Developing a Suite of Energy Performance Indicators (EnPIs) to Optimize Outcomes

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ABSTRACT

Energy Management Systems standards such as ISO 50001 require the participating organization to develop an energy performance improvement plan utilizing quantitative Energy Performance Indicators (EnPIs). ISO 50001 and parallel government systems such as the U.S. Department of Energy's Superior Energy Performance program are not prescriptive but rather provide flexibility in allowing the organization to select its own EnPIs. The standard and its related guidance documents discuss a variety of different EnPIs, ranging from simple energy consumption and energy intensities to complex regression or engineering models. During the development of the ISO standard, there was considerable debate over the merits of simple versus more complex EnPIs.

Managing energy has been troublesome for many organizations because of the notion that energy performance is single faceted and must therefore be measured using a single, universally applied EnPI. Only rarely can energy performance be represented accurately by a single value or measure. Rather it is best to think about an organization's energy performance as represented by a set of measures that provide performance related information to the variety of levels of management and staff within the organization that control or influence it

This paper discusses why a suite of "fit for purpose" EnPIs that includes both ends of the complexity spectrum is often the best way to manage continual improvement in energy performance, especially for larger organizations. It makes the case that good energy performance depends on expressing performance in meaningful, simple-to-derive and easy-to-explain EnPIs.

For a multi-level organization, in which each level has specific responsibility and a defined sphere of control, a tiered set of EnPIs will need to be established to provide the organization with the appropriate information to effectively manage and improve energy performance. And at any given level, it may be important to separate the performance of equipment and systems from the operational effectiveness of the staff that run it or use it.

The paper provides some examples of EnPIs that can be appropriate for different levels of management in an organization and for different types of planned improvements.

Introduction

Energy Management Systems standards are a relatively new development in most of the world, with standards in North America and Europe having only been published in this millennium. Programs such as the U.S. Department of Energy's Superior Energy Performance have been pilot tested in recent years as a way of developing guidelines that have some field experience behind them, and of facilitating the public discussion that goes on in the context of developing consensus standards.

Performance improvement, in the context of ISO 50001 (ISO 50001, 2011) – the most recent International Standard on Energy Management Systems – relies heavily on having the appropriate measurement in place and on collecting relevant data concerning energy consumption and the variables that affect it. Energy performance must be managed in order to achieve continual improvement, but it can't be managed unless it is measured.

Energy performance measurement through use of one or more Energy Performance Indicators (EnPIs) is based on a quantitative relationship between energy consumption and one or more relevant variables, such as production volumes at an industrial plant or weather in a building context. The field experience over the years has shown that there has been a strong reliance on relatively simple EnPIs in the management of energy performance. Even large and complex industrial plants run by some of the world's most successful and experienced users of the methods of continual-improvement-based energy management systems often rely on quite simple formulations of EnPIs.

EnPIs, whether simple or complex expressions of performance, have occasionally offered misleading or confusing interpretations of progress. (Goldstein, McKane & Desai, 2011) In most cases, this has been due to misapplication or wrong design of the EnPI. In order to be used effectively, EnPIs must be designed and used for the intended and specific purpose.

To illustrate, in one case a facility's output was impacted by the global economic slowdown of the last 6 years, reducing output substantially. The EnPI of energy consumption per unit output indicated a significant drop in performance, (increased energy consumption per unit output); this, while significant improvements in the energy efficiency of the systems were implemented and achieved. The low-production mode of the plant[s] made overhead or base load consumption the dominant factor of the EnPI, hence the lower performance indication. Upper management declared a drop in energy performance and disappointing results while staff, at the system level, were expecting a celebration for energy efficiency improvements achieved.

Neither group understood the EnPI and what it was really measuring. This then brought up the question of whether the organization desired to measure the energy efficiency of its systems or the energy performance of the facility or both. In the last case a single EnPI would not be sufficient to adequately describe the organization's energy performance.

