The Complete Cycle to Institutionalize Industrial Energy Efficiency: Conceptual Framework, Tools, and Industrial Cases

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ABSTRACT

This paper describes the cycle required to help an industrial organization to institutionalize best practices in energy efficiency. From strategic planning and implementation, to performance monitoring and continuous improvement, it presents the structure of a conceptual framework, the tools developed to support the framework, and the organizational and operational requirements to complete the cycle.

The conceptual framework follows a closed-loop that is designed to help companies elevate energy efficiency importance as a key part of the organization's strategic matrix, identify and adapt best practices, develop standardized operational procedures, implement the strategic and operational plans, establish monitoring mechanisms, and achieve continuous improvements. To support the framework, an integrated, web-based tool has been developed to establish a platform to provide training and to help actual application. It integrates all necessary materials, such as teaching materials, task flowcharts, data sheets and specific tools for technical and financial analysis, in a task-centered way. This framework can be adapted and developed for each company's specific needs.

The paper also presents the case of a multi-national manufacturing organization, which is in the process of adapting the framework and its web-based tool, to institutionalize best practices within its global network of over 300 manufacturing organizations. The relevance of this work to the industrial organization's future compliance to the forthcoming ISO50001 is also highlighted.

Opportunities

The industrial sector accounts for 28% of the energy used world wide, 25.6% of which is by means of burning coal (EPA 2007). To reduce greenhouse emissions, the industrial sector needs to focus on ways to reduce the need for non-renewable energy sources, and increase the use of renewable energy sources and become energy efficient.

These have been plenty of real life cases to support the claim that "energy efficiency is a source of energy. For example, as part of the U.S. Department of Energy's Industrial Assessment Program (IAC), in the past few years, the University of Missouri IAC Center (MoIAC) has covered the State of Missouri with its energy analysis services. According to the statistics on the amount of actual energy reduction achieved through implementation of industrial energy saving measures, identified by the center's service and recommended to small-to-medium sized manufacturing companies, the following have been achieved (see Figure 1). Furthermore, our experiences have shown that many industrial corporations and companies have realized the importance of energy efficiency initiatives to their operation, both from an environmental and business point of view.

- Average annual saving on energy costs per plant approximately: $80,000/year
- Average period for 100% return on investment: less than one year

Figure 1 MoIAC Energy Savings – Sample Statistics of Energy Savings Achieved through Actual Implementation of Recommendations

Company Case # (MZ00xx)	Company Annual Energy Cost ($/Year)	Implementation Cost ($)	Annual Savings ($)	Annual Savings %	Simple Payback Period (Years)	Electricity Savings (kWh)	Natural Gas Savings (MMBtu)	CO2 Reduction (lbs)
17	$215,858	$17,363	$22,677	10.51%	0.77	305,071		561,331
19	$469,607	$42,065	$67,370	14.35%	0.62	363,626	3,431	1,070,773
20	$109,063	$4,590	$16,054	14.72%	0.29	52,860		97,262
21	$457,186	$47,365	$45,932	10.05%	1.03	899,296		1,654,705
22	$322,046	$9,158	$55,068	17.10%	0.17	7,764	4,945	593,246
23	$3,884,345	$67,080	$89,605	2.31%	0.75	215,536	5,307	1,017,930
24	$328,392	$33,700	$27,945	8.51%	1.21	465,995		857,431
25	$36,550	$1,900	$3,032	8.30%	0.63	43,300	22	82,248
28	$894,748	$7,500	$11,837	1.32%	0.63	295,560	55	550,270
29	$517,088	$43,420	$32,081	6.20%	1.35	600,499	1	1,105,035
32	$217,701	$1,012	$2,916	1.34%	0.35	47,795		87,943
33	$1,024,728	$47,656	$28,404	2.77%	1.68	406,033		747,101
34	$2,609,730	$54,182	$62,602	2.40%	0.87	684,535		1,259,544
36	$1,795,922	$36,462	$99,152	5.52%	0.37	1,449,188		2,666,506
38	$72,388	$3,768	$3,060	4.23%	1.23	21,684		39,899
39	$1,751,524	$538,296	$100,566	5.74%	5.35	1,238,305		2,278,481
41	$2,011,276	$87,580	$107,479	5.34%	0.81	42,000	11,566	1,431,427
42	$708,200	$364,200	$485,671	68.58%	0.75	2,248,000	19,495	6,418,795
43	$989,295	$42,221	$227,799	23.03%	0.19	2,950,889	5,329	6,053,555
44	$384,769	$45,050	$31,751	8.25%	1.42	475,653		875,202
45	$372,660	$47,000	$56,915	15.27%	0.83	716,530		1,318,415
46	$2,090,549	$81,210	$166,550	7.97%	0.49	1,758,644		3,235,905
Total	$21,263,625	$1,622,778	**$1,744,466**	**8.20%**	**0.93**	**15,288,763**	**50,151**	**34,003,003**

