Energy management systems in a vertically integrated power utility

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ABSTRACT

The ISO 50001 standard institutes the guidelines for energy management systems (EnMSs), and conformance to this standard has gained interest in commercial and industrial sectors worldwide. For a vertically integrated power utility in South Asia that employs more than 9,000 direct staff, operates 5 power plants and 60 grid stations to generate, transmit and distribute power to over 2 million consumers, the activities of internally planning, implementing and monitoring an EnMS according to the ISO 50001 guidelines is a momentous task. Ensuring the practice of "plan-do-check-act" (PDCA) for EnMSs across an organization of this size and nature for a continual energy performance monitoring process involves multiple technical, financial and human resource challenges. This paper develops a business case for energy efficiency for power utilities. The paper identifies, for utilities, the best practices in creating a companywide energy policy, developing an energy planning process, empowering management representatives to carry out activities for departmental, cross functional EnMSs, undertaking the strongest competency development and communications practices, and working on the feedback from auditors, management and employees. Based on this paper, power utilities can derive essential lessons as to the resources and activities vital for establishing effective EnMSs in buildings and power plants, the benefits of attaining ISO 50001 certification, and the success factors for EnMS implementation.

Introduction to ISO 50001

Improving energy performance and reducing energy costs is one of the most important tasks that organizations throughout the world have to achieve to be energy efficient. The ISO 50001 standard on energy management systems can help organizations with this exercise and since its publication six years ago it has gained much importance. ISO 50001, as a standard on Energy Management Systems (EnMS) developed by the International Organization for Standardization, gives a company the requirements for EnMS on their way to become a sustainable, energy conscious business tackling climate change. In the energy and sustainability industry, becoming an ISO 50001 certified organization can enable K-Electric (KE), a power utility, to stand with some of the top energy businesses in the world by maximizing use of energy sources, reducing both energy cost and consumption. ISO 50001 is based on the management system model of continual improvement, which is also used for other well-known standards such as ISO 9001 or ISO 14001. The belief is that complying with the ISO 50001 standard will make it easier for KE as an organization to integrate energy management into their overall efforts to improve quality and environmental management.

ISO 50001 Rollout at K-Electric

K-Electric Limited caters to an area of 6,500 square kilometers of Karachi, and supplies electricity to all the industrial, commercial, agricultural and residential areas of the city that come under its network, which equates to over 20 million people. Operating in southern Pakistan

provinces of Sindh and Balochistan, the organization has 2.5 million customer accounts in Karachi and beyond. As the only vertically-integrated power utility in Pakistan, which means managing all three key stages of generation, transmission and distribution, KE produces and delivers energy to its consumers. KE is also one of the city's largest employers, with nearly 9,000 direct employees and many more as contract staff.

Motivation toward energy management

As part of KE's mission toward energy conservation and energy efficiency, embarking on the implementation of energy management systems as per ISO 50001 seemed the natural course of action. ISO 50001 provides a comprehensive framework to implement energy management standards in order to achieve optimal energy performance under a continuous improvement plan. The motivation that geared the organization toward energy management stemmed from the following reasons:

1. Valid business case for energy management: In recent years, the environment has become an increasingly significant concern to the sustainability of global business community, and poses serious challenges to individual organizations affecting their development in the long run. Managing energy resources to sustain business is the main reason for the energy issue drawing serious attention.
2. Companywide commitment to curbing climate change: Climate change has caused extreme weather patterns and rising sea levels. The concentration of greenhouse gases (GHG) such as carbon dioxide, methane and nitrous oxide keeps increasing, which leads to the greenhouse effect and global warming.
3. Sustaining business: Energy costs have gone through a considerable increase over the past few years. Since modern business operations rely heavily on energy, primarily electricity and fuel to carry on, the direct impact of energy price fluctuation to overhead of organizations is significant.
4. Corporate responsibility: The increasing public awareness on being an energy efficient organization is another driving force for KE to reconsider their energy policy. People are paying more attention on the energy performance of organizations. As part of corporate responsibility and investor confidence, besides making profits, KE aims to practice due diligence to sustainable development of the environment and community, including addressing the public concerns on reducing energy wastage.