Perhaps based on such experiences, the discussion during the development of ISO 50001 focused on the EnPI application level, equipment, system, facility, enterprise, etc., and on the complexity that is needed in an EnPI. Proponents of simpler EnPIs argued that to introduce the standard successfully, especially to small and medium enterprises, required that the EnPIs suggested be easy to develop and monitor. They also argued that if simple ratios were adequate for large, well-managed global companies there was no reason to encourage more complexity. They were concerned that even a non-mandatory recommendation for complex EnPIs could harm the market acceptance of the standard and retard the growth in use of Energy Management Systems standards.

Proponents of more detailed EnPIs argued that simple options did not capture needed explanatory factors and could lead to misleading interpretations of the trend in the EnPIs. They advocated the use of multi-variant regressions and engineering-based process models instead of energy intensities or other simple ratios.

ISO 50001 does not require or even recommend any particular degree of complexity or accuracy in the selection of EnPIs. Guidance documents currently in the process of development instead describe various levels of complexity and the advantages and disadvantages of each. These draft guidance standards may, when finalized, also address the major recommendation of this paper: that a suite of EnPIs that is tailored to the different needs of different users may be more effective than exclusive use of one EnPI.

This paper examines how the way the ISO 50001 standard is intended to be used leads to the conclusion that different levels of authority and responsibility in an organization will need different EnPIs and that the choice of EnPI should be fit for purpose based on what they are intended to measure and at what system/facility level and on the needs of those that will be implementing them and responsible for continual performance improvement.

Requirement of the ISO Standard

The overall structure of ISO 50001 requires the qualifying organization to:

- adopt an energy policy at the executive management level;
- create a cross-divisional management team led by a representative who reports directly to top management;
- undertake an energy planning process that includes an energy review;
- create baseline(s) of the organization's energy use;
- track energy performance indicators against the baseline to measure progress;
- develop energy objectives and targets for energy performance improvement at relevant functions, levels, processes or facilities;
- develop action plans to meet those targets and objectives;
- establish operating controls and procedures for significant energy uses;
- measure, manage, and document energy performance for continuous improvement for energy efficiency;
- providing the resources needed to establish, implement, maintain and improve the energy management system (EnMS) and the resulting energy performance; noting that resources include human resources, specialized skills, technology and financial resources; and
- report progress periodically to top management.

This structure assumes a management process that is structured at different levels of authority and expertise. The distinction between these levels becomes increasingly important with the size of the organization.

For a small organization, senior management may also perform day-to-day operational tasks. The energy management team may consist of only one or two people. In such a case, the argument for simplicity versus accuracy revolves around the expertise and time availability of the energy manager(s). More complexity would tend to be better provided that the energy manager can afford the time to establish and monitor the EnPI; but the ultimate level of complexity would likely be low due to the resource limitations found in a small organization.

For a large organization, the first step outlined is the creation of an energy plan, towards which staff must demonstrate continual improvement. This is to be reported back to senior management at regular intervals, as noted in the final bullet. Reporting is important because of the second-to-last bullet: senior management is directed to provide the funding and staffing needed to implement the energy policy. How is an energy plan based on measuring and monitoring, through use of EnPIs, the energy performance likely to develop in a larger organization?

Appropriate Types of EnPIs

An appropriate choice of EnPI is one that, at the minimum cost and effort necessary, provides direction and feedback on how much progress is being made and if the energy plan is on track to meeting its goals.

Perhaps the simplest EnPI is metered energy consumption. This EnPI might work very well for some facilities, such as municipal waste treatment systems, whose inputs do not change seasonally and whose processes are not very temperature-dependent. It could be the most appropriate EnPI, as it will show improvement if the treatment system's organization can induce its customers to reduce water waste.

More typically, energy consumption in buildings is responsive to such factors as use, occupancy, and weather. For industrial operations, production levels are key factors. Thus energy per occupant might be meaningful to building managers while consumption per unit of production could be a useful EnPI for industrials.

