weather conditions.

Outliers

Calculated savings that are much higher or lower than expected (e.g., more than 20% above or below) can be used to trig-ger performance audits of the building to determine whether the measures are operating properly or building conditions have changed (and an adjustment should be made to the baseline for non-program site changes). However, this can lead to changes in the energy savings estimate <u>only</u> when the verification plan includes a detailed description of the basis on which any adjustments will be made.

Cost

Low cost is one of the major advantages of this method. No special metering is required and all routine calculations can be made in a few hours each year. Use of computer spreadsheets to automate savings calculations helps reduce costs further.

Routine data collection and calculations should cost under $250 annually, if no provisions are made for site visits and/or adjustments to savings. If site visits to assess persistence or outlier adjustments are included, costs significantly increase. Also, weather normalization may add to cost if the analyst does not already have personnel, data, and facilities to perform this function.

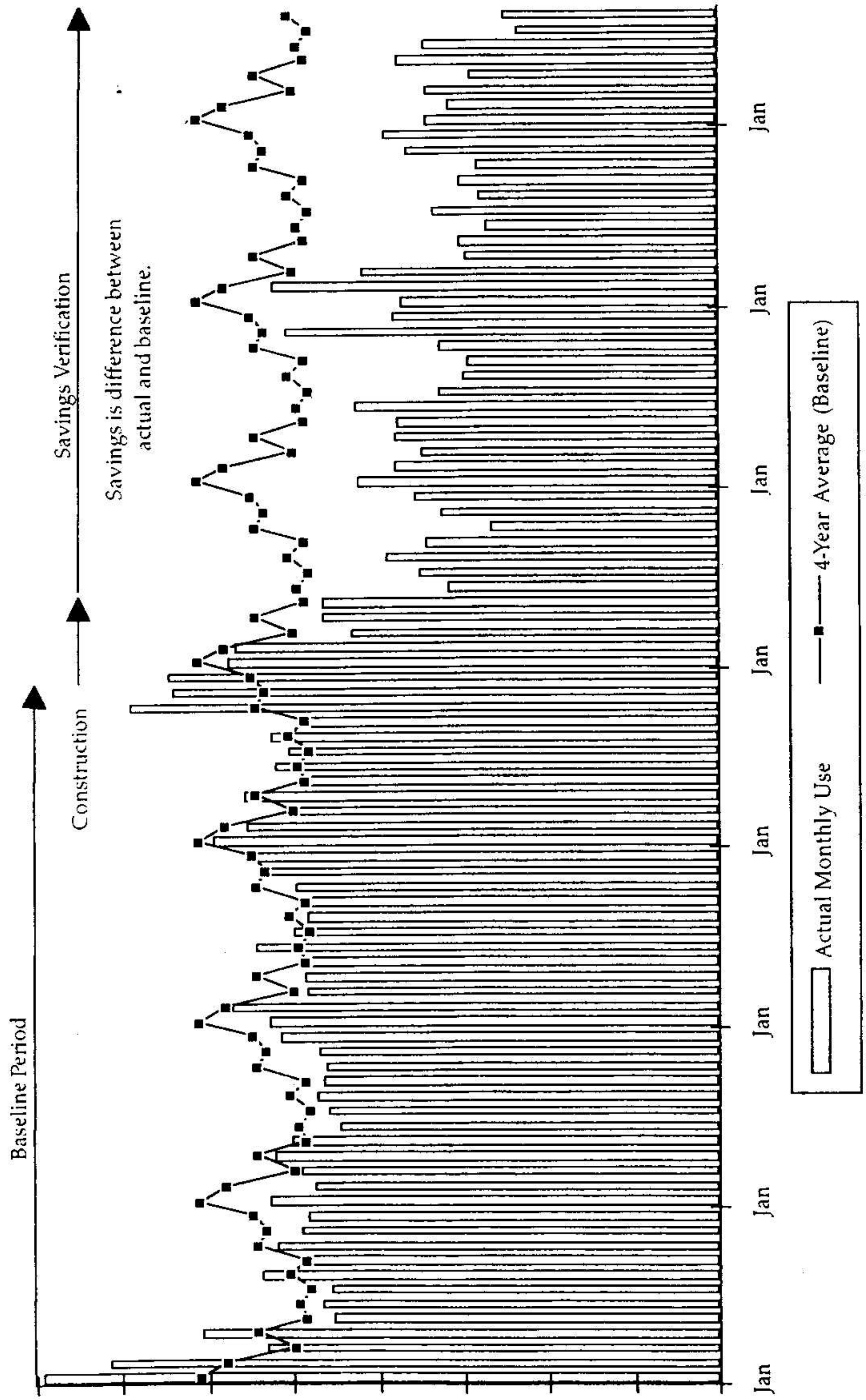

Figure 1: Use of Billing Analysis To Verify Energy Savings

Case Study: Union High School

Facility: Union High School, Union, Oregon

Facility Description: Union High School is a secondary education facility located in northeast Oregon. The school consists of classrooms, a library, labs, an industrial shop, a maintenance room, and administrative offices. The building encloses nearly 55,000 square feet in a three-story masonry and wood structure.