Note: MZ0037 - company closed; MZ0018, 26,27,30,31,35,40 - case no. not used/data not obtainable

Notes: based on ALL assessment conducted in the 2009 financial year by the center. Missing reports: company No. MZ0037 – company closed; MZ0018,26,2730,31,35,40 – number not used/data not obtainable. Reason for high value of percentage saving of MZ0042 – saving amount accurate, company total annual costs incomplete.

Obstacles

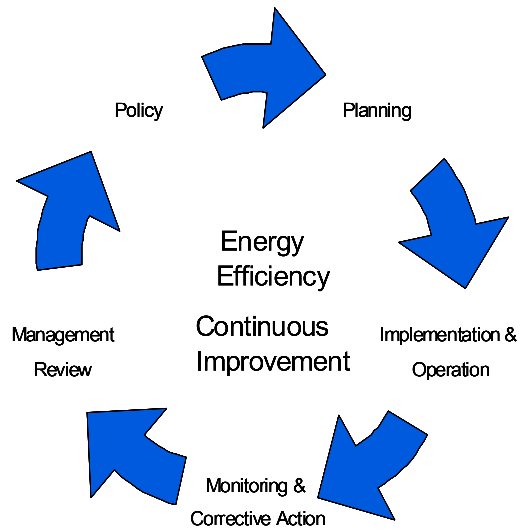
In the industrial sectors, it is a well understood fact that a complete cycle is required to achieve continuous improvement of system performance: setting strategy and goals – analysis and design – implementation and operation, performance monitoring and setting of new goals (Wu 2000). When related to the improvement of industrial energy efficiency, this cycle can be presented by a close-loop as shown in Figure 2. In addition, a large amount of information are readily available regarding the current technologies and general best practices (for example, see: http://www.eere.energy.gov, http://iac.rutgers.edu).

However, despite the potentials and the increasing level of awareness, quite often industrial organizations in reality are still not motivated to implement energy efficiency measures. Energy efficiency programs in the actual industrial settings still are in the low-priority list, mainly due to the following reasons:

- Lack of in-house expertise or team, know-how, and resources to initiate and implement energy program
- Lack of effective methodology to help industrial organizations to plan, adopt and institutionalize energy efficiency solutions in their facilities
- Lack of user-friendly tools
- Lack of institutionalized operational procedures and standard to set the energy efficiency program in the facilities
- Lack of partnership with governments and other energy efficiency organizations.

- Lack of funding for implementation of energy efficiency measures, or lack of awareness of available funding from the government agencies and other entities to support such measures for local companies

Figure 2. The Complete Cycle of Continuous Improvement of Industrial Energy Efficiency: Strategy, Planning, Implementation, Monitoring



To overcome the obstacles, a systematic approach is needed to help the industrial sectors to effectively initiate and implement an energy efficiency programs in a logical manner. Approaches and tools are needed by the industrial organizations to help tasks in the key areas:

