A Systematic Effort to Promote Best Practices in Industrial Energy Efficiency

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ABSTRACT

This paper describes how a systematic effort is being carried out at the University of Missouri-Columbia (MU), to promote best practices in industrial energy efficiency and productivity improvements. In particular, it illustrates how the activities of a newly established Missouri Industrial Assessment Center (U.S. Department of Energy, IAC Program) in the MU College of Engineering can be logically integrated with the university, the state agencies, the MU Extension, and the major utilities in the state, to:

- Promote best practice in industry by conducting regional outreach seminars
- Utilize the synergy resulting from its partnerships with MU Extension and the MEP (Manufacturing Extension Partnership, U.S. Department of Commerce) program, jointly to offer and deliver a more comprehensive range of business services and solutions to small and medium manufacturers, to help them become Lean in terms of both operational productivity and energy consumption
- Develop a computer-aided energy audit book, and an on-line course as a training and auditing tool for both university students and manufacturing organizations.

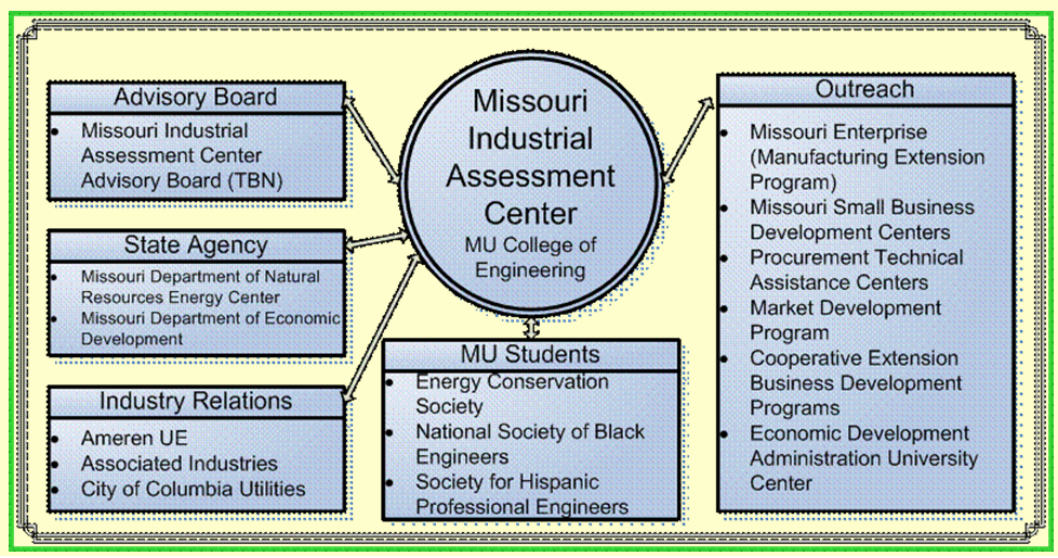
The State-Wide Network of Missouri Industrial Assessment Center

With the backing of the U.S. Department of Energy's IAC (Industrial Assessment Center) program, and in partnership with the Missouri State Department of Natural Resources (MoDNR), the State Department of Economic Development, the MU Extension, and the Missouri Manufacturing Extension Partnership (MEP) center, a new Industrial Assessment Center (IAC) has been established in the MU College of Engineering (Missouri IAC, see: http://iac.missouri.edu). The primary objectives of the Missouri IAC are to (see IAC Website, IAC Field Mangers' Website):

- Provide students with practical experience and training in energy engineering
- Help small- to medium-sized manufacturers improve energy efficiency, minimize waste and improve productivity
- Integrate the IAC program into other areas to create innovative approaches to delivering services

The overall structure of Missouri IAC is summarized in Figure 1. Since early 2005, the Missouri IAC team began a number of state-wide initiatives that lay a strong foundation for the organization and operation of the center. Integration of activities between the center and its partners are logical and seamless, so that the mission of each can be directly supported or supplemented by those of the other:

Figure 1. The State-Wide Network of Missouri IAC



- State Agencies: Due to the importance of the center to the economy, the competitiveness and the stability of the manufacturers in the state, both Missouri Department of Natural Resources and Department of Economic Development offer their full support for the center, committing resources to support the center, including administrative effort, technical assistance staff, and specialist equipments. Through working side-by-side on the various initiatives, the MU team and the state energy managers and engineers have developed a very fruitful working relationship.
- Manufacturing Extension Partners (MEP) program: In concert with the U.S. Department of Commerce National Institute of Standards and Technology (NIST), Missouri Enterprise is part of a nation-wide network of seventy-four MEP centers. With a cadre of field engineers and consultants to serve all Missouri small and medium manufacturers, its success is measured in client impact that can be directly enhanced by the mission of the Missouri Industrial Assessment Center. In return, the center benefits significantly from Missouri Enterprise's wide network of industrial clients in the state.
- MU Extension: As part of the MU Extension, MU Business Development Programs are housed within the MU College of Engineering, and work with partner host institutions across the state to provide Missouri's prospective and existing small business owners the educational and technical assistance resources they need to remain competitive. Using individualized counseling and instructional resources, the network promotes the services and best practices with Missouri IAC.
- Industry Partnerships: Associated Industries of Missouri is a non-profit organization that represents Missouri's industrial base. Since 1919, Associated Industries has helped Missouri businesses succeed at business by offering training and educational opportunities; providing a variety of valuable resources to its members at a reasonable cost. As representative of Missouri's industries, AIM is a key to reaching industries and promoting best practices to Missouri industries.
- State-Wide and Local Utilities: As part of the Ameren Corporation (a Future 500 energy company), AmerenUE is Missouri's largest electric utility, and provides energy services to approximately 1.1 million customers across the eastern half of Missouri. It serves 65

Missouri counties and 500 towns. From the company's perspective, Missouri IAC is: "a good fit with energy efficiency concepts we have proposed as part of our integrated resource plan filing with the Missouri Public Service Commission."

- Student Organization: Affiliated with the center, the MU Student Society of Energy Conservation if formed: "To promote energy awareness, conservation, and efficiency. To promote renewable and clean energy systems. To educate ourselves and the public about energy conservation…" The Society collaborates with, and compliments to the center activities in a number of areas.

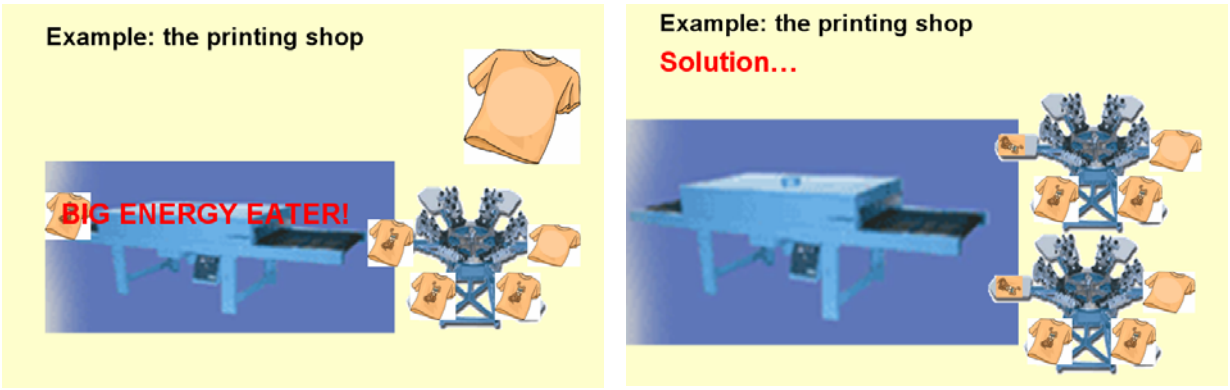
The LEAN^{+} Concept

For any manufacturing organization, it is important to realize, and to promote the concept, that Lean Production should mean to be "lean" in terms of both operational productivity and energy efficiency. That is:

$$Lean^{+} = Lean\ production\ processes + Lean\ energy\ consumption$$

During a system improvement effort, the importance and benefits of taking both simultaneously into consideration is illustrated clearly by the following real-life example. Company X is a printing shop that utilizes the printing facilities as shown in Figure 2 to print customer-specific designs on T-shirts: the design is first printed on the shirts, and the shirts are then baked in an oven to dry the printing. The company had eight such lines and the eight ovens were on almost all the time, consuming a significant amount of energy.