Energy Use Patterns: Space and water heating are served by natural gas. Electricity is used for lighting, office and shop equipment, laundry (washing and drying), and ventilation fans.

Space heating accounted for 91% of natural gas use with the remaining 9% used in water heating. Electricity use was 66% lighting, 32% equipment, and 2% ventilation fans.

In 1989, the school used 341,800 kWh at a cost of $21,673 and 43,400 therms at a cost of $18,484.

Energy Use Drivers: Operating schedules are the principal driver of electricity use at Union High School. Lighting is manually switched by occupants. Students and staff do a good job of turning out lights in unoccupied rooms. Current schedules are not anticipated to change in the future. The school's curriculum and use have not changed significantly in the past five years and are expected to continue unchanged.

ECMs: Convert existing incandescent lighting to fluorescent or high-intensity discharge (H.I.D.)lightsources. These conversions are estimated to save 110,000 kWh annually (80% of total savings).
Various weatherization measures save 28,000 kWh annually by reducing the operation of electrically operated heating system auxiliaries (pumps and fans).

Verification Method: Billing Analysis

Baseline Establishment Because energy use and building operations at Union High School have remained stable over a number of years, a single calendar year (1989) was used as the baseline for energy use. A baseline for weather data was not established because electricity savings were not considered sufficiently weather sensitive to require normalizing.

Efficiency Improvement Efficiency improvements were verified by documenting the number, type, and efficiency of the existing lighting systems and of the new fixtures after installation.

Persistence

Persistence of savings was verified by using billing comparisons as the basis of energy savings calculations for the duration of Bonneville's payments.

Measure Interactions

Measure interactions did not have to be separately verified, since the billing comparison method captures the results of all measures in a single measurement.

Independence

Data used in the savings calculations come from the local utility.

Analysis Algorithms

The formula used for energy savings is as follows:

BL kWh- Actual kWh= Saved kWh

where "BL" is baseline use for the period and "Actual" is actual use for the comparable period. These calculations will be performed on an annual basis, at the end of June.

Discussion

In designing its verification proposal, the sponsor considered the following:

1) the sponsor wished to minimize the cost of the savings verification, including initial costs to install hardware and especially, long term labor costs to collect and analyze data.

2) The building site is remote from the sponsor's main offices and travel to the site is time consuming and expensive.

3) The operation of me school is predictable and has not changed appreciably overlong periods. Major changes in the structure or use of the building are not anticipated.

4) The proposed energy conservation measures will have a large impact on the building's electricity use. If all measures are implemented, electricity savings are estimated at 40% of the total use. If only lighting measures are implemented, the savings are over 30% of the total.

5) If significant changes occur in the future, the sponsor has agreed to work out a method to normalize or adjust for the change(s).

Verification by Connected Load Measurement

Description

In many cases, anticipated facility changes, large fluctuations in energy use, or measures with a gross effect too small to reliably measure using billing data will make billing comparison an undesirable method. Often a majority of a project's energy savings are achieved by installing more efficient equipment that saves energy in proportion to a reduction in connected load and the hours of use of the equipment. Load measurement uses measurement of connected load (kW) of equipment before and after modification to verify efficiency improvements and energy savings.

In this method, energy savings are inferred by measuring hours of use of the equipment after and multiplying a measured connected load reduction (pre minus post) by the measured hours of use.

Application

This method is useful for equipment with a fixed load, where energy use is strongly proportional to operating hours. For example, replacement of incandescent lighting with fluorescent or high-intensity discharge light sources would be a good candidate for connected load measurement. Measures that do not save energy in direct proportion to operating hours are not good candidates for this method. For example, installation of a variable speed drive (VSD)on a fan system will save energy in proportion to flowrate and operating hours. Because energy use is not a simple linear function of hours use, pre/post load measurement is not a reliable measure of savings for a VSD installation.

It is desirable to have all the affected load on readily identifiable and isolated circuits, to make installation of metering simpler. Where this is not possible, a careful inventory of loads and operating hours can be used to establish a representative sample for metering. This minimizes the need for expensive rewiring.

Advantages/Disadvantages

The method is simple, straightforward, and transparent enough for any interested party to understand. Because the impact of a specific measure is directly measured, data need not be normalized. Unrelated facility changes are less likely to confound savings estimates made by this method so less attention must be paid to other operating changes.