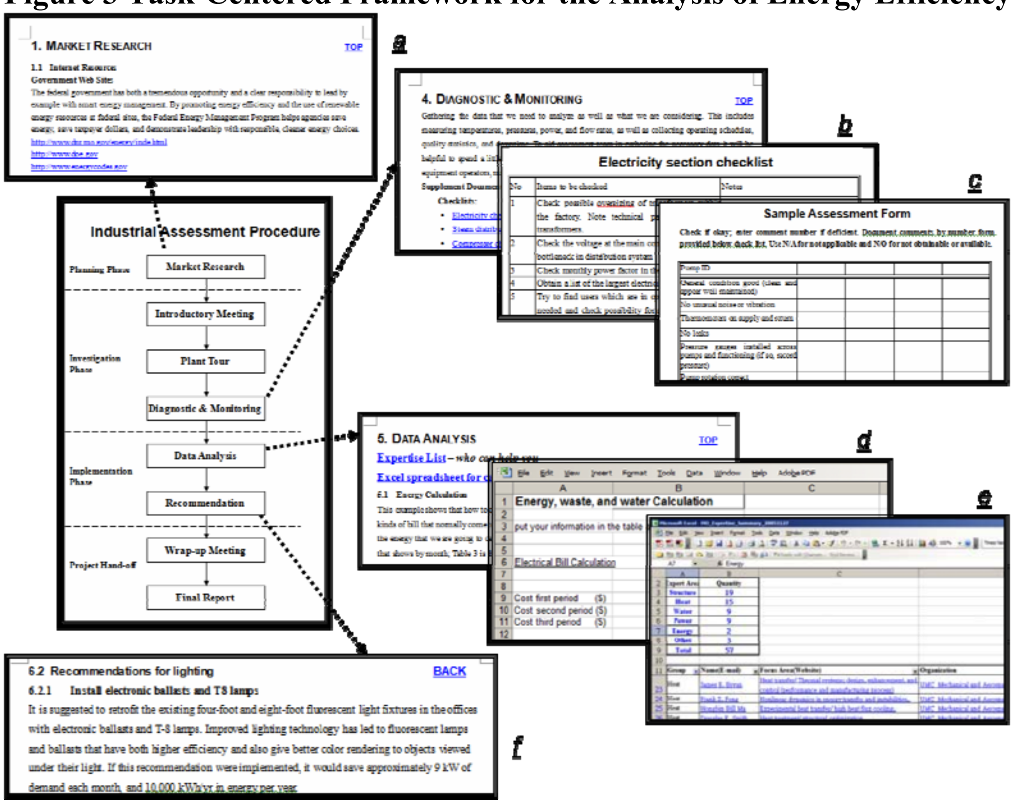
- *Education and training of personnel*
- *Planning and execution of energy efficiency projects*: planning, data collection and analysis, identification of opportunities, detailing and justification of recommendations, implementation tasks
- *Institutionalization of best practices* in the organizational and operational structure: analysis and investigation of a organization's specific needs, identification of best practices guides and operational procedures, documentation

Task-Centered Framework for the Education and Application in Industrial Energy Efficiency

A task-centered approach provides an ideal framework to help achieving the above. Initially, task-centered methodology was used to introduce the manufacturing system design and management (MSM) workbook with a systemic approach for industrial manufacturers (Wu 2001). The concept is based on the integration of all tasks to accomplish the work. These tasks may include tasks descriptions, instructions, processes, drawings, tools, data, etc. All elements, with the task-centered methodology, are integrated into one single platform. Within the web environment, this can be further enhanced by a web-based design in a focus way to provide good usability, so that the users can focus only on the tasks at hand and ignore the irrelevant contents and the system structure and navigation needs.

Since industrial energy efficiency analysis – sometimes also referred to as an industrial energy audit - involves with a large number of documents and multitude of analysis and decisions, the concept of task-centered approach can be used as the basis for the development of a computer-aided workbook to incorporate energy audit procedures, processes, and tasks, following the life-cycle of an energy efficiency analysis. Following this approach, the conceptual structure of a task-center workbook has been proposed, so that, as shown in Figure 3, a computer-aided workbook can be developed and implemented to provide a complete guide to the processes, tasks and outcomes of an energy audit. From the initial audit planning to the final recommendation and follow-up, the workbook utilizes a front-end flowchart to specify the steps and tasks involved, and then logically integrate all the relevant entities such as instructions (Figure 3, a), data collecting tools, procedures of analysis and calculation, and worksheets to support task execution and project management (Figure 3, b, c). Other notable features include links to other resources (Figure 3, a), the experts/expertise database (Figure 3, e), and a specially developed worksheet for calculating organization-wide energy consumption (Figure 3, d). With the completion of the necessary steps, the workbook provides templates for generating final recommendations and report (Figure 3, f). In essence, it is a unified project tool that organizes and links instructional materials, worksheets, analytical tools, and resources in a logical and task-centered manner.