The organization aims to adopt an energy efficient routine throughout its systems to reduce net energy expenses and improve system efficiencies. As an energy and environmentally responsible organization, the intent is to work toward reducing carbon footprint. Adhering to ISO 50001 guidelines is expected to reduce electricity costs, enhance productivity, and save natural resources for future generations.

Fashioning the ISO 50001 guidelines to local settings

The purpose of ISO 50001 is to enable organizations to establish the systems and processes necessary to improve energy performance including energy efficiency, its use and consumption (ISO 2011). Implementation of this standard is intended to lead to reductions in greenhouse gas emissions, energy costs, and other related environmental impacts through

systematic management of energy usage. Based on ISO 50001 guidelines, the EnMS catered to the PDCA cycle with the following activities in each phase:

1. Plan: conducting an energy review of generating plants, transmission lines and grid stations, distribution substations including all working areas, like warehouses, workshops and office areas, by establishing an energy baseline using energy performance indicators (EnPIs), objectives and targets. Based on this, action plans are to be developed necessary to deliver results in accordance with opportunities to improve energy performance and the organization's energy efficiency policy.
2. Do: implement the energy management action plans throughout the organization.
3. Check: monitor and measure processes and the key characteristics of its operations that determine energy performance against the energy policy and objectives and report the results.
4. Act: take actions to continually improve energy performance.

To ensure the organization stays on course, aspects in the plan included the areas mentioned below.

1. ***Training and awareness sessions*** for KE employees on ISO 50001 and energy management. The goal is to introduce the guidelines, ensure understanding of the system, and how it fits in with daily job routines.
2. A comprehensive companywide ***energy policy*** based on ISO 50001 guidelines that would be applicable throughout the organizational systems.
3. ***Energy management representatives*** in all departments and facilities, trained on the ISO 50001 standard, its requirements and how to integrate the system in their location in its entirety.
4. Facility based ***energy audits*** conducted by KE's own certified energy audit team.
5. ***Certifications*** for each facility/department after the successful completion of local energy audits, and adoption of their recommendations to receive ISO 50001 certification for achieving on energy efficiency and management.

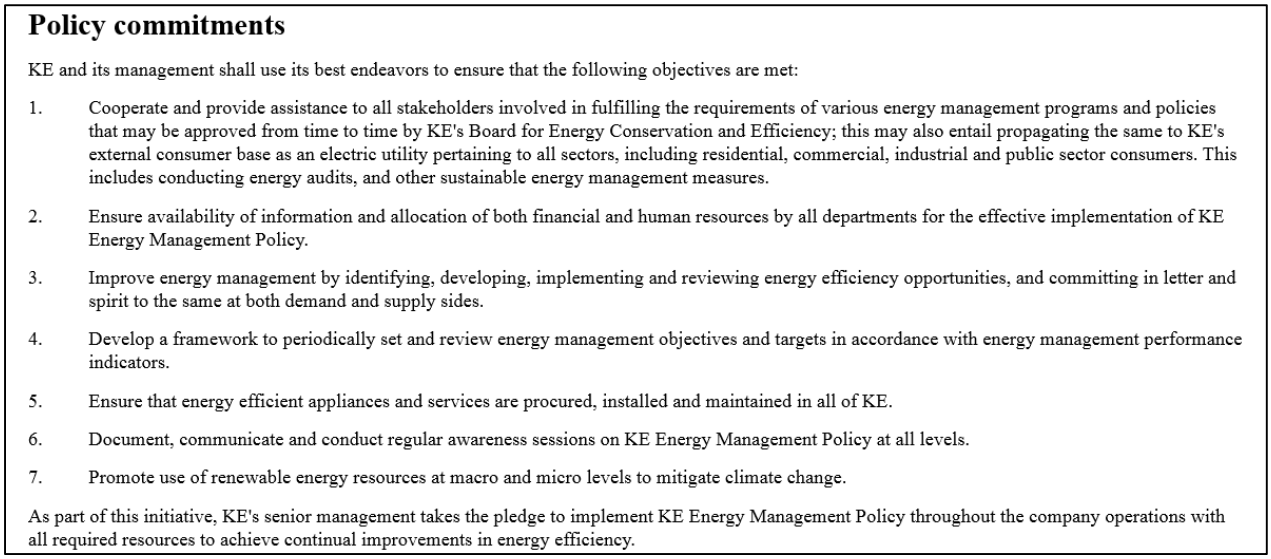
EnMS Phases

The entire energy management system, when broken down under the phases of the program, has three main areas: planning, implementation and monitoring.