Figure 2. An Example of the Lean+ Approach



An alternative solution is also illustrated in Figure 2, where the facilities are rearranged so that each oven serves two printers. All needed is for the operators to, before putting the shirt into the oven; fold the printed shirts in such a way so that only the printed portion is exposed. As a result the conveyor of the oven is now wide enough to handle two lines of folded shirts at the same time. Instead of eight, only four ovens are now needed for the factory, cutting the utility bills for the printing processes almost immediately to half. So that significant savings are possible through a lean process design, in addition to the normal energy related, technical considerations such as efficiency of the ovens.

The above is an excellent example of how, when process improvement and energy consumption are taken into consideration in the same time, system improvement can have a more significant impact.

Missouri IAC, Missouri Enterprise, and MU Extension Partnership

Based on this philosophy, we have developed a very close working relationship with Missouri Enterprise (http://www.missourienterprise.org), and MU Business Development Programs. Jointly, the partnership aims to deliver a more comprehensive range of business services and solutions to small and medium manufacturers, offering services to help clients to become more competitive through achieving lean production and energy efficiency and waste minimization. Clients are offered a complete package of system improvement, involving:

- Lean process analysis
- Energy audit
- Environmental protection and Green Suppliers Network

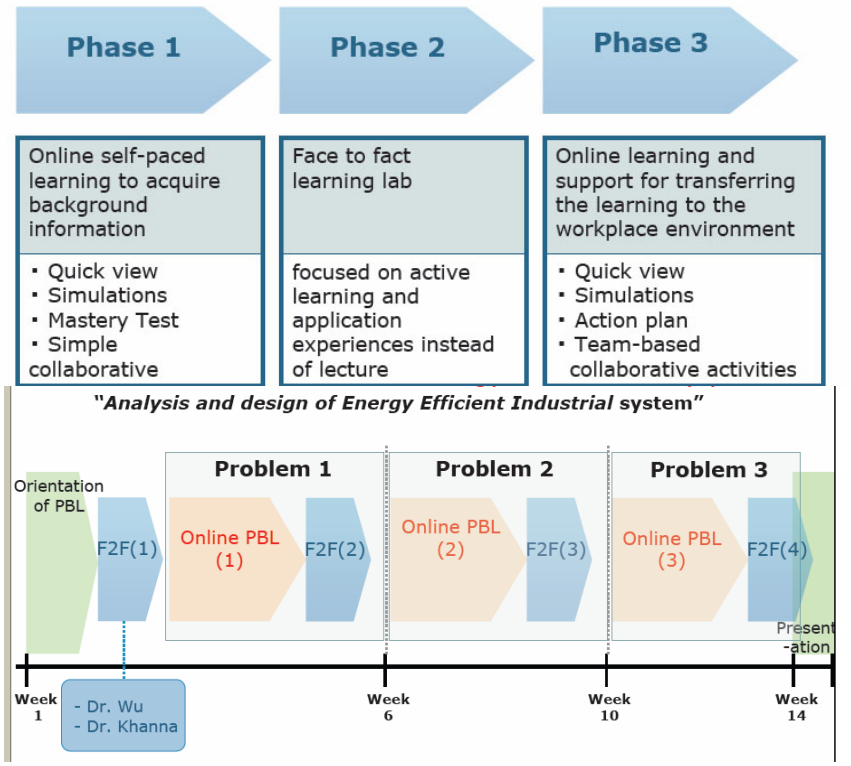
The package is also flexible with a modular structure, so that it can be tailored to the specific needs of a client. Up-to-date we have conducted a number of such joint assessment/consulting project, with others to follow, to increase the likelihood of major energy and productivity improvement. Many of Missouri Enterprise' personnel have been exposed to the IAC mission, recourses and training. With the adequate skills, Missouri Enterprise consultants have helped Missouri IAC with the identification and solicitation of suitable clients for energy audit.

