Building Efficiency? There's an EnPI for that.

Chad Gilless, EnerNOC, Inc.
David Goldstein, NRDC
Charles Eley, Eley Consulting

ABSTRACT

Commercial building energy efficiency has been stymied by a lack of well understood and deployed energy performance indicators (EnPIs). For every supposedly sound EnPI, there are critics who point to numerous exceptions where the EnPI does not capture the full picture of performance, and produces misleading results. This leads to stakeholders such as program administrators, building managers, and even financial loan institutions being wary of claimed performance and thus being unenthusiastic to encourage energy performance improvement measures.

In 2011, the International Organization of Standardization (ISO) released the ISO 50001 Standard for Energy Management Systems, a standard that codifies organizational energy management and drives energy performance throughout organizations which adopt it. A key component of the standard is the EnPI, used to demonstrate improvement in a defensible way based on what the EnPI is designed to measure. In manufacturing settings, EnPIs are typically based on production, but in the commercial building setting, the lack of EnPI focus creates an opportunity that ISO 50001 can target.

This paper proposes a set of four EnPIs that can be used alone or in combination to measure various aspects of building energy performance. These EnPIs include Operational Rating, Asset Rating, Operations and Maintenance (O&M) Index, and Energy Service Index. By demonstrating how these indicators work in a clear manner, this paper will help program administrators and other stakeholders gain a better understanding in how to utilize the EnPIs to improve building energy efficiency.

Introduction

Energy performance management has inherent benefits in that, in most cases, it is possible to measure results. That is, most building owners pay a utility company for their energy, and for these buildings, there is a meter that quantifies the energy consumption. Unfortunately, these quantified results have numerous limitations. Looking at meter information is only possible after the energy is used. Also, metered results do not speak in terms of energy efficiency, but instead are in terms of outright consumption. Focusing solely on reducing energy (using a consumption-only EnPI) can compromise the delivery of energy services which are important or even critical to building operation, such as occupant comfort (DOER 2010).

Commercial Building EnPI Background

To begin to address these issues in the built environment, different sets of experts created two EnPIs: the Asset Rating and the Operational Rating. The Asset Rating is based on modeled energy use with uniform conditions such as climate, schedules, and occupancy. The result is a metric that designates building quality with respect to typical energy management performance. The Operational Rating is based on measured energy use, typically normalized statistically for climate and some simple metrics for level of energy service.

The Asset Rating describes a building's inherent efficiency, normalizing on a building-specific basis for operation, maintenance and the delivery of energy services. The Asset Rating works well as a metric for purchasers or tenants to select the right building. The purchasers or tenants can understand how the building should perform, on average (Lewry 2013). Once the occupants move into the building, the Asset Rating may not be predictive of energy consumption. It does not reflect, and is not intended to reflect the energy performance resulting from the operation and occupancy of the individual building.

Thus the variation between predicted energy performance (Asset Rating) and actual performance (Operational Rating) can be quite significant (Johnson 2003; Turner and Frankel 2008). Figure 1 graphs the variation for a group of buildings that qualify for the LEED program[1]. The horizontal axis is the predicted energy performance and the vertical axis is the ratio of actual performance to predicted performance. If there was perfect agreement, the points would all align with the horizontal like with a ratio of 1.0. This figure illustrates that there significant numbers of buildings above the "1.0" line which use more, or far more, energy than designed, and also many buildings that use much less. Also the figure shows that the buildings with very low predicted energy performance tend to be the ones that are lower than metered results. This difference has been suggested to result from high levels of IT and other such energy uses in these buildings that are not accounted for in the LEED certification.

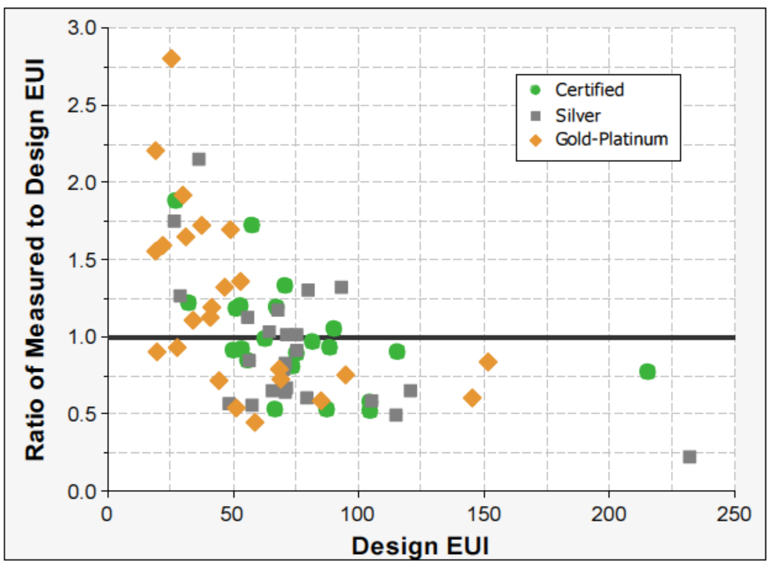

Figure 1. Measured/design ratios relative to design end use intensity (EUI). *Source*: Turner and Frankel, New Buildings Institute, 2008.