1. Planning

As the first step, planning for energy management systems can be a huge organizational conundrum with a number of activities that need to be conducted during the planning phase, beginning with the buy in from the top management to embark on a journey of energy management. Holistically, the planning stage took about three months. Within KE, the championing team of Energy Conservation Department (ECD) conducted a five day training of its technical team, culminating in a written test graded by SGS in the U.K., as per the ISO 50001 Energy Management System Lead Auditor Course. This enabled the team to understand the

philosophy behind the system and equate the local organization on to a plausible EnMS scale. To permeate the thinking behind the move toward energy management, awareness sessions for managerial and officer level employees were held throughout one month in locations around the organization. Once the interest in EnMS became palpable among employees, a companywide Energy Management Policy was formulated and legally vetted as per the national energy conservation bill (Pakistan 2016). This policy was circulated among employees at all levels via email, and was displayed at visible locations at plants and offices. Part of this organization wide policy can be seen in Figure 1 below.



Policy commitments

KE and its management shall use its best endeavors to ensure that the following objectives are met:

1. Cooperate and provide assistance to all stakeholders involved in fulfilling the requirements of various energy management programs and policies that may be approved from time to time by KE's Board for Energy Conservation and Efficiency; this may also entail propagating the same to KE's external consumer base as an electric utility pertaining to all sectors, including residential, commercial, industrial and public sector consumers. This includes conducting energy audits, and other sustainable energy management measures.
2. Ensure availability of information and allocation of both financial and human resources by all departments for the effective implementation of KE Energy Management Policy.
3. Improve energy management by identifying, developing, implementing and reviewing energy efficiency opportunities, and committing in letter and spirit to the same at both demand and supply sides.
4. Develop a framework to periodically set and review energy management objectives and targets in accordance with energy management performance indicators.
5. Ensure that energy efficient appliances and services are procured, installed and maintained in all of KE.
6. Document, communicate and conduct regular awareness sessions on KE Energy Management Policy at all levels.
7. Promote use of renewable energy resources at macro and micro levels to mitigate climate change.

As part of this initiative, KE's senior management takes the pledge to implement KE Energy Management Policy throughout the company operations with all required resources to achieve continual improvements in energy efficiency.

Figure 1. A snapshot of the companywide Energy Management Policy.

The policy was followed by the selection of Management Representatives, called Energy Management Stewards, from the employees working in managerial level positions in all functions of the organization, including generation, transmission, distribution and other enabling functions. A workshop was arranged for the Energy Management Stewards to discuss their status, responsibilities, scope of work and procedure to carry out those activities. It was important to have such a session because all the employees selected as “Stewards” had their original responsibilities in areas like design engineering, health and safety, instrumentation and administration. A companywide, easily accessible web portal was developed on the organization’s intranet to share updates and information, and establish communication among the Stewards, and between the Stewards and ECD. This portal was created for some of the following areas: energy efficiency updates from across the organization; technical modules, tools and latest developments for energy efficient technologies and systems; and, request energy audits, awareness sessions, lighting/HVAC studies and communication materials. Communication materials were developed for dissemination among all the employees. This included development of highly visual content for energy conservation and efficiency, like popup stickers, standee posters, and friendly office notices and memos.

1.1 Data collection

A very important phase is the data collection from management representatives. This stage took another two months. Locally termed as the Energy Management Stewards, energy data was gathered from them for the areas, locations and premises for which they were responsible. An understanding was established of which function they worked in, the number of buildings under their jurisdiction, and the number of people that worked in those areas – permanent, temporary, contract and other staff – to formulate target areas among the significant energy uses. Information was obtained from the Stewards on previously conducted energy analyses, identification of the most energy intensive machines, functions and processes, and the issues they have faced and expect to face. Lessons learned from U.S. DOE pilot projects for ISO 50001 in commercial buildings (Deru et al. 2014) were used to formulate the basic planning procedure as a questionnaire, part of which can be seen in Figure 2 below.

