Measurement and Verification Functionality of the BuildingIQ System

Executive Summary

Continued investment in energy efficiency requires that the delivered savings from energy efficiency projects be accurately measured and the results verified. Moreover, the methodology and processes used for measurement and verification (M&V) themselves must be made clear, transparent, and robust. This analytical rigor is at the heart of BuildingIQ’s cloud-based software, which consistently delivers between 10 and 25 percent verifiable savings for its customers. This whitepaper describes how BuildingIQ’s M&V software module is based upon the established industry-standard for M&V; that is, the International Performance Measurement and Verification Protocol, or IPMVP. The paper details how the platform calculates energy savings by comparing baseline energy consumption before BuildingIQ software is activated to energy consumption after the BuildingIQ system is fully enabled. Assessing baseline energy consumption is a complex undertaking; BuildingIQ models use the highest-resolution data available from a variety of sources, including past meter reads, outputs from the building management system (BMS), adjacent periods of energy consumption, and/or third-party uploads, such as Green Button data. The paper goes on to describe BuildingIQ’s mathematical model for calculating energy savings, and the variety of BuildingIQ display formats. Savings calculations in both energy and dollar terms are made available visually through a variety of graphs and charts. Detailed and tailored reports are also available. Calculated savings are readily accessible by third-party M&V auditors, a critical step in securing financing and energy efficiency rebates.

1.0 Introduction

Reducing building energy use through the implementation of energy efficiency projects is a proven strategy. However, claims of energy efficiency savings must be supported by measurement. Clients, investors, program administrators, and other stakeholders now require quantifiable evidence that the contract or programmatic goals have been met. For every project—whether lighting retrofits or HVAC optimization—providing evidence of energy savings is a critical element to ensure limited dollars are spent in the most cost-effective manner. M&V is the process of quantifying savings delivered from an energy conservation measure. An important element of verification process is that it isolates the energy savings delivered by the project from other factors affecting energy consumption, such as weather or building occupancy.

BuildingIQ is committed to delivering satisfactory and trusted results to its customers and project stakeholders. It is essential at the outset of the contract—and prior to project implementation—that both BuildingIQ and its customer have common expectations about what benefits will be delivered and how they will be quantified.

BuildingIQ’s platform delivers accurate energy savings calculations and visualization through its M&V module. BuildingIQ’s energy efficiency solution
is unique in that it is largely based in the cloud. This allows for centralized and real-time data acquisition of meter, sensor, and weather data.

An important M&V concept is the need to calculate the building’s baseline energy use, which means establishing the business-as-usual energy consumption prior to implementation of the BuildingIQ system. These baselines are automatically adjusted for weather and occupancy by the BuildingIQ software so that they can be accurately compared to energy consumption following implementation. The comparison is the foundation for calculating energy savings.

This whitepaper discusses relevant M&V methods, how the BuildingIQ system calculates baseline energy consumption—including various mathematical models used depending on data availability—and how the system calculates and reports energy savings.

2.0 Measurement and Verification Methods

Industry-Accepted Practices

Protocols for M&V have been agreed upon and documented by the evaluation industry through the International Performance Measurement and Verification Protocol, or IPMVP. The IPMVP provides an overview of current, best-practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects in commercial and industrial facilities. It is also be used by facility operators to assess and improve facility performance. While it documents the state of the art, it remains a high-level framework, which does not specify detailed project design. Experienced M&V auditors develop their own evaluation plans depending on project specifics.

IPMVP provides four options for determining savings—identified as Options A, B, C and D—depending on the specific nature of the project and availability of data. The options range from isolating the specific energy conservation measure (ECM)—such as a lighting retrofit—and then taking field measurements of some or all performance parameters (e.g., power drawn, hours of operation, etc.). For those parameters not selected for field measurement, evaluators can use estimates based on historical data, manufacturers’ specifications, or engineering judgment. For the lighting retrofit example, if hours of operation cannot be recorded, they can be estimated using industry estimates.

The choice among the options involves many considerations. The decision of which IPMVP option to use for a given project is left to the designer of the M&V program.