[1] Note that this is not a random sample of buildings, first because the buildings that choose to apply for LEED certification are self-selected, and second because the availability of data was insufficient to allow a random sample to be analyzed.

The Operational Rating describes a building's metered performance using data that is then normalized and benchmarked against buildings of a similar type. A common Operational Rating is the ENERGY STAR Portfolio Manager rating. The Operational Rating works well as a metric for building managers to understand the general effectiveness of energy management activities. The building managers and their executives can readily understand their year over year performance, or they can compare improvement across a building portfolio. However, the simplicity of the Operational Rating is a result of it combining numerous building performance dimensions, which can make it difficult to understand specific results.

In addition to the limitations of Asset Ratings and Operational Ratings, it is clear that the multiple dimensions of energy performance require more than a single EnPI (Goldstein and Eley 2014). This is akin to buying a car based on its highway miles per gallon (MPG), when the driver will actually spend a significant amount of time driving in town, or they plan to drive at speeds far faster than typical. The car buyer requires more information to make the right decisions for their purchase as well as for their driving habits.

Energy performance depends on three dimensions: the inherent energy efficiency of the building, e.g. the quality of the windows and the efficiency of the equipment; the level of energy service demanded by the occupants, e.g. the hours of operation, temperature requirements and power requirements for equipment; and the quality of operation and maintenance practices.

ISO 50001

In June 2011, the International Organization for Standards (ISO) launched ISO 50001, after a multi-year development effort. ISO 50001 aims to deliver continual improvement in energy efficiency through the use of management systems, in the same way that the well-known ISO 9001 standard aims at continual improvement in quality.

ISO 50001 is based around a comprehensive Energy Management System (EnMS), a management system for energy, similar to a Quality Management System. An ISO-compliant EnMS includes an energy policy, energy teams, clear management involvement, energy-related purchasing procedures, energy goals, employee engagement, training, and numerous other structures and processes (ISO 2011).

ISO-compliant companies also have Energy Performance Indicators (EnPIs), which are the metrics that they use to drive improvement and meet goals. The standard does not define which EnPIs to adopt; it leaves that flexibility to each organization (e.g. therms/square foot, BTUs/month) (Batmale, Gilless and Hart 2013). Companies can have as many EnPIs as they require to appropriately manage their energy performance. Energy teams use EnPIs to track progress on a regular basis, often monthly. Management uses EnPIs to monitor the entire energy management effort, to apply more resources in terms of funds or personnel time. Executives set organizational energy policies that commit to an EnPI (e.g. LEED) when building a new facility, and commit to another EnPI to drive operational effectiveness. Organizations set goals based on the EnPIs, and then they use the EnPI progress as a clear metric to engage the organization.

It is up to the organization to determine their EnPI, and like any metric, one size does not fit all, and not every metric is good for every situation (Goldstein and Almaguer 2013). An EnPI built around energy consumption alone would lead landlords to rent preferentially to tenants with low energy service demands and tenants to think that they should stop using energy in the workplace and instead outsource the required services. When considering the benefits of efficiency retrofits, or whether to buy or rent one building rather than another, energy managers need a measure of energy efficiency. A relatively static EnPI such as an Asset Rating may be useful to demonstrate that a building has an efficient design, but it would be relatively useless on a monthly basis to demonstrate progress and meet other organizational needs.

EnPI Classification

Asset Rating

For Asset Ratings, the rated building's simulated energy consumption is compared to that of a reference building with the same size and occupancy type, and with an established level of energy efficiency measures. This enables comparisons between buildings. Asset Ratings are typically shown on a scale of 0 to 100 and beyond, with zero meaning zero energy use. 100 can represent energy codes as of a given year in an index like the HERS Index. Other ratings scales use other benchmarks, such as the US "Commercial Buildings Energy Consumption Survey" (CBECS) using median energy use (EIA 2012). The simulation model basis is required to control for behavior, energy service level, weather and other factors. The Asset Rating is not intended to predict measured energy use for a particular building, but should be designed to be predictive on average. Well developed Asset Ratings are based on as-constructed and on-site tested inputs rather than just building plans. These can also relate to energy efficiency by controlling for variables that are irrelevant to efficiency, such as temperature preferences, information technology needs, etc.