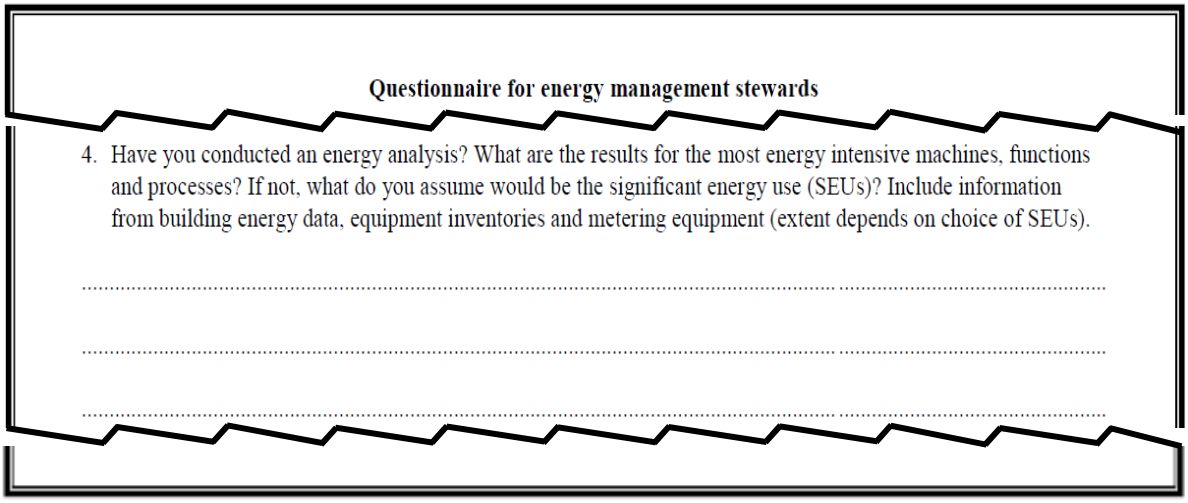


Figure 2. A part of the survey form to gather data from management representatives (Energy Management Stewards).

It was found out that occasionally there were competing departmental priorities, which helped in smoothing out early challenges. Moreover, the departmental buy in was also observed – some departments like the transformer switchgear workshop had top to bottom engagement and budget allocation, while others like the distribution centers for consumers had limited financial access and lower priority with regards to energy management. The issues that the Stewards faced with their supervisors/management also differed in each scenario. Data was collected with regards to the calculation of time dedicated to energy management activities. Although it was difficult to gauge exactly how many man hours, days and weeks were devoted to each activity, however, an approximate duration was estimated as to time *spent* and time that was *expected to be spent* in future, where an increase/decrease was accounted for in each instance. For example, one of the gas fired generating plants stipulated an expected increase owing to a new plant and its auxiliary setup. Additionally, the size of the Stewards' operational teams was also assessed, which comprised of internal staff, contractors and suppliers. Records were obtained of competency credentials, of the metering equipment, where the extent of the data depended on choice of SEUs, building energy data, and equipment inventories. To establish the use of technical expertise, the following areas were assessed: depth of energy modeling and

analysis software that were being used; access to and use of standard operating procedures and/or control sequences; and, access to ISO 50001 guidelines and technical support on the local intranet portal.

2. Implementation

As the second step, implementation of EnMS included competence development, putting action plans in play, installing energy efficient equipment and processes among other developments. This phase took an upward of five months. Some of the areas that were focused throughout the organization included the following:

1. Energy efficient lighting: After lighting surveys in office buildings and in plant environments, LED and efficient metal halide fixtures were installed in maximum locations, based on IESNA and ASHRAE standards. Civil and Works department were taken on board to include this aspect as part of their standard operating procedure. Additionally, booths that sold LED fixtures were set up in different locations for employees to purchase lighting for their residential use.
2. Energy efficient fans: Available products in the market were tested, and wherever they were used, ceiling fans were replaced by more energy efficient alternatives. As a thumb rule, an energy efficient ceiling fan consumed 55 watts as compared to 85 to 100 watts for a conventional one.
3. Energy audits for generating plants: Facility audits were conducted. Motor and rotary loads were optimized based on the guidelines developed and made public by National Electrical Manufacturers Association (NEMA), Consortium of Energy Efficiency (CEE), and American Council for an Energy-Efficient Economy (ACEEE).
4. Power factor improvement for generating areas. Relay synchronization issues were solved by capacitive solutions wherever applicable.
5. Installation of energy meters at all locations. While this feature was available at a number of locations, conscientious effort was made to make this aspect ubiquitous.
6. Competence development: Expert training sessions on energy efficient technologies were arranged by the EC Department for the Civil/Works Department, Energy Management Stewards and other employees who used large machinery or equipment used.