Comparing Baseline to Actual (Post-Retrofit) Conditions

To identify the savings associated with an energy efficiency project, an evaluator must compare baseline conditions (i.e., pre-retrofit) to actual conditions (i.e., post-retrofit). Figure 1 depicts the process BuildingIQ uses to gather data, create a baseline model, and compare baseline consumption with actual meter readings to calculate and report savings. This approach is consistent with IPMVP Options B and C. Option B refers to measurement techniques that isolate the energy savings for the specific system or equipment being treated. Option C refers to measurement methods that evaluate savings for the whole building. While it is desirable to use Option B, it is not always possible or feasible due to lack of energy metering for the specific equipment or system being treated.
### IPMVP Option

<table>
<thead>
<tr>
<th>Option</th>
<th>Supported by BIQ Automated M&amp;V</th>
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<tbody>
<tr>
<td>A. Partially Measured Retrofit Isolation</td>
<td></td>
</tr>
<tr>
<td>Savings are determined by partial field measurement of the energy use of the system(s) to which an ECM was applied, isolated from the energy use of the rest of the facility. Measurements may be either short-term or continuous.</td>
<td>No</td>
</tr>
<tr>
<td>B. Retrofit Isolation</td>
<td></td>
</tr>
<tr>
<td>Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, isolated from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.</td>
<td>Yes</td>
</tr>
<tr>
<td>C. Whole Facility</td>
<td></td>
</tr>
<tr>
<td>Savings are determined by measuring energy use at the whole facility level. Short-term or continuous measurements are taken throughout the post-retrofit period.</td>
<td>Yes</td>
</tr>
<tr>
<td>D. Calibrated Simulation</td>
<td></td>
</tr>
<tr>
<td>Savings are determined through simulation of the energy use of components or the whole facility. Simulation routines must be demonstrated that adequately model actual energy performance measured in the facility. This option usually requires considerable skill in calibrated simulation.</td>
<td>No</td>
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Baseline conditions can be created using mathematical data from one of two sources. The model can use past interval metering data, or alternatively, can use data from turning the energy conservation system off and comparing it to lower consumption level when the system is on.

Savings are expressed in energy units and in US dollars (or other currency). Because a utility company’s energy rates can vary depending on time of day, day of week, and season of the year, BuildingIQ’s system incorporates a real-time tariff engine that models the specific utility’s time-of-use (TOU) rates for any hour of the day.
3.0 Identifying Baseline Energy Consumption

Acquiring Baseline Data

BuildingIQ’s energy model can be applied to whole-building energy use, or focused on the specific load of the HVAC equipment. Often the choice depends on whether metering exists only for the HVAC equipment. The measurement boundary can include:

- A single, whole-building meter for electricity, gas, and/or steam
- An aggregation of sub-metering equipment that is representative of the whole building load, or
- An aggregation of sub-metering equipment representative of the total HVAC load.

Real-time baseline data is acquired either through a direct connection to the meter or through access to the existing building management system (BMS). While metering is an indispensable part of M&V, data availability can vary widely from one building to another. Some buildings have a single utility meter inaccessible to the wider building systems, others have extensive sub-metering systems, while still others have metering points located only at the HVAC systems. Monthly bill data by itself does not provide sufficient resolution to establish baseline. Additional metering data is required.

With BuildingIQ, available data is automatically converted into hourly interval energy and demand data, to which unit conversions are applied. Data is then aggregated according to a user-configured meter hierarchy to ensure that energy readings are not double-counted. This approach allows for flexible configuration of the measurement boundary, whether it is the whole building or confined to the HVAC systems only.

In those cases where the meter is not connected to the BMS but is instead monitored through a third-party service, data can be uploaded into the BuildingIQ system through conversion to a comma separated value (CSV) file. Examples of such third parties services include Green Button, Net Metering, Johnson Controls’ Panoptix® and others.