Disadvantages include the need to collect data and confirm its accuracy on an ongoing basis. However, advances in metering technology make it increasingly easy to interrogate metered data remotely, reducing cost and allowing for independent data checks without the expense of site visits. Also, some of the data collected may be useful to maintenance personnel in managing energy use and produce additional savings by giving a more detailed picture of building operations.

Measurements do not represent overall program results, but only the result of a single measure. Measure interactions that may result in double-counting or undercounting must be considered. These can generally be identified and allowed for during the planning stage.

Baseline Establishment

Baseline loads (kW) are established by pre-implementation measurement. Baseline hours of use are assumed equal to hours of use after installation, which are measured on an ongoing basis.

Persistence

Periodic surveys should be used to verify that the measures are still in place and operating as intended. Where agreeable to Bonneville, these surveys might be conducted by knowledgeable on-site staff to minimize costs. These surveys could be conducted jointly with Bonneville staff or subject to re-audit at Bonneville's discretion.

Where feasible, savings persistence should be further verified by repeating connected load measurements on a scheduled basis. These measurements would be made at the same points as the original measurements, and would identify any change in the efficiency improvement. In addition, measurement of hours usage of the equipment would be made on an ongoing basis.

Independence

Because this method relies on data that will be collected at the site that is not already available from a third party, independence of data is problematic. In most cases, it will be adequate to have an independent party check and vouch for the accuracy of the data on a periodic basis. This party could be the facility owner or the local utility when not a direct beneficiary from the verification agreement. Methods for establishing independence of data need not be elaborate but should give BPA reasonable comfort that the data are being checked by a disinterested party.

Data Requirements and Sources

An accurate inventory of the equipment to b e modified must be taken, and its connected load (or that of a representative sample) must be measured. If a sample is used, the sample population should be carefully documented so that it can be accurately checked in later inventories. After the measure is implemented a similar inventory and load measurement must be made.

Run time of the installed measure must be measured with an elapsed rime meter.

Analysis Required

Energy savings are determined by multiplying the measured change in load by the measured operating hours after implementation:

ρ kW x Hours = Saved kWh

In cases where a significant measure interaction occurs, this equation will require an adjustment factor to account for interactive effects. For example, reductions in lighting energy use may result in increased heating consumption and decreased cooling consumption.

These adjustments should be prespecified and agreed to by Bonneville as part of be project agreement before implemen-ting the measures. The adjustment can be based on engineering estimates or computer modelling.

Outliers

Measurements of load or operating hours that fall outside expected ranges should trigger a check of the measurement. This check might involve examining the affected circuits to see if other loads have been added or removed. Understanding the cause of an unexpected load change is the key to adjusting for it appropriately. Any adjustments to savings calculations for outlier data should be prespecifiedinthe verification agreement.

Cost

Wireless run-time meters for lighting equipment are available for under $100 per measurement point. Meters for individual circuits and motors are also available.

The largest costs involved will belabor for data collection and management on an ongoing basis.

Verification by Equipment or End-Use Metering

Description

Many measures do not save energy as a simple function of operating hours. Savings from variable speed drives, for example, depend on both operating hours and the flowrate through the system. Energy management controls and other system optimizing techniques also save energy as complex functions of several variables. In these cases, simple measurement of connected load does not provide a basis for verifying savings. In many cases (as, for example, control systems) measures save energy without any change in connected load.

End-use or equipment metering can be used to obtain energy data with higher resolution than building or facility-level billing data to better estimate energy savings. These metered data are used in a manner similar to pre and post billing comparison except that measurespecific metering is used instead of existing utility company meters. Metering may be at the end-use, circuit, or equipment level.

Application

This method is useful where savings are not a simple function of operating hours and utility metering does not provide adequate resolution to observe the effects of the measure. It is also desirable to have a single point or relatively few points that need to be metered to measure the energy use of me affected equipment.

For example, installation of a variable speed drive on a fan system within a large commercial or industrial facility could be measured with watt-hour metering installed at a single motor control center or circuit panel. This is an ideal application of equipment metering to verify savings.

Advantages/Disadvantages

The method is simple, straightforward, and transparent enough for any interested party to understand. Because metering is installed to isolate only the effects of a single piece of equipment or end-use and other facility changes will not be measured, data generally do not need to be normalized. If the measured load is temperature sensitive, normalizing for weather may still be necessary, but should be more reliable because the amount of usage to adjust is known with more certainty.
Disadvantages are that data must be specially collected and accuracy confirmed. There is the additional cost of dedicated metering but this may offer benefits to facility maintenance personnel by giving them more detailed information on facility operations and improve overall savings performance.

Measurements do not represent overall program results, but only the result of a single measure. This is a disadvantage in terms of cost but is also the primary purpose of the method, since metering a single measure is what gives this method adequate resolution for confidence in the estimated savings.

