LEAN OPERATIONS: AN ENERGY MANAGEMENT PERSPECTIVE

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ABSTRACT

The plan-do-check-act (PDCA) cycle underpins many lean principles and offers a paradigm for continuous improvement of design, construction, and operations processes. For the operations phase, the PDCA cycle has traditionally been used to improve operations and maintenance (O&M) processes. As part of these O&M process improvements, facility managers are beginning to implement PDCA as a framework for managing building energy consumption. This exploratory paper discusses the application of PDCA and other lean principles--including transparency, alignment around a common goal, and cross-functional teaming--to energy management. It begins with a discussion of how energy management fits in to the Lean Project Delivery System. It then presents the international standard for energy management, ISO 50001, which is underpinned by PDCA. The authors illustrate the effectiveness of the PDCA cycle for energy management through examples from the literature and their own experience, citing how the PDCA could be implemented in various building types in different markets to achieve energy savings goals. The aim of this paper is to begin a discussion within the IGLC community about how energy management fits into lean operations; the authors explore data required to effectively implement PDCA for energy management and discuss work structuring issues related to energy management. Finally, the paper presents best practices for integrating energy management and PDCA into existing O&M processes.

KEY WORDS

Sustainability, Energy Management, Lean Operations

INTRODUCTION

Shewhart (1939) and Deming (1986; 2000) discuss the plan-do-check-act (PDCA) cycle that supports continuous process improvement. In the buildings industry, this cycle can be implemented in support of lean design, construction, and operations processes. Implementation of PDCA for improving the building design and construction process is well-documented (e.g., (Hassan 2006; Parrish et al. 2009; Sobek II and Smalley 2008; Zhichun and Yuejun 2011). O&M staff in the buildings industry have traditionally implemented the PDCA cycle to improve their processes, not necessarily to improve energy performance (Ishikawa et al. 2012; Smith and Hawkins 2004). However, as energy prices and awareness rise, owners and facility managers are beginning to implement PDCA as a framework for managing building

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energy consumption. This paper presents one PDCA implementation for energy management, the ISO 50001:2011 Standard (ISO 2011). This standard is the most mature model for implementing PDCA for energy management, and thus, the authors present it as a model for future PDCA implementations for energy management. This paper explores the need for lean processes for energy management and highlights how PDCA supports other lean principles, including transparency, alignment around a common goal, and standardized operating procedures. The paper links the PDCA process for energy management to the lean project delivery system, LPDS (Ballard 2008) and illustrates the effectiveness of the PDCA cycle for energy management through successful examples from the literature.

As the ISO 50001 standard is relatively new, and thus not yet widely implemented, this paper draws examples from literature and presents a small sample size of projects ($n < 30$). This paper does not, therefore, present a lot of data or case studies, rather, it presents anecdotal examples to illustrate a proof-of-concept for applying lean principles to energy management. This paper essentially presents the authors' hypothesis that energy management should be a vital part of the LPDS, particularly within the "use" phase.

ENERGY MANAGEMENT IN THE LPDS CONTEXT

Energy management is an increasingly important function within the facilities operations and maintenance for an organization. An energy management system is an integral component of facilities management best practices. The LPDS (Ballard 2008), illustrates the links between project delivery phases, beginning with project definition and culminating in use. This paper focuses largely on the "use" phase, and discusses lean operations of a building. Many IGLC researchers focus on lean design and lean construction (understandably, given the focus of the group). However, relatively little literature explores lean operations within the built environment. The authors see parallels between lean design and construction and lean operations. Namely, the need to focus of the user, build a lean culture, and formalize the relationship with the owners' facilities operations performance and the feedback loop to the capital project definition phase of LPDS. The Lean Construction Institute 2012 Congress highlighted the Industry need to understand the performance of (Owner-based) "program management" of capital projects. This research draws attention to this relationship and discusses how it may relate to the development and implementation of an effective energy management system.

THE INTERNATIONAL ENERGY MANAGEMENT STANDARD, ISO 50001:2011

Figure 1 illustrates how requirements of the ISO 50001:2011 standard map to the plan-do-check-act cycle. ISO 50001 implements the PDCA cycle to build an energy management system, or EnMS. A complete discussion of all elements of the ISO 50001 standard is outside the scope of this paper. However, Parrish et al. (In review) discuss the standard in more detail than this paper presents below.