Asset Ratings are simple and accurate efficiency indicators for both new and existing buildings, and can help support energy code compliance as well as serve as a basis for incorporating energy costs into building financing.

Asset Ratings do have barriers, the first being cost. Asset ratings require energy modeling, which can be expensive compared to meter reading data. Cost can be reduced by increasing the level of expertise through certification programs like ASHRAE's Building Energy Modeling Professional (BEMP) program and by developing software that automates much of the process, as is the case for the HERS Index. In California, most commercial buildings use the performance approach to code compliance, which requires modeling and practically all of residential buildings use the performance approach. Costs are low, primarily because software which automates the process has matured and become easy to use. Automating the process reduces errors in creating the baseline energy models and increases the confidence we have in the results. This does not mean, however, that the predicted energy performance will agree with the utility bills because the schedules of operation, levels of energy services and other factors assumed in the models will undoubtedly be different when the building is actually operated, especially for commercial buildings.

The second barrier is the ability of software applications to model advanced energy features like daylighting, natural ventilation and advanced HVAC systems that use radiant energy or thermal displacement to provide ventilation. Such features will become more common as we attempt to design our buildings to achieve low levels of energy performance. Modeling techniques exist for just about all advanced features, but some are more akin to workarounds. This barrier is being steadily addressed by software developers and industry representatives and slowly a consensus is emerging on how to model advanced features. This effort undoubtedly will increase as more building energy managers start to rely on Asset Ratings as part of a suite of EnPIs that includes indices such as those proposed below that make use of metered data. We anticipate a continual improvement process in both energy efficiency measures and the modeling algorithms needed to simulate their performance.

COMNET was created to improve standardize energy analysis for asset ratings, automate the process, and recommend modeling procedures for advanced energy design features. It is a non-residential energy analysis software specification. Users of COMNET accredited software should be able to conduct performance analyses in less than half the typical time required. In addition, COMNET's specifications are open to public review so that the procedures can be continuously improved. (COMNET 2014)

Technically, an Asset Rating is expressed as a ratio of the rated building's energy performance to a baseline building's energy performance. Energy performance of the rated building and the baseline building are determined through energy models using standard characteristics, such as schedules of operation, plug loads, and temperature settings. These standard characteristics are referred to as neutral independent (NI) operating assumptions. They are neutral because they are the same for both the baseline building and the rated building and independent because they are prescribed independently of any choice made for the rated building. Asset Ratings can be expressed in Equation 1 (Goldstein and Eley 2014).

Equation 1

$$Asset\,Rating = Asset\,EnPI = \frac{EP_{RB,NI}}{EP_{BB,NI}}$$

where

$EP_{RB,NI}$ The energy performance of the rated building determined from an energy model. The "NI" subscript means that neutral independent modeling assumptions are used.

$EP_{BB,NI}$ The energy performance of the baseline building determined through the same modeling procedure. The same neutral independent modeling assumptions are used as for the rated building

In usage, while Asset Ratings are the best way to illustrate how efficient the technology of a building is, the efficient technology does not assure low energy use. For example, a LEED platinum building may attract tenants who have higher energy needs. An important point is that Asset Ratings work better when combined with other ratings. For example, predicted low energy use coupled with measured average/high use indicates bad operating procedures, different user needs, or that the actual construction was less efficient than planned. In addition, energy managers should understand that some technologies such as more intuitive controls and design features that broaden thermal comfort ranges may not actually save energy, but would facilitate more efficient operation. Finally, simulation accuracy can be improved by conducting ongoing comparisons of predicted and metered use over time.

Operational Rating

With Operational Ratings, the rated building's metered energy consumption from a year or more is benchmarked to buildings of a similar type or function, with adjustments for factors such as weather. This enables comparison of year over year performance of a single building or comparisons between building portfolios. Their specific focus of their use in practice is on the quality of building operation, rather than the design focus of the Asset Rating, although they are equally effective and equally flawed for both purposes.

Operational Ratings usually are simple to use and derive. They do not require energy audits in order to be created. They can be effective to get executives aligned around importance of energy management. Operational Ratings provide an overview of all aspects of energy performance and include the effects of all three dimensions that affect performance. As such, they are unable to pinpoint which dimension is dominant in causing a high or low rating.