Baseline Establishment

The baseline is established by a period of pre-installation metering. This provides a record of energy consumption over a period that should include all operating modes of the equipment. In determining a suitable period to establish a baseline, the key is understanding what variables affect the operation of the equipment. In the case of a VSD installed on a fan system, the operation of the fan system must be known to determine what is an adequate period for baseline metering.

For example, if the fan operation is a function of weather conditions then pre-installation metering should belong enough to capture seasonal variations. If operation follows a schedule, metering should cover both “occupied” and “vacant” periods and include a representative number of holidays. The key concept is to meter a sufficient period to get a fair representation of conditions before implementation of the measure.

The key concept is to meter a sufficient period to get a fair representation of conditions before implementation of the measure.

In all cases, pre-installation metering should be conducted long enough to make “gaming” of the data impractical. Pre-installation metering for a minimum of two months should achieve this goal.

Persistence

Persistence of savings is verified by continued metering after the measure is installed. Measurement may occur as long as payments occur. Continued metering documents the measure’s continued operation and effectiveness.

Independence

Like other methods that rely on data collected at the site that is not already available from a third party, data independence is problematic. In most cases, it will be adequate to have a second party check and vouch for the accuracy of the data on a periodic basis. This second party could be the facility owner or the local utility. Use of metering which can be remotely interrogated by modem and telephone lines may be useful to permit a third party to independently take readings of the data.

Methods for establishing independence of data need not be elaborate but should give B PA reasonable comfort that the data are being checked by a disinterested party.

Data Requirements and Sources

This method requires a baseline of pre-installation energy use established by watthour metering and energy use readings from the same metering after installation of the measure. Unless metering is already present, special purpose metering must be installed and maintained for the duration of payments. If possible, metering should be installed so that it measures only the impact of the equipment affected by the measure, since this will minimize the need to normalize data. Existing metering devices are sufficient only if they provide appropriate data and have an adequate and verifiable level of accuracy and reliability.

Analysis Required

Savings are calculated by subtracting actual energy use from the baseline use established before installation. The formula used is:

BL kWh - Actual kWh = Savings kWh

where BL is baseline energy used and Actual is actual energy used for a comparable period. Unless the load is strongly weather dependent, normalizing should not be necessary and the calculation of savings is straightforward.

Outliers

Measurements that fall outside expected ranges should trigger a check of the measurement and the operation of the equipment. Identifying unusual operation for prompt maintenance attention is a potential benefit of this method. Any adjustments to savings calculations for outlier data should be prespecified in the verification plan.

Cost

The cost of this method will vary depending on the facility wiring and ease of meter installation and the duration of pre-installation metering needed for a representative baseline.

Collecting sub-metered energy data costs $1,500 to $3,000 per channel[4]. In addition, data must be retrieved periodically (as often as every 30 days) but this can be done remotely. The data retrieval process can be automated to minimize cost.

Data analysis costs will be about the same magnitude as data collection costs. Study design costs may also be significant.

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[4] Claridge, et. al., *Improving energy conservation retrofits with measured savings*, ASHRAE Journal. This article cites costs of $1,500 to $2,500 per channel of sub-metered data.

Case Study: Equipment Metering[5]

Due to the difficulty of observing relatively small energy savings with billing data and the expense of long-term end-use metering, many energy professionals propose short term measurements to estimate energy conservation measure impacts.

The drawback of short term measurements for most ECMs is that energy use and ECM savings vary depending upon the operation mode and the season. Energy use and ECM savings must be calculated for a whole year. If one is evaluating a night ventilation routine, a simple on/off test on two comparable days with a whole building electric meter or a fan and chiller meter will provide a good estimate of savings for that day. This result must then be extended to the whole season. How many days are like the metered day? Are there other common operating modes and conditions that need to be measured also? Many parts of this calculation procedure require judgment by the analyst, raising concerns about the independence of the analysis. Short term measurements also do not address persistence, unless the measurements are repeated periodically.

To explore verification using short term metering, we modeled a variable speed drive (VSD) retrofit in a large, internal gain dominated all-electric office building with a dual duct variable air volume (VAV) system and inlet vane control of air volume. Sixty-four percent of all building energy consumption was for lights and equipment, 23.3% for fans and pumps, 10.1% for heating, and 2.6% for mechanical cooling. This represents the extreme end of the spectrum in terms of internal gain domination and fan power.

Installing VSDs on the supply and return fans yielded a total building energy reduction of 5.2%. This represents 86% of the fan power savings, the remainder being offset by increased space heat.