PLAN

Preplanning and planning are key to any project (Brown 2002; Gibson Jr. et al. 1995). In the context of ISO 50001, "plan" refers to a plan for implementing an EnMS, and involves data gathering, setting targets and objectives, and securing management commitment for the EnMS implementation. Generally, an Energy Team, in concert with a management representative, executes the plan phase of the EnMS. Ensuring a cross-functional energy team increases the effectiveness of the plan phase, as this promotes participates from various departments within an organization.

Cross-functional teams promote energy efficiency throughout an organization. One organization that implemented ISO 50001, the Massachusetts Institute of Technology (MIT), engaged the Energy Team, the Environmental Health and Safety (EH&S) group, and the procurement department to leverage existing resources in developing their campus-wide EnMS (Parrish et al. 2012). While this minimized the effort required by the Energy Team, it also instilled energy awareness in other departments at the university and raised energy consciousness across campus.

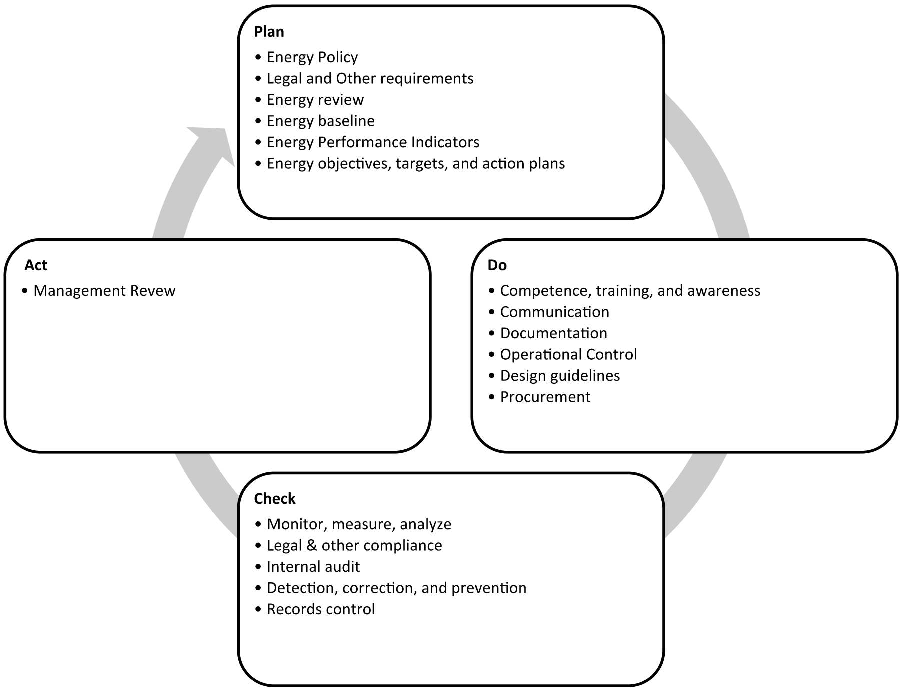

Figure 1. Energy Management System Requirements mapped to the Plan-Do-Check-Act Cycle

DO

The "Do" portion of ISO 50001 requires training, implementing, and measuring the effectiveness of energy efficiency measures (EEMs) in those areas determined to be significant during the energy review (an inventory of the type and amount of energy consumed across an organization). This energy review is intended to reveal opportunities for energy performance improvement. The Energy Team may identify opportunities with varied costs. The PDCA cycle supports capital investment decisions in energy upgrades at various scales and depths. Figure 2 presents a taxonomy of energy retrofits from routine O&M, to systems replacement upgrades, bundling of EEMs, and finally an advanced or deep energy retrofit comprising of integrated design solutions. This taxonomy illustrates the complexities involved with energy decision-making within the LPDS, as this full taxonomy essentially populates the "Operations & Maintenance" of the LPDS.

The training phase, in particular, can be challenging, as the scope may be broad. The organization is responsible for training those "working for or on its behalf, related to significant energy uses" and must ensure they "are competent on the basis of appropriate education, training, skills or experience" (ISO 2011). This requires employees be aware of how their work impacts energy consumption and use. Energy consumption refers to the amount of energy consumed and energy use refers to how the energy is consumed.