<table>
<thead>
<tr>
<th>Energy Data Source</th>
<th>Supported by BIOQ Automated M&amp;V</th>
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<tbody>
<tr>
<td>Energy metering from BMS (VFD, CTs…)</td>
<td>Yes</td>
</tr>
<tr>
<td>Interval energy data from CSV (sub-metering system, or utility)</td>
<td>Yes</td>
</tr>
<tr>
<td>Web Services (Panoptix)</td>
<td>Yes</td>
</tr>
<tr>
<td>FTP interval data</td>
<td>Yes</td>
</tr>
<tr>
<td>Monthly bills</td>
<td>No</td>
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Calculating a Baseline

Identifying baseline energy consumption is the first step in calculating energy savings attributable to the BuildingIQ system. The automated M&V module produces consumption models that are weather and occupancy normalized. These baselines are derived from the highest resolution data available using automated calculations and data pre-processing techniques based on industry best practices.
There are two ways in which baseline energy consumption data can be obtained:

- **Historical Data:** When available, historical data should be used to determine a baseline. This data comes from past meter reads, outputs from the BMS, or third-party data uploads such as Green Button data. This method is practical if the historical energy usage patterns are comparable to current energy usage patterns. If however, the building has undergone significant changes in its utilization profile (e.g., changes in layout, occupancy, work practices, etc.), or in its HVAC equipment, this method might not be useful to determine an accurate baseline. In this case, an alternative approach is desirable.

- **Adjacent Period Data:** If historical data is not available, BuildingIQ uses a widely accepted alternative methodology that relies on adjacent period data, as described by the IPMVP process. Using this methodology, BuildingIQ conservation measures are disabled for a few days, while the BuildingIQ system creates a model of the energy use. BuildingIQ is then turned back on and the reduction in energy consumption is calculated. The comparison is used to determine how much savings can be delivered through BuildingIQ intelligence. This on/off adjacent period process needs to be repeated during the peak and shoulder seasons to provide a projection of the annual savings.

Data cleanup is an important part of data selection and baseline calculation. BuildingIQ operations staff routinely verifies the building meter data and can exclude sections of data from the analysis when there are gaps, significant outliers, or simply when the data is not considered to be comparable, such as during an equipment shutdown.

<table>
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<tr>
<th>Data Availability</th>
<th>Baseline Data Acquisition</th>
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<tbody>
<tr>
<td>Historical data available</td>
<td>Use historical data prior to BuildingIQ installation as the baseline.</td>
</tr>
<tr>
<td>No historical interval data available</td>
<td>Use BMS trends or install CTs and schedule BuildingIQ outages throughout deployment</td>
</tr>
<tr>
<td>Other measurements taken with BIQ</td>
<td>Schedule BuildingIQ outages throughout the deployment</td>
</tr>
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**Adjusting for Weather and Occupancy**

BuildingIQ’s energy model produces high-resolution hourly estimates of energy use adjusted for variables that will have a direct impact on energy use. For example, if two business days have the same weather conditions but different occupancy intensities, then the energy use will differ. The converse is also true: same occupancy, but differing weather changes energy usage. The three key independent variables are:

- **Weather Adjustments** - Hourly dry-bulb temperature or outside air enthalpy (depending on the local climate) are a key driver of energy consumption.
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- **Occupancy Adjustments** - During scheduled outages, an occupancy profile of the building is obtained by taking the average load each hour and normalizing it to a 0-to-1 value. A representative profile is provided in Figure 2. Identifying occupancy is one of the two significant non-weather drivers of the model.

- **Day-Type Adjustments** - Weekdays and weekends are modeled separately to reflect the differences in occupancy. This is the other significant non-weather driver of the model.

**Least Squares Regression**

A two-variable, second-degree polynomial is used to develop predictions when the least-squares method is chosen. The independent variables (along the x-axis of the Figure 3) are dry bulb outside air temperature (or outside air enthalpy) and the occupancy profile for each hour of the day. The data points in red represent the predicted hourly consumption; the data points in black are the actual hourly consumption. Figure 4 shows a typical least squares fit capturing linear building load behavior.