Because of be small overall savings, billing analysis is unsuitable as a verification tool in this example. An 8% change in the equipment and lighting energy would also have a 5% impact on the overall energy consumption. This might result from a daily one hour increase or decrease in building use, installation of new plug loads, a change in building vacancy, or weather fluctuations.

An alternative approach to verification would be to monitor the fan electric consumption directly for a year before and after the retrofit. This measurement would miss interactions with space heat and cooling and would be sensitive to weather-induced fan power variation (typically 3% and as much as 7% from year to year). This method would require monitoring for a year before the installation of the ECM and a year after (longer to verify persistence). The method, like billing analysis, would still be subject to significant errors arising from changes in building occupancy or schedule.

Another alternative is to measure the fan electric consumption for a short period, e.g., a month, before and after the retrofit. On the surface, this seems a reasonable method, provided that goodjudgmentisusedin selecting the months and extrapolating to an annual value. However, in practice this method gives very unreliable results due to substantial and quick changes in fan operating characteristics with seasonal changes.

[5] This example was developed and modelled by Mike Kennedy of Ecotope, Inc. Seattle, Washington

The table below presents the savings estimate one would get if measured inlet vane consumption for the previous month were subtracted from the VSD consumption for the current month. Depending on the time of the test, estimated savings vary from negative 120,260 kWh to 237,240 kWh.

Table 1: Savings Estimated by Pre and Post Short Term Metering (one month before and one month after).

Month	Total Consumption (kWh)		Savings
	Inlet Vane	VSD	(kWh)
January	119,512	37,775	78,568
February	116,758	39,323	80,189
March	133,737	53,944	62,814
April	148,829	87,985	45,752
May	342,728	269,092	-120,263
June	483,713	431,868	-89,140
July	415,395	352,105	131,608
August	469,184	404,950	10,445
September	375,703	296,981	172,203
October	280,655	195,018	180,685
November	119,393	43,410	237,245
December	116,343	37,598	81,795
Annual Total	3,121,950	2,250,049	871,901

A simple method that avoids all the above problems is as follows:

The pre-installation load of the fan (in kW) is measured at a number of flow rates (in cubic feet per minute, cfm) to establish the kW/cfin characteristics of the existing inlet vane system.

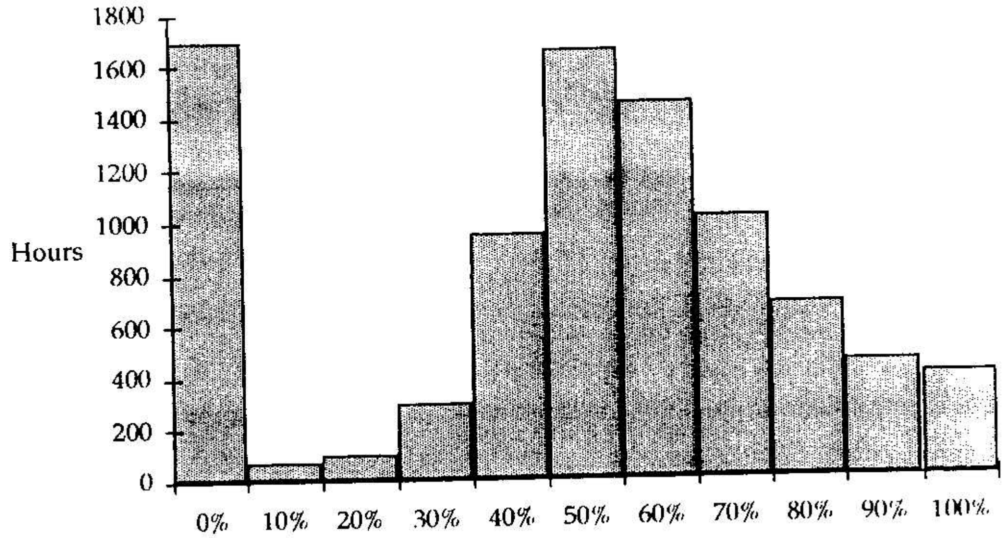
After installation, the kW/cfm characteristics of the VSD system are measured at the same flow rates. Now, for any given flow rate, the savings in kW can be determined.

After installation, a data acquisition system or EMS trending capability is used to monitor and store a record of runtimes and flow levels. These data can be represented in a histogram such as that pictured in Figure 2.

Total energy savings can be calculated from these data as the product of the kW/cfm savings at each flow level and the hours logged at that flow level.

Since this method collects the operating profile of the fan, as actually occurring, no assumptions orjudgments are required to extrapolate long run savings from short term measurements. Year to year weather variations do not affect the measurement. Changes in controls, fan logic, or heating and cooling loads are accounted for. Savings can be estimated for any operating profile without the need to make assumptions about the profile.