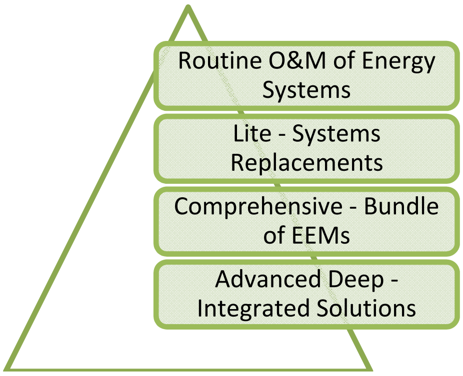

Figure 2. Hierarchy of Energy Retrofits, in order of increasing capital investment (EEB-Hub[3])

Beyond the training, the "Do" phase also requires organizations to address energy performance in other aspects of their business, including design, procurement, and communications. At MIT, implementing the EnMS drove development of design guidelines organization-wide (Parrish et al. 2012). For procurement, efforts may focus on ensuring existing procurement policies include energy performance as a metric for selecting materials, labour, and equipment. The communications aspect of this phase may be the easiest, as most organizations who intend to manage energy, through ISO 50001 or another means, already communicate about energy within and outside their organization. Finally, this phase requires operational control – implementing control of building system operations, representing a savings opportunity of about 20% (Roth et al. 2006).

CHECK

The "Check" phase of EnMS implementation requires the organization review the effectiveness of the measures enacted during the "Do" phase of implementation. In addition, this phase requires detection, correction, and prevention. Organizations may be inclined to create an EnMS where faults do not exist, thus they have little or no

[3] The Energy Efficient Buildings Hub has a working operational model for characterizing and classifying the Advanced Energy Retrofit Marketplace. Url: www.eebhub.org.

material for the detection, correction, and prevention step of this phase. However, part of what makes the EnMS, or any other PDCA cycle, successful is the ability to detect faults in the system and correct them. Thus, organizations should strive to ensure their EnMS is implemented such that faults not only exist, but are detected and corrected and preventative measures developed to address these proactively.

ACT

The “Act” portion of ISO 50001 appears easiest at first glance. Only one task is required; namely, the Management Review. Despite the seemingly small requirement, this task is often the most challenging of the set. One challenge is that planning, doing, and checking tend to begin in a pilot project. However, the “acting” is rarely a pilot-based scope. Rather, acting should be done across the organization. When an organization’s management engages in their Management Review, they determine whether the pilot was successful, and make adjustments to the EnMS to ensure continued success with a broader scope. This management review offers an organization’s management the opportunity to promote broad EnMS implementation with a “top-down” approach that is critical for securing their continued support, financially and culturally, of the EnMS.

DATA REQUIRED FOR SUCCESSFUL ENMS IMPLEMENTATION

Many managers argue that which cannot be measured cannot be managed. Indeed, implementing lean processes requires an understanding of how the existing system works, in turn allowing managers to understand where improvements can be made (i.e., going to the genba). For energy management, this may take the form of visiting major pieces of building equipment, like the chillers and boilers, and recording their energy consumption at various points in the building’s cooling and heating cycles. While this may be instructional, it likely will not provide the observer the data required to identify opportunities for improvement. In fact, most data required to identify these opportunities will not be available through observation alone. Rather, data must be collected about internal functioning of the equipment and building systems. For example, if a manager seeks to improve mechanical system efficiency, (s)he would likely require information about the temperature of water flowing in and out of the chiller. Comparing these values to the power draw of the chiller may reveal the chiller is not operating efficiently.

While this data is undeniably helpful, it may not be readily available. Depending on the building vintage, energy data may be highly aggregated or very granular. On the one hand, older buildings may not even have their own energy meter. On the other hand, newer buildings may have energy meters for each building system or even each circuit. Regardless of the granularity of data, PDCA can be implemented. However, data available controls the opportunities revealed will be controlled by the data available, and may limit the options available to achieve savings. An energy team will struggle to determine which building systems account for the greatest percentage of energy consumption in a building with a single meter. Energy teams with this type of data will likely need to make assumptions about the energy-end-use breakdown (that is, how much energy is consumed by each building system, or end use) through benchmarking to peers (discussed later) or another means. These assumptions will dictate the opportunities revealed and actions taken. Conversely, an energy team working on a building that includes energy meters for each system will be able to identify more specific opportunities and more reliably predict the reduction in overall energy consumption based on acting on a given opportunity.