2.1 Workshop for Energy Management Stewards

A series of workshop sessions were held, each with a unique agenda, to engender energy management commitment among the Energy Management Stewards, i.e. the management representatives, throughout KE operations, and to impress the potential gains this program can provide to the organization. This included guidelines to achieve energy conservation and energy efficiency to serve the entire circle of energy within KE's generation, transmission and distribution businesses and beyond. Energy Management Stewards were communicated their responsibilities to champion the cause of energy management in their domains – be it an office area, a power plant, a grid station or an integrated business center (IBC). The session included introduction, ideation, execution and operation of energy management systems, with lively exercises and dynamic question and answer sessions to activate ideas and channel practices for continual improvement of energy efficiency. Participants shared their experiences with changes

they had already made and had planned, for example, for lighting in their offices, replacement of air conditioning systems, and installation of PV systems at a power plant. ECD representatives enabled the exchange of information and suggested improvements in the existing systems that can potentially improve energy efficiency.

2.2 Energy analysis for the organization

The utility's output numbers include the following: a total of 11,410 gigawatt-hours were produced for distribution in July 2015, which increased to 11,838 gigawatt-hours in July 2016, a reduction of transmission and distribution losses from 23.4% in July 2015 to 22.8% in July 2016, and an uptake of 4.5% in recovery from distribution end from July 2015 to July 2016 (KE 2016). On the energy usage side, based on the energy audits conducted for the organization, the following loads were estimated as the load consumed by the organization.

Table 1. Estimated energy consumption of the organization

Load	**Megawatts**
Plant auxiliary	126.32
Motor/rotary load	52.82
Air conditioning	4.52
HVAC systems	4.32
Lighting	2.61
Variable refrigerant flow AC	0.92
IT equipment	0.77
Miscellaneous appliances	0.54
Ceiling/bracket fans	0.23
UPS systems	0.21
Total	**193.26**

In-house electricity consumption costs amounted to PKR 92.832 million in 2014 (USD 0.89 million[1]), and PKR 96.839 million (USD 0.92 million[2]) in 2015. Similarly, Table 2 and Figure 3 show the load consumed by one power plant of 270 MW, as a representative of the total consumed energy by different locations within the organization.

Table 2. Metered energy consumption of one combined cycle power plant (CCPP)

	Auxiliary plant load (kWh)		
Date	**Generating sections 1-4**	**Steam turbine**	**Plant with steam turbine**
July 2015	1,016,572	0	1,016,572
August 2015	613,488	0	613,488
September 2015	689,561	0	689,561
October 2015	679,547	0	679,547
November 2015	501,886	0	501,886
December 2015	332,955	0	332,955

[1] As per the exchange rate in March 2017.
[2] As per the exchange rate in March 2017.

Date	Auxiliary plant load (kWh)		
	Generating sections 1-4	Steam turbine	Plant with steam turbine
January 2016	398,800	0	398,800
February 2016	547,420	0	547,420
March 2016	1,268,820	0	1,268,820
April 2016	1,315,990	0	1,315,990
May 2016	1,081,640	0	1,081,640
June 2016	1,174,080	0	1,174,080
July 2016	1,166,980	105,617	1,272,597
August 2016	1,228,139	7,062	1,235,201
September 2016	1,009,410	0	1,009,410
October 2016	1,126,850	76,880	1,203,730
November 2016	375,170	14,547	389,717
December 2016	316,630	0	316,630