Figure 2: Fan Duty Cycle Data



This figure shows the total hours of fan operation at different percentages of full flow for a one year period. These hours would be multiplied by the measured kW savings at each flow rate to determine annual energy savins.

Verification by Energy Indexing

Description

In some cases, routine changes in a building's operation or production variables require normalizing to prevent non-program changes from confounding savings estimates. A common method to provide such normalizing is through comparison of some form of energy use index. This method estimates savings by observing changes in efficiency over time, as determined by energy use on a per unit basis. Units may be square foot of occupied commercial space, pounds of manufactured output, or gallons of fluid pumped, for example.

Application

This method is broadly applicable, especially in industrial situations where energy use per unit production is not too heavily dependent on uncontrollable variables, such as quality of raw materials received. For this method to be used effectively, it is essential that the impacts of different variables on energy use are well understood, and that all non-program variables can be adequately controlled for measurement or can be normalized through statistically significant tests.

Advantages/Disadvantages

This method is simple and straightforward, measures persistence over time (if indices are based on continued measurement overtime), and is sufficiently transparent for any interested party to understand.

Disadvantages are primarily in the need to verify additional data that may in some cases be proprietary and confidential, and possible need to normalize for other influences on energy use per unit measured. Inability to anticipate and control non-program variables affecting energy use can be a significant risk with this method.

Baseline Establishment

A baseline is established by determining a pre-measure energy use per unit. This may be done with utility billing data and data on output or another use index if the billing data provide sufficient resolution, or with submetering of the affected equipment.

If equipment submetering is used, metering should be conducted for a sufficient period to capture seasonal or production input variations, and make gaming of the data impractical. In general, pre-installation metering for at least two months will be necessary to meet these conditions. If seasonal variations are significant, longer periods (up to a year) may be advisable.

Given Bonneville's interest in paying only for decreases in load, limiting savings estimates to a baseline production level may also be appropriate. In this case, energy savings would be estimated as a percentage reduction in energy use index, but this percentage would be applied to actual or pre-measure production levels, whichever is less. The purpose of this is to ensure that program-induced cost savings do not lead to increased energy use as a result of increased production.

Independence

If this method is applied with reliance on data collected at the site that is not already available from a third party, data independence is problematic. This is particularly true of production data that may be confidential and proprietary. While generally it is desirable to have someone who is not an interested party to the B PA transaction provide data, in some cases it may simply be adequate to have someone in a responsible position (not directly involved in the project) vouch for the accuracy of the data on a periodic basis. This could be the facility owner, the local utility, or, in the case of proprietary data, the chief financial officer of the company involved.

Methods for establishing independence of data need not be elaborate but should give BPA reasonable comfort that the data are being checked by a disinterested party.

Data Requirements and Sources

Pre-measure energy use and coincident units of measurement are needed to establish a baseline index.

Post-measure energy use and units of measurement are needed on an ongoing basis for comparison with the baseline to determine savings.

Analysis Required

Savings are calculated by the percentage reduction in energy use per unit measurement before and after measure installation. This percentage is applied to pre-measure energy use to determine savings.

The appropriate equations are:

(BL kWh/unit- Actual kWh/unit))BL kWh/unit

to determine the percentage savings, where BL is the baseline index and Actual is the measured index after measure installation.

This percentage saving is then multiplied by pre-measure energy use to determine energy savings.

Outliers

Measurements that fall outside expected ranges should trigger a check of the measurement. Any adjustments to savings calculations for outlier data should b e prespecified in the verification plan.

Cost

Cost of this method is intermediate to high, depending on the level of metering required to isolate energy use per unit measurement.

Case Study: Bellingham Cold Storage[6]

Facility: Bellingham Cold Storage, Bellingham, Washington

Facility Description: The facility is four cold storage warehouses operating from a common ammonia refrigeration system. The facility freezes and stores fish and produce for others. These storage warehouses are maintained at 0°F or -20°F, depending on the product being stored.

In addition to cold storage, tenants at the site operate fish processing and freezing operations at the facility. Tenant equipment is operated separately and submetered.

Energy Use Patterns: BCS is an all-electric facility.

Energy Use Drivers: Electricity use is strongly influenced by the amount of product moved in and out from storage, the amount of product processed (fruits and berries at ambient temperature placed in the cold rooms for freezing), weather conditions, and tenant energy use.

ECMs: BCSinstalled an energy management control system (EMCS) consisting of a computer, software, and peripherals connected to sensors measuring pressure, temperature, humidity, and power at various points throughout the plant.

Verification Method: Energy Indexing based on billing data.

Baseline Establishment Baseline energy usage was established by a six-month period (January through June 1988) before implementation of the measure. This period was chosen because it was unaffected by processing energy consumption (fiuits and berries at ambient temperature placed in the rooms for freezing) which could not be normalized due to insufficient data.