**Modeling Based on Data Availability**

BuildingIQ’s baseline model produces hourly estimates of what the energy use would have been if the system had been turned off, a scenario referred to as “business as usual”. Two modeling techniques are available to generate business-as-usual energy baselines: least squares regression and support vector machine regression. The first provides a robust prediction based on a linear model that is well suited for limited amounts of baseline data. The second is a Non-Parametric Model that provides higher accuracy; this model is especially effective when large historical data sets are available.

**Support Vector Machine Regression**

The second modeling option is support vector machine regression. Support vector machines are techniques used in pattern recognition applications, such as classification and prediction. They are very effective at generating predictions in conditions...
where the mathematical relationships between inputs and outputs are not known beforehand (in contrast to the least squares regression method). In BuildingIQ’s case, these are used in buildings that exhibit complex or non-linear behavior. Figure 5 shows a typical support vector regression model fit predicting load behavior. The fit is graphically illustrated by the two different color curves being almost exactly superimposed, indicating that an accurate prediction can be made despite the non-linearities.

### 4.0 Calculating Energy Savings

The fundamental approach that the BuildingIQ M&V system uses to determine energy savings is to compare the Actual energy use (BuildingIQ enabled) to the Baseline energy use (business as usual conditions). The calculated difference constitutes the energy savings (or waste elimination). The savings are expressed in both energy units and in dollars. Because the utility company’s energy rates can vary depending on time of day, day of week, and season of the year, BuildingIQ has created a powerful software “tariff engine” that incorporates the specific utility’s time-of-use (TOU) rate structure. The BuildingIQ M&V system uses the BuildingIQ Tariff Engine to calculate the monetary value of the savings for each hour of energy usage. This is done separately for each energy commodity—gas, electricity, steam—since each has its own TOU tariff. The table below highlights the fact that the percentage savings in energy units may be different from the dollar percentage savings when a TOU tariff applies. A unique feature of the BuildingIQ platform is that optimizing decisions are made with full awareness of the economic tariffs.

### 5.0 Reporting Results

While the BuildingIQ system automates much of the baselining and energy calculation process, users retain access to both the methodology and the underlying data. All data used in the generation of savings calculations is visualized through graphs and detailed reports. The data can also be exported for off-line analysis if desired. The M&V module is designed so that the measurement and verification process is transparent and accessible, and all stakeholders can confidently stand behind the calculated energy savings figures and key performance indicators.

The BuildingIQ system enables administrators to create reports and analyses in a variety of formats useful for different audiences. An online savings dashboard is always available where results are updated in real, or near-real time. Figure 6 depicts a dashboard that shows the BuildingIQ system’s performance for the last 30 days as well as the lifetime of the project.
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A comprehensive record of the data selected and the data excluded is kept in BuildingIQ’s data storage, and it is available in both Savings and Fit Reports, which can be used for M&V purposes. During client meetings, BuildingIQ operations staff may present additional versions of these reports.

**Savings Report**

The Savings Report is available upon request and shows the daily consumption in kWh. It contrasts Baseline conditions (business as usual) and Actual conditions (BuildingIQ system enabled). It also shows outside air temperature for reference purposes. Users can select different time periods to suit their needs. Figure 7 provides an example Savings Report.

![Figure 7: Savings Report Example](image)

**Baseline Fit Report**

The Baseline Fit report displays the accuracy of the baseline through trend charts, as well as important fit parameters, such as the coefficient of multiple determination ($R^2$) and the normalized root mean square error. The baseline represents what the energy consumption would have been if the BuildingIQ system were turned off. This report also specifies the temperature range over which the model is valid, as well as the periods in which data was collected to feed into the energy model (baseline periods). Figure 8 shows an example of a Fit Report.

![Figure 8: Fit Report Example](image)

### 6.0 Conclusion

To provide confidence to system users and project stakeholders, BuildingIQ offers built-in M&V system functionality that automates much of process in an easy to use and transparent way. Through its automated platform, stakeholders can evaluate system performance without costly and time consuming third-party analysis while allowing M&V auditors to drill down and verify that intended measures are taking effect.