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ABSTRACT

The Bonneville Power Administration (BPA) has been using a free add-in to common workplace software and two easily available data inputs to verify savings from energy efficiency projects. Regression-based energy modeling is a technique that uses observed energy use and measured temperature to model behavior of an existing building. These empirical models reflect actual building operations and observed response to temperatures, unlike theoretical energy models (such as eQuest or EnergyPlus) that assume design conditions and ideal operation. Readily obtainable data—energy consumption (such as daily usage from advanced meters or monthly billing data) and recorded outdoor temperature from a nearby airport—are used with a free Excel-based tool called ECAM+ to construct models of baseline and post-retrofit energy use. These empirical models describe real-world building energy response to outside air temperature, and can be normalized to typical local temperatures to determine the energy savings from major retrofit projects. They can also help spot operational issues during the project performance period. This modeling technique is especially useful for hard-to-measure, interactive projects such as controls or retro-commissioning, but can be applied to any project with savings expected to be greater than a few percent of whole-building energy use.

INTRODUCTION

Utilities are increasingly turning to energy efficiency as a low-cost alternative to building expensive power plants and transmission lines. The Bonneville Power Administration has a long history of energy efficiency dating back to the 1980 Pacific Northwest Electric Power

Planning and Conservation Act (colloquially known as "the Regional Act") [1], which mandated that BPA do all cost-effective conservation in lieu of building new plants. Businesses appreciate energy efficiency projects because they can lower operating costs. Consumers like the idea of "green" and saving money. All of these factors have led to a profusion of energy efficiency projects. The question is how much will any given energy efficiency project save?

This topic is important to electrical utilities, who need to know about their load shapes, and also to consumers, who want to evaluate the financial benefits and costs of energy efficiency projects. Measurement and verification (M&V) of energy savings is a critical component of this process.

M&V STRATEGIES

There are numerous ways to determine savings. While many approaches have been developed by different organizations over the years, (e.g., ASHRAE Guideline 14), some of the most commonly used methods are described by the International Performance Measurement and Verification Protocol (IPMVP). These are: A. Retrofit Isolation: Key Parameter Measurement; B. Retrofit Isolation: All Parameter Measurement; C. Whole Facility; and D. Calibrated Simulation [2].

If the IPMVP guidelines were followed to the letter, the results would undoubtedly be credible to all parties. For proper implementation of these guidelines, M&V should be incorporated into the project design. Full project information, including installation details and operating conditions, should be known to the party performing the M&V. Unfortunately, this is seldom the case. Contract officials overseeing projects may not be familiar with energy-related M&V protocols, and contracts seldom sufficiently address M&V. Performance verification is often done by parties not involved in project installation, who must determine what happened from reports and bills. Most of these reviews are done post hoc by technical staff who are familiar with energy efficiency implementation but do not know project details. Also, in the case of most large projects, multiple measures with complex interactive effects are installed at once, so metering of installed equipment might not capture total project performance.

Data to the Rescue

Whole-building energy use is commonly available from utility meters on an approximately monthly basis, and increasingly on finer intervals. The post-project use could be compared as-is to baseline (pre-project) energy use, but such comparisons are often contentious due to fluctuations in weather, which can lead to lower or higher savings when compared to the baseline.

Regression analysis eliminates this objection by describing relationships among multiple variables. In industrial environments, energy use might be closely linked to production. In commercial facilities, energy is mainly consumed by lighting, plug load (e.g., office equipment), and HVAC equipment (heating, ventilation, and cooling). Thus, outdoor temperature and occupancy are the main drivers in commercial facilities. At the monthly level, occupancy is generally consistent; for example, an office building that is occupied weekdays and not occupied weekends does not generally change this schedule. Minor occupancy variations do occur from month to month (holidays, seasonal effects), but in aggregate are typically insignificant, leaving only temperature as the significant independent driver of energy usage.

In the internet age, recorded temperature is easily available for a wide variety of geographic locations. In the United States, temperature is consistently recorded at airports throughout the country.

Regression modeling of energy usage versus outdoor air temperature has become BPA's preferred method for determining energy usage for large non-standard efficiency projects. While this type of analysis can be performed using any statistical software package, a number of free tools are available which can make this task easier and more consistent. Energy Charting and Metrics Plus (ECAM+) is one such tool, which automates the model types set forth in ASHRAE 1050 [3] [*]. Since the ECAM+ statistical analysis is free, works with intervals or monthly data, was developed specifically to work with energy data, and is integrated into common Microsoft Office software, it has become BPA's tool of choice for large custom efficiency projects. Other software on the market (e.g., Metrix, EnergyCAP, Utility Manager) has had the capability for monthly bill analysis, but cost restrictions have limited their usage, especially in the federal sector.