Depending on the size of an organization's building portfolio, the data available may vary across buildings. In this case, the organization may choose to first work on buildings with rich data sets to better learn how energy consumption is divided amongst end uses in buildings of that type. Moreover, organizations may identify installation of additional energy meters as an opportunity for improvement in energy performance. Alternatively, organizations may assess the energy consumption of various buildings at the whole-building level and identify the largest energy consumer as the opportunity for improvement. Figure 3 illustrates a screenshot of Arizona State University's Tempe campus energy dashboard. This plot compares the electricity consumption of 8 campus buildings. If a data set like this is available, the energy team may use it to help identify and prioritize improvement opportunities.

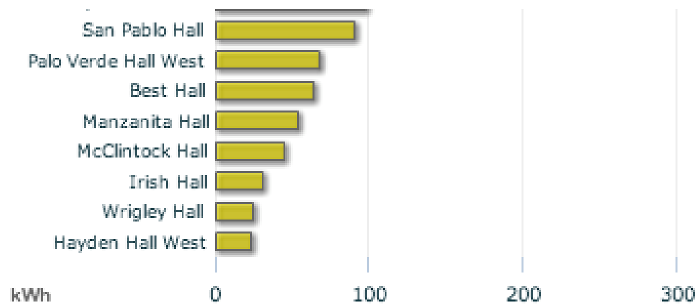

Figure 3: Comparison of Instantaneous Electricity Consumption on the Arizona State University Tempe Campus (cm.asu.edu)

BENCHMARKING ENERGY CONSUMPTION AND USE

Given the need for data in successfully managing energy consumption, energy managers often turn to benchmarking as a basis for comparison. Benchmarking efforts range from the city-level down to the single-building level. For example, in an effort to improve energy and environmental performance, and to stimulate local market demand for energy efficiency, large US cities such as New York[4], Boston, Philadelphia and Washington DC have passed legal ordinances requiring buildings greater than ~5,000 m^2 (50,000 ft^2) to publicly disclose energy and water usage. Thus, energy teams in these cities can use city-specific benchmarks to identify how their buildings compare to similar buildings in the same geographic area. Beyond ordinances, energy teams can access regionally- and nationally-averaged energy performance for most major building types through the Commercial Building Energy Consumption Survey, CBECS (U.S. EIA 2003). Facilities owners and operators can use CBECS to benchmark their energy consumption with buildings and spaces of similar characteristics. Energy managers can compare the energy consumed by their particular building with the national trends tracked by CBECS. Portfolio Manager (EPA 2011) also offers the ability to track energy and water consumption for the

[4] URL: http://www.nyc.gov/html/gbee/html/plan/ll84_scores.shtml

campus and building level. Tracking metered energy data provides transparent information for energy managers to enact the PDCA principles, i.e., identify energy upgrade opportunities, and monitor post retrofit performance.

ENERGY MANAGEMENT APPLICATIONS OF LEAN PRINCIPLES

PDCA supports other lean principles, including alignment around a common goal, transparency, and standardized operating procedures. In the case of energy management, these lean principles support process efficiency as well as energy efficiency and culture change. Liker (2004) cites alignment around a common goal as an effective means for promoting culture change. An energy savings target provides a goal the organization can align around and may motivate implementation of the remainder of the EnMS. Further, EnMS implementation makes energy consumption and use transparent so all members of an organization can see the organization's energy performance. Perhaps more importantly, transparency allows members of the organization to understand the impact of their daily activities on energy consumption, thus empowering them to be accountable for the energy impact of their behaviour.

Similar to successfully implementing lean, successfully implementing an EnMS requires cultural change in an organization. Chesworth et al. (2010) explain successful implementation strategies as well as barriers to lean thinking within an organization. The successful strategies include fostering cross-functional teams, situational leadership opportunities, and employee commitment and involvement. These same strategies support successful EnMS development and implementation in the anecdotal evidence presented in this paper. The authors hypothesize the most successful EnMS will be in an organization with a culture of energy efficiency.