Baseline data were compared to data for January through June 1989 to determine savings.

Efficiency Improvement Verification of efficiency improvement was done by on-site inspection of the installed EMCS.

Persistence Persistence of savings was verified only for the first year of energy savings. Because the measure was extremely cost-effective, Bonneville paid only 13% of the measure cost in a one-time payment,

[6] This case study is adapted from a Letter Report titled: "Impact Evaluation of an Energy $avings Plan Project at Bellingham Cold Storage" prepared for Bonneville Power Administration by Spanner, et. al., Pacific Northwest Laboratory, June, 1990

and the sponsor had plans to expand and improve the measure, further measurement was not considered necessary for purposes of verification.

In general, persistence in this type of project might be verified by periodic inspections of the installed equipment. These inspections should be in the form of ongoing commissioning tests, in which the proper operation of the control system is checked on an ongoing basis as well as continued operating schedules. Annual or biannual testing would be adequate for verification purposes.

Measure Interactions

Measure interactions were accounted for by normalizing for all other significant variables (product level and weather) in the verification method.

Independence

Energy data used in the savings calculations come from the local utility and from existing watt-hour meters at the facility to measure tenant energy use. Data on production and product storage levels were provided by the customer.

Analysis Algorithms

For each of the months in the comparison, cooling degree days were calculated against a -15°F base. The base temperature was a rough estimate of the average storage temperature.

Net energy consumption (billed consumption minus energy consumed by the tenants) was calculated and then normalized consumption was determined by dividing the monthly net energy use by its corresponding cooling degree-days and tons of inventory in storage.

The baseline normalized energy use averaged 0.0124 kWh/ton-degree day. After the installation of the measure, normalized energy use fell to 0.0095 kWh/ton-degree day, a reduction of 23% from the baseline period.

Savings were calculated by multiplying the net annual energy use (facility consumption less tenant consumption) by the calculated percentage savings.

Discussion

This is an example of a situation in which the measurement is not perfect and does not control for every conceivable variation, but still is sufficient as a basis for an acceptable business deal.

Verification by Hybrid Methods

In many cases, multiple ECM s will be simultaneously verified within a facility. This will often require apphcatson of several ECM-specific measurements at the same time.

Various problems may arise in simultaneous measurements, including the following:

1. One ECM affects the data used to evaluate another ECM.

a) Example: A chain store has a portion of its light fixtures retrofitted with energy efficient lamps and ballasts. In addition, energy management controls are installed to reduce operating hours of all lighting and HVAC systems in the building.

b) Problem: The project sponsor proposes to use an index based on utility billing data to verify EMCS savings and connected load measurement to verify lighting savings. Lighting savings will be double counted because they will affect data in both measurements.

c) Remedy: Savings for all measures should be verified based on a single measurement (e.g., by including the lighting savings in the index comparison) or savings for the lighting measure should be separately calculated and then subtracted from the apparent savings of the energy management control system.

This problem is common when utility billing data are used to evaluate one measure and load measurements or deeming are proposed for other measures (which will also affect the billing data). Care should be taken to avoid this type of double-counting.

II. An ECM affects an end-use which is not being measured.

a) Example: A large lighting efficiency retrofit is made in a commercial building with electric heat (or cooling). The project sponsor proposes verification by measurement of the connected lighting load before and after.

b) Problem: The change in internal heat gains will increase building heating requirements (and/or decrease cooling). Depending on the site, these changes in other end-uses may be significant. The proposed method will under- or over-state savings as a result.

c) Remedy: A computer model of the building’s base load - HVAC interactions can be used to determine an adequate adjustment factor for interactions with space conditioning. In other cases where interactions are significant, a similar adjustment factor should be developed.

When proposing hybrid methods, project sponsors should pre-specify what methods will be applied under given circumstances.

Appendix I: Data Quality Management

All verification methods require the collection and analysis of data that are subject to errors in measurement or use. When setting up a process for data collection, reviewing a check list of potential sources of error can help avoid mistakes and reduce the risk that energy savings estimates will be randomly or systematically biased.

The focus in planning a process for data quality management should be actions ensure good data and prevent defects, rather than detecting and repairing bad data. Doing things right the first time is less costly, faster, and easier than correcting poor quality work.[7]

Errors may result from poor design of the measurement process. Errors may be caused by collection of data that cannot address the issue at hand, measurement of consideration of the possible sources of errors nonrepresentative samples, non typical conditions, or failure to control or recognize collection has begun. other variables. Bad measurement design is the source of the largest errors in verification measurement.

Even when appropriate data are being Measurements below). Where already available data are being used, the data provided may be incorrect or inappropriate. Accurate data may be misapplied, altered by mistakes in data entry, or misread. Arithmetic mistakes in the analysis of data are another source of simple mistakes.