EnPIs could provide misleading or confusing information, if not used appropriately. In a number of circumstances, when an EnPI is developed to measure the performance at one level of the organization or of a particular system or activity and then applied to measure performance at a higher or lower level(s), the wrong conclusion is reached.

In the case noted earlier, where production volume drops (or increases) drastically and unexpectedly, an EnPI designed to measure energy consumption as a ratio to product output would appropriately indicate that in whole, the organization's energy consumption has increased relative to its output. It would not however be useful in measuring the system's efficiency improvements achieved by the organization, unless that EnPI was modified to take into account the differences in operating rates. Another illustration would be a plant producing three similar but not identical products, and the energy needed for each product is very different. If the relative volumes of production change, a single or uncompensated EnPI could be misleading. A third example is a plant where the quality of the input materials affects the energy consumption: for example where a wet input material requires more energy than it would if it were dry and the facility has no control over the moisture content. To get a more complete picture of the energy performance in this case, several specific EnPIs would need to be used: one could measure the overall energy consumption; another could measure the energy per unit output, without regard to the condition of the input material; and a third could measure the energy consumed per unit output and taking into account the condition of the input material. Together the set of EnPIs would more adequately describe the energy performance at different levels and for different purposes and use. Performance targets could be specific and activities more focused and relevant to the individuals charged with managing performance at particular levels of the operation.

Simple EnPIs—other than absolute unadjusted metered energy consumption—are almost always derived from statistical analysis. This process, though, leads to a generic flaw. In the banking and economics field, the problem is referred to as "Goodhart's Law" which states:

"Any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes." (Chrystal and Mizen, 2001)

The problem to which it refers—using a metric that has had statistical explanatory value in the past as a Key Performance Indicator—brings the statistical relationship under which the regressions were derived into question. Thus, if the statistical relationship between output and energy use becomes better when the product mix is more of product A and less of product B, the use of a metric of energy use per ton of product may bias the production decision at that plant to product A. This could be solved by using two EnPIs, one for each product, but at the risk that some secondary factor could cause the similar problem later.

But, note that the use of Goodhart's Law is also less sound when the metric has already been used as a control variable for long enough to derive the statistical relationships. So, a simple EnPI with a long track record of encouraging the appropriate behavior may work better than one that is being tried for the first time.

More complex and detailed EnPIs could address these issues. To the extent that these EnPIs are based on direct measurements or process models rather than statistics, the Goodhart's Law critique would not apply. But at the senior management level, where the decisions are made regarding the resources available for energy management, the CEO may not care. Energy is a cost to the operation, and if costs are over budget, the CEO may consider this a problem that needs to be addressed by his staff even if there are good reasons why the costs would be high. (Conversely, if the energy use and costs are under budget due to reasons other than the success of the energy plan, the CEO may be less concerned that year about whether the plan is on track.)

Our conclusion is that in many cases, even for multi-billion-dollar operations, very simple EnPIs such as energy use per ton of product may be sufficient at the CEO level.

But, because these simple measures may mislead their users as to how well the energy plan is working, lower-level managers with the responsibility for O&M expenses or for capital upgrades may benefit from some more detailed EnPIs. In the former case, an EnPI that looked separately at different product lines and that normalized for production rate and product mix would provide much better feedback on whether the management plan for O&M is working that more aggregated and unprocessed EnPIs would.

For the case of evaluating capital upgrades, an EnPI based on the modeled performance of the chemical or physical process might be needed. This would allow a comparison of actual energy consumption at the meter with predicted energy consumption given the physical plant and what the engineer knows about how it is operated and maintained. If a simulation model can be calibrated to metered energy consumption, then it can be varied to account for the value of changes in the plant in terms of energy savings, both for prospective and retrospective changes.

While developing such a model and calibrating it may be an aspirational goal for many industrial plants at present, this is already being done for buildings.