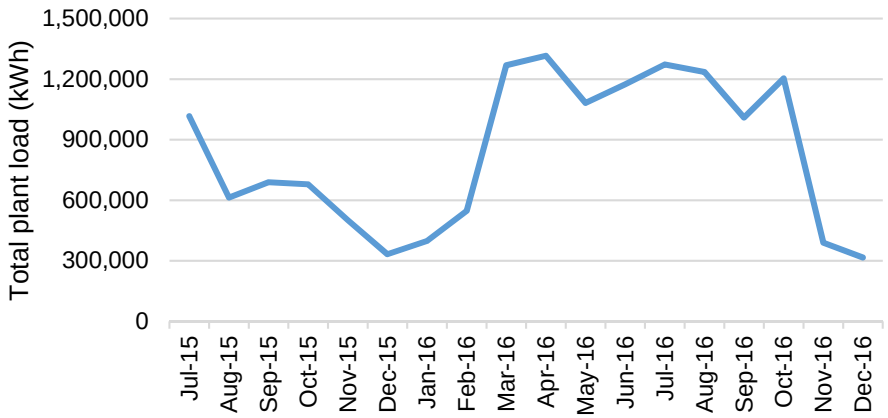


Figure 3. Total auxiliary plant load, i.e. energy consumed by the plant itself, for one of the CCPP generating stations of KE.

3. Monitoring

The monitoring phase, lasting more than five months, included implementation and operation, checking and management review. The implementation and operation aspects covered competence, training and awareness of Stewards in particular and all employees in general; communication among the Stewards and between the EC Department and Stewards; documentation of all EnMS aspects like audit reports, energy manuals and action plans; operational control of appliances, processes and equipment; incorporating energy efficiency in design of new processes and mechanisms and in procurement of energy services, products, equipment and energy. The checking part included monitoring, measurement and analysis of areas that can have increased energy efficiencies; evaluation of compliance with legal and other requirements; conducting internal facility and location audits of the EnMS in place; identifying nonconformities, and planning and implementing correction, corrective action and preventive action measures; and, putting the mechanisms for control of records in place, and ensuring they

work effectively. The management review aspect included discussion with the management on the running of EnMS, evaluating results, and discussing changing policies, if any.

The “monitoring” phase was a particularly trying area because the entire premise was based on the fact of improvising solutions to unexpected problems – which was an interesting challenge. Initially, EnMS documentation was encouraged on all formats: on paper, electronic or any other media. However, it transpired very quickly that a standardized method was not possible, and the most appropriate and secure way was to log information comprehensively in an electronic format to preserve solidity of relevant data. This generally included scope and boundaries of the EnMS, energy policy, energy review (objectives, targets and action plans), and other documents that were determined by each Steward/Department to be necessary, depending on the scale of their department, type of activities, the complexity of the processes and their interactions, and the competence of personnel.

The control procedure of the EnMS documents included usage of the local intranet web portal to learn about updates, document EnMS requests, obtain and log their information, and link them with design/project/construction requests in the organization wide SAP system to ensure finance aspects are similarly linked. Immense help was procured from the IT teams to ensure the process was as seamless as possible, by tracking the entire request flow for authorization to approval with minimum hitches. Additionally, it was encouraged that each Steward, while having complete autonomy on developing their energy efficiency systems, were able to discuss documents and mechanisms for adequacy with the EC Department prior to use. These documents were periodically reviewed and updated as necessary, relevant versions of documents were made available at all points of use, particularly in plant environments and in grid stations, and these documents were kept legible and readily identifiable.

The progress and development within this area was catered by documenting continual learnings to serve as lessons learned for larger teams, and necessary information within the teams and with supervisors was discussed, especially when there was a turnover within a team to prevent loss of information. Reviews were consistently conducted on the work to ensure continuous improvement within the EnMS. The local intranet portal was used to learn, discover and post requests. The key players, top management and Energy Management Stewards were encouraged to remain in touch with the EC Department for 24/7 help. To ensure inspiration in this area, an annual recognition of best performers within the organization by way of rewarding best performance.

Challenges

A number of challenges were faced during this program: technical, financial and management resources. With the locations of the organization spread across the city, geographic challenges in terms of getting the staff together were some of the most difficult ones to ease the energy management systems.

Figure 4. Location of integrated business centers of KE spread across the city to give a representation of the physical challenges of the organization. Note that power plants and grid stations are additional locations not identified in this figure.

Technical challenges included expertise in innovative energy efficient technologies, and the method of their incorporation in the existing system. Financial challenges included issues with budgeting. Challenges in the human resource areas included the gaps in competence, and problems with development of relevant skills in the right people. It was learned that often energy efficiency improvements with very favorable payback periods did not get implemented due to competing departmental priorities. Even projects that are implemented were not sustained due to lack of supportive operational and maintenance practices (U.S. DOE Superior Performance 2015). As a representative cost, the total cost for a 3 year third party ISO 50001 certification cycle for the corporate office of the organization were quoted as USD 11,625 inclusive of federal and local duty. The first year certification audit would be conducted by an international auditor, followed by a regional auditor for the surveillance audit.