Figure 3 Task-Centered Framework for the Analysis of Energy Efficiency

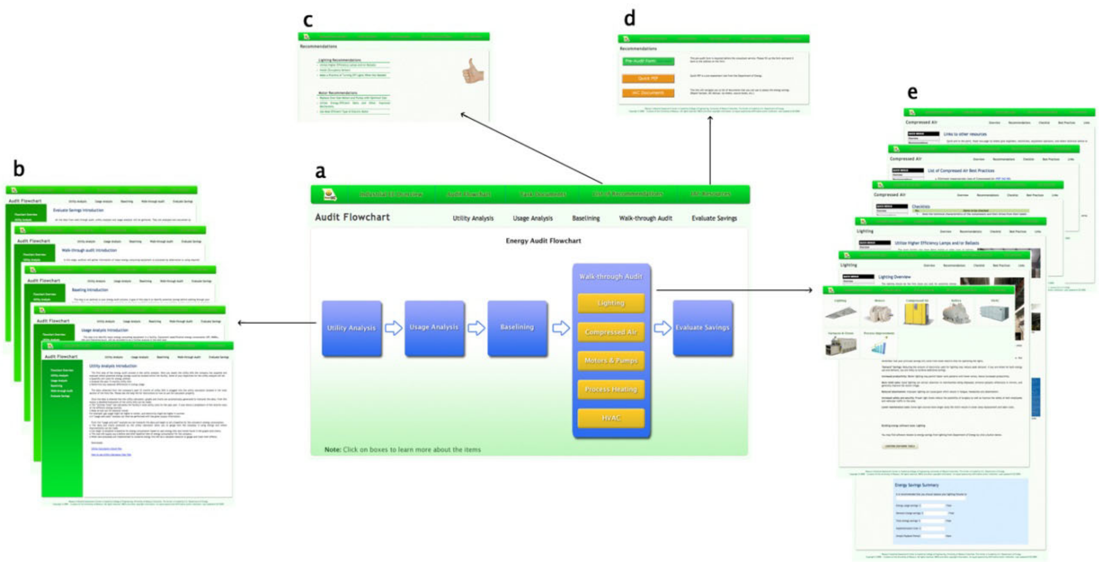


A Web-Based Implementation

A web-based implementation of this task-centered framework has been developed. It represents a knowledge base and project tool, in the form of a computer-aided "workbook" (see: http://iac.missouri.edu/webtool/flowchart/flowchart.html). It provides a complete guide to the processes, tasks and outcomes of an industrial energy analysis, as shown in Figure 3. From the initial audit planning to the final recommendation and follow-up, the workbook should utilize a front-end flowchart to specify the steps and tasks involved, and then logically integrate all the relevant entities such as training materials and instructions, data collecting tools, procedures of analysis and calculation, and worksheets to support task execution and project management. In essence, it is a unified project tool that organizes and links instructional materials, worksheets, analytical tools, and resources in a logical and task-centered manner.

Based on this frontend, the conceptual structure of Figure 3 has been implemented to provide all the functionalities as specified, as illustrated in Figure 4. This implementation has proven to be effective as an integrated computer-aided training/application tool for industrial energy efficiency, because following locally through the complete cycle of the energy improvement project, it is structured in a user-friendly and practical way to support:

Figure 4 Web-Based Task-Centered Workbook: Frontend and Collections of "Task Documents"



- Interactive learning and training, by providing learning materials and best practice guides and resources in a focused way, for instance, see Figure 5. Each of the recommendations in the best practice list is supported by a task document that provides both theoretical details and tools.
- Application in actual energy improvement project through the provision of a collection of "task documents" that: (a) aid diagnosis and solution identification by providing on-line and up-to-date on-line checklist, and (b) help with the problem-solving tasks required through live tools for data collection, calculation and justification (Figure 6).