Developing a process model is a potentially useful energy management tool because it allows the energy manager to separate energy performance improvements that are a consequence of better O&M behavior from those that are a result of capital upgrades. One can imagine separate goals in the Energy Plan for capital-based EnPIs than for operationally or (behavior)-based EnPIs. The former might be expected to remain relatively constant for five or ten years and then be improved when the production line is being modernized; while the latter should expect slow but continuous improvement over the years.

The discussion above referred to the performance of an entire facility. At a lower level of management, it may be valuable to develop EnPIs that correspond to one particular process line or even a large individual piece of equipment. For example, it may be useful to develop EnPIs related to the capital structure and operational characteristics of a single distillation column, or a boiler system, or a compressed air production and delivery system.

In the last examples, the use of different EnPIs at different levels of an organization could allow two different types of optimizations to be planned and implemented. For a boiler system, the lower-level EnPI could track the in-use thermal efficiency of the boiler and encourage proper maintenance of heat exchangers and monitoring of inlet and outlet water temperatures, while the higher-level EnPI could change the characteristics at the load end of the pipe to allow, for example, the level or return water temperature that optimizes whole-system performance. For the compressed air system, the lower-level EnPI could encourage the operator to find and seal air leaks and to schedule the compressor, such that it shuts off during work-shift breaks, while the higher-level EnPI could allow the energy manager to determine whether a given end use is best supplied with compressed air or whether a small electric motor at the work site would be more efficient.

The point is that in a larger organization, each staff member on the energy management team will have some aspect of energy under their authority. The extent of their personal involvement in the technical or behavioral aspects of energy management will suggest an appropriate level of detail and complexity for the EnPIs they need to do their job optimally. These may or may not be the same EnPIs throughout the organization. Indeed, it is not even clear that the energy manager or the senior management even needs to know all the EnPIs in use in the organization.

An Example from the Building Sector

A real estate firm may develop a relatively simple suite of EnPIs following this model, and using methodologies that are already well developed. At the most simple end of the spectrum, the organization might choose energy use per unit floor area, adjusted for weather and occupancy, as the EnPI. This is the basis of the Energy Star program for commercial buildings, a program that has seen widespread and increasing use in this sector. Energy use per unit floor area for a given building type is a simple-to-understand and easy-to-measure EnPI that offers useful management feedback in many cases.

A CEO setting organization-wide energy goals would likely not go wrong using this EnPI, especially for a portfolio of properties. But at the operational level, this EnPI would not offer enough guidance to the maintenance staff or to the energy manager contemplating possible retrofits.

The problem is that energy use in buildings is a three dimensional problem. The dimensions are:

- The efficiency of the building's design and equipment/insulation
- The level of energy service provided
- The quality of operation and maintenance (O&M)

Three parameters are needed to characterize a three-dimensional problem. A useful, and well-used, EnPI for energy efficiency is the asset rating of the building: the predicted energy use when operated according to standardized assumption in standardized conditions. For residential buildings in the United States, such ratings have already been performed for over a million homes.

Energy services should be measured with a separate EnPI because if the building adds or eliminates a major energy service, this change will affect the overall energy use in a way that is unrelated to the plan for continual improvement in energy performance. For example, if a remodeled school adds welding shops and an indoor heated swimming pool, these changes will affect energy performance strongly. And energy service level EnPI will allow normalization for such changes.

O&M requires a separate EnPI because many of the changes needed to create continual improvement in energy performance involve evolution of O&M practices. These plans need to be evaluated independently of changes in efficiency through retrofits or changes in energy service level.

These last three EnPIs may be of little interest to the CEO of the organization. But they are fundamental to the operational-level achievement of advanced energy goals.

Conclusions

Given that a principle objective of ISO 50001 is to establish a structured, data-driven approach to managing energy and energy performance improvement based on measured data, our conclusion is: to achieve this, a set of EnPIs rather than just one EnPI will be necessary. The choice of EnPIs should be fit for purpose, be appropriate to what they are intended to measure, be applied at the intended level, (system/facility/etc.), and be based on the needs of those who will be implementing them and that are responsible for continual performance improvement.

References

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