One Operational Rating barrier is that there can be too many underlying performance factors to be helpful to accurately measure progress toward any specific energy performance goal. While it can be useful to have an "overview metric", the lack of individual dimensions can make it difficult to achieve specific energy management objectives or to understand specific causes of energy performance. For example, low energy use in an Operational Rating may result from good operations and maintenance, low tenant demands, or low levels of energy service, such as low comfort level or outsourced energy services such as information technology server rooms.

ENERGY STAR's commercial buildings program Portfolio Manager has provided the most prominent example of an Operational Rating scale. This free, online, and non-technical resource utilizes a statistical scale that compares to other buildings. In this program, average energy bills are based on CBECS data, supplemented by other data as required. The baseline building's metered energy performance is adjusted based on statistical data to match climate and operating conditions of the rated building.

Technically, an Operational Rating is expressed as a ratio of rated building's energy bills (EB) over 12 months over the average or median energy bills (AEB) of the baseline building normalized for climate and certain operating conditions. Operational Ratings can be expressed in Equation 2.

Equation 2

$$Operational\ Rating = Operational\ EnPI = \frac{EP_{RB,EB}}{EP_{BB,AEB}}$$

where

$EP_{RB,EB}$ The energy performance of the rated building determined from the utility bills. Electricity, gas and other fuels measured at the meter would be converted to common units, such as source energy or cost.

$EP_{BB,AEB}$ The energy performance of the baseline building with the same conditioned floor space as the rated building, but adjusted for the operating conditions of the rated building. ENERGY STAR does this through a statistical analysis of CBECS data.

In usage, while Operational Ratings are excellent at providing an overview of energy management effectiveness, by themselves they offer little or no information on how to specifically improve energy performance.

O&M Index

A relatively new EnPI is the Operations and Maintenance (O&M) Index, which calculates how the building would be expected to perform if it operated in the way it did in the prior year. It combines elements of Asset Ratings and Operational Ratings to indicate the quality of energy management activities, typically showing results on a monthly basis.

O&M Indices can be more finely tuned than Operational Ratings during the modeling process. The simulation-based analysis also enables more precise model tuning than would be enabled in statistically based methods like ENERGY STAR.

The O&M Index is able to go a step farther than the Operational Rating, to produce results indicative of performance that the latter would not specifically identify. For example, a multi-floor, multi-tenant office building has a law office with long hours on one floor. This building would have different results if there is a separate cooling system for each floor than a single system for all of the floors. Another example is an office building that hosts large servers provides more energy service than an otherwise identical building that outsources their IT needs

Technically, the O&M Index is a ratio of energy consumption as measured at the meter to the simulated energy performance from the models used to determine the asset rating. It focuses on the impact of O&M on energy performance, just one of the three dimensions discussed above. In contrast to the simulation used for the asset rating, the O&M Index accounts for actual conditions of building operation. O&M Indices can be expressed in Equation 3:

Equation 3

$$O\,\&\,M\ Index = \frac{EP_{RB,EB}}{EP_{RB,ND}}$$

where

$EP_{RB,EB}$	The energy performance of the rated building determined from the utility bills. Electricity, gas and other fuels measured at the meter would be converted to common units.
$EP_{RB,ND}$	The energy performance of the rated building determined through modeling using the actual operating conditions of the rated building, e.g. neutral dependent or “ND”. See explanation below.

The building simulation in the denominator relies on “neutral dependent” building descriptors derived from the rated building’s actual (and potentially varying) conditions. That is, the simulation inputs are calibrated to how the building is being used.

In use, the O&M Index produces numbers at or around 1.0. If the O&M Index is 1.0, this is likely to be an indication of reasonably good energy management practices. A value greater than 1.0 suggests opportunities to inspect or analyze the building systems and operations to ensure operations are working as planned. A value less than 1.0 may indicate successful energy management activities, such as controls turning off unneeded energy uses as requested by individual workers. But it may also indicate inadequate energy service compared to what the modeler expected.

Well managed buildings will tend to have a ratio of 1.0 for all 12 months of a year. Variations in the O&M Index may indicate inaccurate underlying models or assumptions as well as specific operational or control problems. This indication may start to provide a feedback loop between energy modelers, model developers, and energy managers that will improve all three of these aspects of energy management systems.

A calibrated model is needed for the denominator of the O&M Index. Calibrated models can be expensive to develop and could require that an energy modeler be engaged during building operation. An approach to reduce costs is to develop a database of modeling results when the asset rating is developed to cover the expected range in energy services and operation. Alternatively, the scope of the energy modeler's services could be increased to include development of a calibrated model during building operation. This service is already provided by some analysts.