Figure 5 Web-Based Task-Centered Workbook: Sample Training Materials and Task Document Providing Details to Specific Best Practice Measures

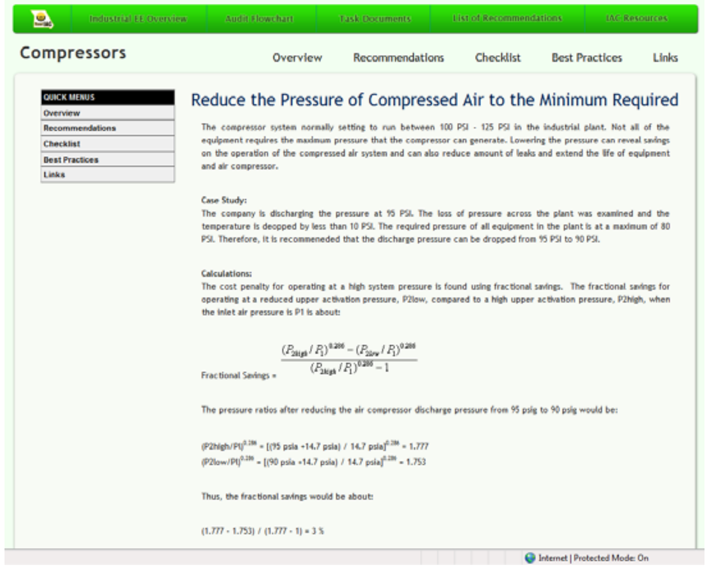
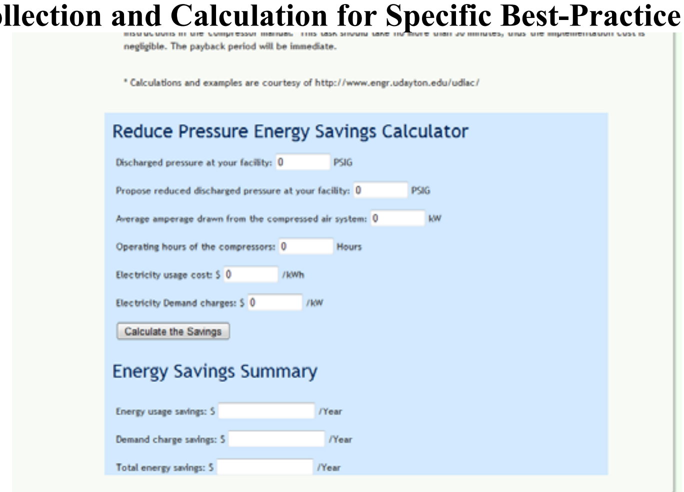


Figure 6 Web-Based Task-Centered Workbook: Live Calculator to Support Data Collection and Calculation for Specific Best-Practice