An example of one such baseline regression model, using billing history, is shown in Figure 1. Monthly average temperature is plotted

*ECAM+ is available for download from http://www.northwrite.com/ecamregistration.asp. (Free, registration required).

on the x-axis, and average energy use (measured in kWh/day) over the analysis period is on the y-axis.

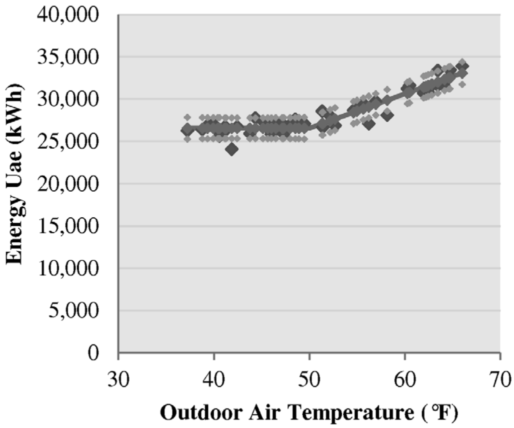

Figure 1: Sample Regression Model

When this model is applied to the average historical temperatures (e.g., typical meteorological year [TMY3]) for the area, the resulting annual baseline is calculated at 10,398,000 kWh per year. The detailed modeled results are shown in Table 1.

It should be noted that building energy simulation programs such as eQuest and EnergyPlus are theoretical, physics-based models, and not the type of "model" under discussion here.

Fast, Cheap, Good?

When performed by a skilled user, ECAM+ regression analysis can quickly determine relationships and apply them to average weather data, normalizing the baseline and post-project model to the same weather conditions. In this way, savings are attributed to consumption changes, rather than to flukes of temperature. With sufficient baseline data (generally available from the electric utility), merely charting the relationship of energy to temperature can identify unusual readings. This analysis, particularly in combination with normalization, can eliminate the problem of choosing an anomalous period as the baseline.

While the analysis itself can be performed quickly, the data collection process necessarily takes some time. Ideally, a multi-year history is used to determine the baseline, and the post-period data are collected for a year after the project is installed and commissioned,

Table 1: Normalized Modeled Baseline Energy Usage

Month	Historical Average Temperature (°F)	Modeled Usage (kWh)
January	39.7	823,000
February	42.3	744,000
March	45.4	823,000
April	49.6	797,000
May	55.3	890,000
June	60.0	918,000
July	64.3	1,003,000
August	64.5	1,006,000
September	60.2	921,000
October	52.4	853,000
November	44.6	797,000
December	40.4	823,000
Total		**10,398,000**

to determine energy performance over the full range of operating temperatures, as different equipment may be engaged at different times of year. This data collection, while slow, is beneficial for both the M&V analyst, who enjoys greater statistical confidence, and for the building owner, who can be more confident of equipment performance across a variety of outdoor conditions.

It is easy to confirm whether equipment is running or not, but determining whether control strategies are effective is a slightly less straightforward task. Looking at energy performance after project installation can verify that energy projects are working as designed and, if not, help identify issues that may be diminishing the amount of energy savings expected from an efficiency project. This information can be fed back to the building managers and used to address and improve performance.

Although this strategy for energy savings verification has many advantages, there are limitations. Particularly in the case of monthly data, it can be difficult to separate small changes from the natural variation inherent in operations (noise). For this reason this technique is best applied when expected project savings are a large percentage of building energy use (10% savings minimum as a rule of thumb). If equipment metering is available, it will obviously give more information about the performance of that equipment. ECAM+ has M&V features designed for interval meter data, and when these more granular data are available, smaller savings percentages can be credibly estimated.

SUMMARY AND CONCLUSIONS

While many strategies exist for M&V of projects, most of them are difficult and expensive. Whole-building regression modeling is a tool that can transparently and consistently determine savings from energy efficiency projects. This method does require an extended data-gathering period, but once that has elapsed it provides reliable savings verification for building owners and utilities, based on easily available data. Free software tools are making this analysis ever simpler.

Because new software tools make the analysis easier to perform and interpret, and because of substantial increases in accuracy and precision over other methods, whole-building regression modeling is poised to become the strategy of choice for major energy-efficiency projects of the future.

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ABOUT THE AUTHOR

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