These sources of error can be minimized by carefully documenting the process of collecting and analyzing data and training those who will perform these tasks. Training should include a description of the kind of errors that can arise and their consequences in the process.

[7] BPA Draft Policy on Quality Assurance, February, 1992

While a verification plan is being implemented, it is likely that the personnel collecting and analyzing data will change. Clear documentation of the verification process, including a systematic approach for collecting and analyzing data, will enable these transitions to occur with minimum disruption. The verification process should be documented as part of the purchase agreement with Bonneville. Additional detail, to train verification personnel, should be documented *before* measurement or analyses begin.

Site Measurements

When collecting data from site measurements, consideration of the possible sources of errors can help eliminate inaccuracies before data collection has begun.

Errors can occur due to any of the following causes[8]:

Instrumentation errors result from improper selection, installation, maintenance, or calibration of the metering equipment installed. These errors include use of instruments with inappropriate range, sensitivity, accuracy, or response for the variable being measured; poor maintenance or installation, and poor calibration or calibration drift.

Observational errors result from mistakes in reading or interpreting meter indications of data. These can be due to scale reading errors,

[8] The source for this list is Table 1., Chapter 13, February, 1992 ASHRAE Handbook of Fundamentals, 1989

inaccurate estimates of average readings, poor timing or non-simultaneous readings, and pure mistakes.

The following example[9] illustrates how large errors are possible when sources of measurement error are not adequately considered:

Measurement of a chilled water temperature difference is being used to determine building cooling load. A technician uses a pair of installed mercury-glass thermometers installed in the chilled water loop with a precision of ∀ 2.5 degrees F. to measure water temperatures leaving the chiller and returning to the chiller.

If the temperature difference is 8 degrees F., the measurement error is ∀ 44% (∀ 3.54 degrees F.).[10] Considering that typical precision of mercury glass thermometers is anywhere from 0.1 to 10 degrees F., the error could be much larger. This error would also be compounded by other measurement errors (such as chilled water flowrate) in determining building cooling load.

Errors of this magnitude arise when measurement goals are not clearly defined and an analysis of possible sources of error is not performed. Because accuracy of many common instruments can vary by as much as two orders of magnitude, checking instrument calibration in the field is essential to good measurement.

Data Cleaning

Any site metering activity may be subject to data that is lost or known to be inappropriate due to metering malfunctions. To allow for these events, some method must be specified for adjusting the measured data or substituting other data.

Methods for data “cleaning” in the case of metering malfunctions must be prespecified and agreed on during negotiation of the verification plan. Key principles for data cleaning are similar to those for outlier data. The rules for when data cleaning will be applied must be prespecified (i.e. under what circumstances data will be subject to adjustment or substitution) and how alternate data will be selected or created must also be prespecified.

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[9]Example taken from Landsberg, *Field Measurements for DSM Program Evaluation*, ADSMP, 1991

[lO]For a discussion of measurement error analysis, including errors introduced by computations, see Chapter 13, ASHRAE Handbook of Fundamentals, 1989

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Glossary

Attribution:	The likelihood that an efficiency improvement would not have occurred in the absence of a program.
Baseline:	The level of energy use or equipment efficiency used as a basis for comparison to determine energy savings.
Billing Analysis:	Measurement of energy savings by comparing utility billing records for a customer before and after installation of ECMs.
CFM:	Cubic Feet per Minute. Common units for measurement of air flow in space heating and cooling systems.
Decay:	Decay refers to any decline in energy-saving effectiveness that may take place over a measure's useful life. See "persistence."
Deeming:	A verification technique in which savings per installed measure are pre-specified and no measurement is required beyond counting or verifying the actual number of measures installed or units treated.
ECM:	Energy Conservation Measure. Equipment installed or procedures implemented to improve efficiency and reduce energy consumption.
EMCS:	Energy Management and Control System. A computer based system that monitors and controls building or process equipment to maintain desired temperatures, humidity, pressure, flow, etc.
Energy Savings:	A reduction in energy consumption resulting from efficiency improvement beyond what would have occurred without a defined project or program.
Hybrid Methods:	The application of two or more techniques to verify different measures in a building, e.g., use of connected load measurement for lighting ECMs and end use metering for a chiller ECM within a building.
Outliers:	Measurements which deviate by more than a predetermined amount from expected values.
Persistence:	Persistence refers to maintenance of a consistent level of energy-saving effectiveness for the duration of a measure's useful life. See "decay."
Verification:	The measurement of energy savings for the purpose of determining payments to a project sponsor.
VSD:	Variable Speed Drive. An energy conservation measure which reduces energy consumption by reducing fan or pump speed in response to reduced flow requirements.

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