Notably, lean tools, such as a value stream map (Rother and Shook 2003) and the Last Planner (Ballard 2000) also aid in EnMS implementation. While many value stream maps focus on identifying wasted time, the technique can also be used to identify energy waste. For example, at Connacht Gold (an animal feed production facility in Ireland), physical areas of the facility with significant energy use were identified through a value stream map. EnMS development then focused on developing performance metrics for the operations and management of these areas (Murphy et al. 2012). Similarly, though the Last Planner was developed to help schedule construction activities, the method is also effective for planning energy efficiency improvements. During EnMS development, the energy team will likely identify more opportunities for improvement than the organization has resources to implement. Rather than discarding those opportunities that are not initially implemented, organizations can document these opportunities and store them in a workable backlog, revisiting them in successive PDCA cycles.

WORK STRUCTURING FOR ENERGY MANAGEMENT

Many in the buildings industry may classify energy management as a responsibility for the O&M staff within a building. While the O&M staff undoubtedly has a large role to play in energy management, others within an organization must also take on responsibility for energy management. Ideally, individuals within an organization appreciate their contribution to and responsibility for energy management. However, this may not always be the case, and will likely not be the case in initial EnMS implementation. Rather, energy management will fall to a few key teams and individuals within an organization. Specifically, individuals with authority over any given element of the EnMS will need to take on leadership roles in the EnMS development and implementation processes. Typically, this includes the director of facilities, the director of procurement, directors of design and operations, and at least one representative of the organization's management team.

Individuals involved in EnMS development and implementation may need to take on roles that seem "atypical." For instance, a procurement director may not be familiar with his/her role in promoting energy management throughout the organization, let alone accustomed to considering energy when making procurement decisions. Likewise, a facilities manager may be very comfortable with building system operations in support of energy efficiency, but may be unfamiliar with developing and implementing policy within her organization. In keeping with lean practice, cross-functional teams help all members to learn about something outside of their core competency. Moreover, in working together, the team is in a better position to consider energy management across the entire organization, rather than within their home department, thus they are more likely to "optimize the whole" (Lichtig 2005).

BEST PRACTICES FOR ENMS IMPLEMENTATION

Examples suggest two indicators predict the success of EnMS development and implementation: (1) management commitment to the EnMS and (2) energy as a critical operational expense. Multiple case studies support the need for management commitment and highlight the success of their EnMS, not only in achieving energy savings, but also in promoting culture change, when management views energy performance as critical to the corporate agenda. This can take on various forms, from management "walking the talk" and implementing energy-efficient behaviour to management using the EnMS for capital projects planning. Literature also suggests that organizations who see a clear link between energy expenses and their bottom line seem to be more successful at the "act" phase and the subsequent PDCA cycle. The authors advocate a "changing hearts and minds" approach in EnMS implementation, first illustrating success on a pilot project or implementation and then expanding the EnMS when data supports its effectiveness. Sharing the success of the EnMS can go a long way toward changing minds and reinforcing the role of each member of an organization in delivering energy savings.

INTEGRATING ENERGY MANAGEMENT INTO O&M PROCESSES

As mentioned previously, building O&M departments may implement PDCA to continuously improve their processes. For example, an O&M department may implement PDCA to determine the optimal time to change filters in various HVAC equipment. Integrating energy considerations into these existing processes is generally straightforward. After an organization identifies where energy considerations need to be included in existing processes, the O&M departments can determine the best way to integrate energy into the existing processes. For example, an organization may update their existing filter replacement process to include an energy consideration. Though this change may not impact the actual work (i.e., the filter replacement schedule may remain the same), in considering energy, the PDCA cycle "checks" another variable.

CONCLUSIONS

This exploratory paper focused on the "use" triad of the LPDS and examined how energy management could be integrated into existing O&M processes in support of lean operations. The paper presented ISO 50001 as a mature model for energy management through PDCA. The paper illustrated parallels between lean construction and energy management that suggest PDCA for energy management supports lean building operations and highlighted the role of lean principles and tools in delivering energy performance. Specifically, the paper discussed the role of transparency, work structuring, cross-functional teams, and the Last Planner in energy management. Though construction and operations are very different phases of a building's lifecycle that involve different players, the authors found many parallels between these phases, suggesting lean principles can help deliver energy savings. Further, the authors found that implementation of a successful energy management system required culture change within an organization, as does lean construction. Finally, the authors presented data streams required to support effective decision-making about energy efficiency, both for a single project and for capital projects planning. Future work could focus on how the EnMS fits within the LPDS and look at how lean principles support energy savings, through ISO 50001 implementation or another means, supporting the authors' hypothesis the EnMS provide a framework for improved energy performance in facilities.

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