Conclusions

Results

Carrying out energy management system activities for an organization of the size and volume of K-Electric, in an environment where prioritizing business generally takes precedence over quality or energy, spells challenges at every step.

Table 3. Results achieved for one of the combined cycle plants for lighting and HVAC energy efficiency improvements over a time frame of approximately 5 months

Energy use	Audited load (kW)	Optimized load (kW)	Initial investment (USD)[3]	Expected savings			Payback (months)
				kW	kWh/annum	USD/annum[4]	
Lighting	60	17	13,930	43	368,531	81,077	2.06
HVAC	208	104	59,472	104	899,665	197,926	3.61

Summarily, a total investment of around **73,472 USD** was required with a net payback period of around **3 months** resulting in savings of **279,003 USD** per annum. The implementation of this proposal resulted in a reduction of around **664 metric tons** of carbon emissions per annum. Maximum diligence was pursued throughout the process and commitment to ISO 50001 guidelines. In general, strengthening people connections – making new ones and reviving old ones –in various parts of the organization was regularly done for effective data flow between the elements in the organization to create an effective EnMS. Analysis and review of energy data were important means of accomplishing the tasks required in EnMS, and the Stewards generally felt more comfortable with these activities. As compared to other ISO management systems ISO 50001 was typically designed to have fewer documentation requirements, producing an energy manual (document) was considered a substantial effort by the Stewards, which was at par with implementation activities, like improving energy efficiency of a motoring system. This aspect allowed documentation to represent a large segment of the EnMS effort. Energy Management Stewards reported a number of areas within the categories of energy policy, energy manual, energy review tools, documented objectives and targets, and documented action plans. One interesting outcome consisted of positively changed behaviors and increased organizational knowledge, especially one the scale of KE, which speaks volumes about adopting such management systems. Additionally, the Stewards reported distinct results from different areas: generating plants reported energy efficient machinery as one of their largest selling points, distribution centers reported improvements in switchgear and transformers, and office based areas reported identification of gaps in energy efficient building design, lighting and HVAC as some of their highest impact areas. Pursuing third-party ISO 50001 certification was considered the natural next step for the organization.

Challenges yet to overcome – pathway to the next steps

While the ISO 50001 is a continuous improvement program, some of the lessons learned included allocation of resources, management of activities, and overall/incremental benefits and costs of attaining ISO 50001 certification. Interestingly, receiving an ISO 50001 certification was a more sought after title at the power plants than it was at the commercial buildings. Naturally, some of the success factors and best practices for EnMS implementation include answering questions in these areas to help clarify for different organization types as to what processes are best suited to simpler EnMSs that they would potentially benefit from achieving ISO 50001 conformant energy management systems. Certain resources and activities proved to be the most critical to successful EnMS establishment within a power utility, having both industrial and commercial setups. Among the resources utilized, staff time was one of the most important

[3] Exchange rate as per March 2017
[4] Exchange rate as per March 2017

resources required, where cross platform sharing of internal information about KE's current management system was a challenge – solved by the local intranet web portal. Case studies and examples were used to help lighten the initial lift. Technical support was sourced online from the Clean Energy Solutions Center of the Clean Energy Ministerial, CEE and ACEE. This was a critical resource to the success of the Stewards managing their local EnMS programs. Activities that were a huge factor in the success/failure in some locations included a format of evaluation of performance, where collection and analysis of energy consumption data was although difficult but very revealing in a lot of cases. Identification of goals, in terms of energy objectives, targets and action plans seemed cumbersome, especially when finance was put in the equation. Development of organization wide connections, communication of operational controls by formalizing and disseminating standard procedures, and tracking and reviewing progress also emerged as significant issues.

Areas that enabled a comprehensive EnMS within a large power utility included clear management hierarchies over employee staff that impact energy consumption are clear – the energy management representative and top management are positioned to effectively lead implementation. This also involved more access to corporate resources, greater familiarity with documenting processes and procedures, some energy management practices already in place, and larger building, campus, or portfolio.

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