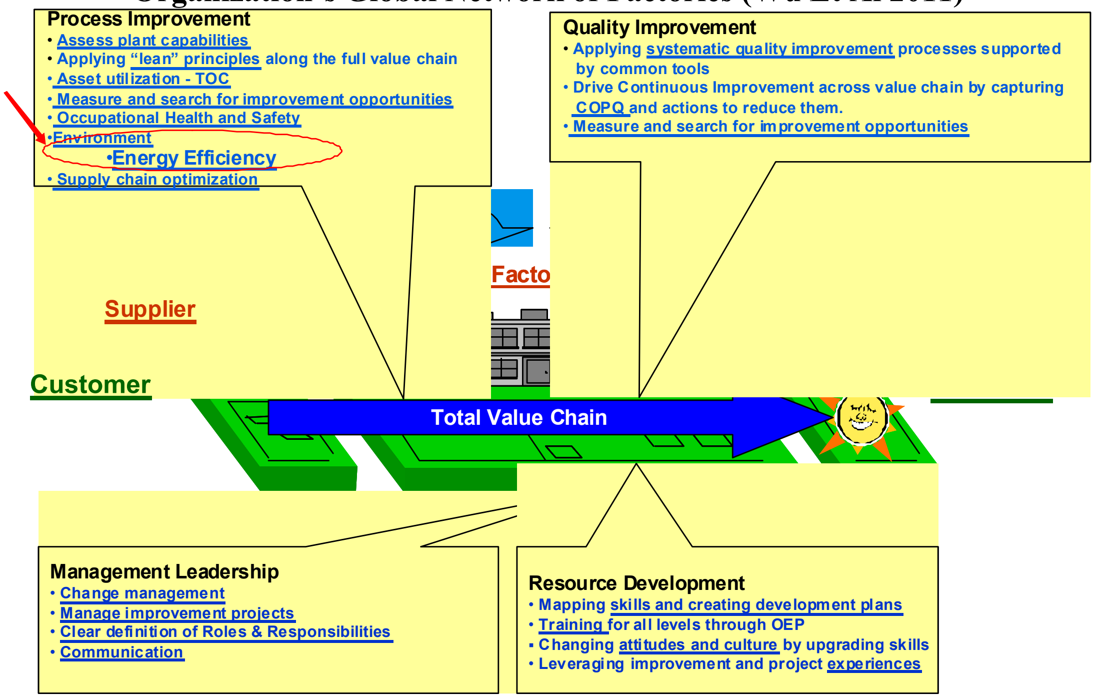


Since its development and implementation, the framework has proven to be effective in helping educating the next generation of energy-savvy engineers amongst the current college student population, as well as helping industrial organizations to achieve energy efficiency in practice. According to statistics, this is a popular site, resulting for example above 6,500 visits over a period of two months in 2009 when statistical data were collected.

Adaptation and Institutionalization – The Case of a Major Global Manufacturing Network

As an example to illustrate the framework's potential as an effective means to help overcome the obstacles as previously identified, this case study outlines how the framework's structure and contents are being adopted by a manufacturing organization, and institutionalized within the organization to help the organization's global wide initiative of energy efficiency.

Figure 7 Overview of the Structure of the Organization's Current Standard Operational Procedures, with the Task-Center Framework Being Adapted to Fill in the Energy Efficiency Gap to Help Institutionalization of Best Energy Practices within the Organization's Global Network of Factories (Wu Et Al 2011)



The industrial organization involved is one of the largest manufacturers in power and automation that employs approximately 117,000 people in over 150 companies based in 100 countries. Organizationally, as part of its effort to become green, the organization has established a global network of personals that consists of a global environmental advisor, a number of regional advisors and country advisors, and followed finally by factories environmental advisors who are located locally at each site. However, up to date, very little have been done to initiate real changes in the factory floor regarding energy efficiency. One wonder how come such a large organization with branches in every continent and so many resources has done so little to improve their energy efficiency and environmental footprint. Again, the list of obstacles outlined previously appears to be in general the main reason why energy efficiency along with other environmental initiatives have been at the bottom on the list of priorities for its facilities. Additionally, the following were identified:

- A vertically integrated hierarchy that did not allow local solutions to be shared by sister companies within the organization. Consequently companies in different regions and country have been re-inventing the wheels times and again, and best practices and experiences are not being shared.

- Energy initiatives, global and local, lacked the involvement of employees in the projects at the operational levels, with people in some cases resisting changes because the potential benefits are not directly reflected in their performance measurements.

It is realized that a key to improve the situation here is to have energy efficiency best practices institutionalized within its organizational and operational structures, and the structure and contents of the task-centered framework provides an ideal platform to help the organization achieve this. It was therefore decided by the organization's leadership to adapt this framework and implement it within its global network of manufacturing companies as part of its standard operational procedures, to fill in the Energy Efficiency gap, as shown in Figure 7.

Conclusion

Up-to-date, the organization's global steering committee has used a top down approach to the framework's adaptation and implementation. Essentially the steering committee shall nominate the division Environmental Officers whom will roll out the initiative to the different factories world wide. Once the improvements are proven in terms of less carbon emissions and energy savings for one division, the same model will then be copied, improved and implemented on other divisions of the corporation. Eventually the division level instructions (adopted task documents) regarding energy efficiency can then be elevated to become the global standard and operational procedures for the organization. It is also decided that the institutionalization of the framework shall follow the upcoming ISO 50001 Energy Management Standard, which gives a complete framework for a continuous improvement process as shown previously. Focus will be given to the Planning Stage where the Task Center Framework will be adapted thus providing the roadmap for the Energy Efficiency Initiative. The current status and results of the project, together with the lessons learnt, will be reported in detail elsewhere (Wu et al 2011).

Acknowledgement

Missouri IAC is supported by the U.S. Department of Energy, the Industrial Assessment Center Program, through the Office of Energy Efficiency and Renewable Energy, Industrial Technologies Program. A significant amount of technical information incorporated into the framework is based on the technical publications by the US Department of Energy's Industrial Technology Program (http://www1.eere.energy.gov/industry), and the IAC Field Managers' Office (http://iac.rutgers.edu).

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