To better understand the O&M Index as well as to isolate potential issues, the user should calculate the O&M Index on a monthly basis. This will reveal trends and sensitivities that can point to refining the underlying model. For example, an O&M Index of 1.3 for all months of a year may indicate an unexpected load.

Because the conditions may change, the O&M Index would likely not be valuable beyond building owners, managers, and tenants. That is, program administrators or certification bodies may not find it valuable as tenants or their needs change. Rather, building managers would evaluate the energy management success that the operations team and tenants are able to achieve. The O&M Index can be used in a multi-year plan to improve practices year over year, while separating out improvements or changes that occur less frequently, such as retrofits or tenant build-outs.

In addition to poor maintenance practices, a poor O&M Index may indicate that modeled equipment and/or controls was/were not commissioned properly. This can serve as a quality check to the Asset Rating, and indicate a re-commissioning opportunity.

Energy Service Index

Rounding out the suite of EnPIs is the Energy Service Index, which calculates a ratio of an as-operated custom simulation to a simulation that uses the standard operating assumptions used for the building asset rating. This provides a measure of how much extra (or less) energy your building should have used last year than a building with average occupants and schedules and weather, assuming the same quality of O&M. The Energy Service Index isolates the impact of the level of energy service. This would be useful if building tenants change their energy service demands from year to year.

The Energy Services Index represents how close the standard Asset Rating conditions are to those of the rated building.

Technically, the Energy Services Index is a ratio of simulated energy performance of the rated building at its observed level of energy service to the energy performance of the rated building at the standard level of energy service assumed for the asset rating. Energy Services Indices can be expressed in Equation 4:

Equation 4

$$Energy\ Services\ Index = \frac{EP_{RB,ND}}{EP_{RB,NI}}$$

where

$EP_{RB,ND}$	The energy performance of the rated building, again determined through modeling, but the actual operating conditions of the rated building are used, e.g. neutral dependent or “ND”. Note that this simulation has already been performed to compute the O&M Index.
$EP_{RB,NI}$	The energy performance of the rated building determined from an energy model. The “NI” subscript means that neutral independent modeling assumptions are used.

In use, when the Energy Service Index is less than one, the energy services are less than for the rated building. When the Energy Service Index is greater than one, the energy services are greater. Energy Service Index variations should explain much of the variation seen between design and actual as illustrated in Figure 1. This information should also support future energy performance research.

Applying the EnPIs

By themselves, each of the four building EnPIs can provide useful information:

- Asset Rating alone tells you how good a building’s efficiency design and technology is
- Operational Rating alone tells you how your building compares to itself in previous years or to other buildings
- O&M Index alone can tell you how effective your day-to-day energy management operations are
- Energy Service Index alone can tell you how demanding the building’s tenants are

The four EnPIs can be combined to meet other needs. By combining the Asset Rating with the Operational Rating as well as the O&M Index, the Building Manager can tell how good a building is as well as what makes it good. By then adding the Energy Service Index, the building manager can then be directed towards most effective energy reduction methods such as improving operations and controls, fixing construction defects, and retrofitting to higher efficiencies.

Combining the Asset Rating, O&M Index and Energy Services Index provides better feedback to Building Managers on inherent building efficiency, O&M, and occupant demands. The Building Managers can better plan future improvements in both the building and its operations, and to control for changes in tenant demands.

Conclusion

If your goal is to responsibly manage energy in a commercial building, then each of the 4 EnPIs addresses unique questions that are important to answer:

- Asset Rating: “How efficient is my building?”
- Operational Rating: “How does my building’s energy intensity compare to that of its peers?”
- O&M Index: “How well am I operating my building?”
- Energy Services Index: “How demanding are my tenants?”

Going forward, there are a series of recommended actions to effectively utilize these EnPIs. For simplicity, these actions are specified by role:

- Building managers should utilize the appropriate EnPIs to gain familiarity with each. This will help these persons establish clear expectations on the effectiveness of each EnPI to support various energy management activities. Effectively deployed, the EnPIs will support tenant behavior, management decision making, operational decisions, and sound capital and procurement decisions.
- Program administrators should also investigate the EnPIs to drive standalone and integrated program designs. For example, the O&M Index alone may be useful to support behavior-based programs. For an integrated program design that demonstrates energy savings from capital equipment measures as well behavioral improvements, a combination of EnPIs may serve multiple needs.
- Program evaluators should also gain EnPI familiarity for many of the same reasons as for Program administrators. In addition, they may be able to add these metrics to their repertoire as methods to evaluate program effectiveness.

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