In addition, working with MU Extension and with participation of State Energy Engineers from MO Department of Natural Resources, the Missouri IAC has delivered a serious of workshops at different locations across the state. These workshops are designed to provide manufacturing companies and industrial consultants a focused overview on the most important aspects regarding current best practice in industrial energy efficiency. These workshops are well attended and the feedback from the attendee organizations is extremely positive.

Curriculum Development

An on-line course, Analysis and Design of Energy Efficient Industrial Systems, is being developed. This aims to help students understand and adopt more energy efficient and environmentally friendly technologies, new materials and manufacturing processes that generate energy savings while improving productivity. We are developing three innovative options: 1) a three-credit-hour senior undergraduate/first year graduate course: Analysis and Design of Energy Efficient Industrial Systems, that is supported by an online version; 2) a derivative of this course to be offered to practicing engineers through MU Extension and MU Continuing Education; and 3) a performance support system to provide advice to companies regarding energy audits.

Figure 3. Structure of Class (PBL: problem-basing learning; F2F: face-to-face session)

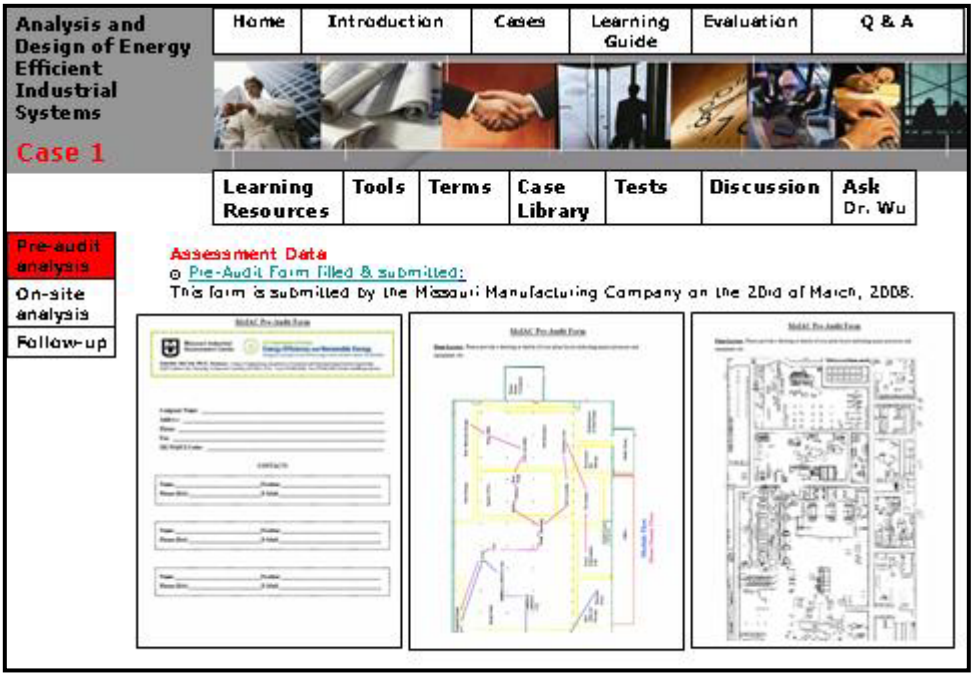


Analysis and Design of Energy Efficient Industrial Systems is a problem-based learning (PBL) course that supports the kind of diagnosis-solution problem solving required to perform a competent energy audit (Figure 3). The justification for a PBL course is that analysis, design, and improvement of energy-efficient industrial systems require a combination of two skill sets: technical knowledge of the systems and problem-solving ability (Wu 1996). A PBL course provides an intensive, interactive and experiential learning environment that is more effective for the students to gain such skills (Jonassen, Schmidt, Miller and Neumeyer, 2005)

Once the problem domains are identified, three problems per domain will be developed for web-based delivery. For each problem, the online course will comprehensively present the problem and provide background conceptual materials (Figure 4). Students are required to analyze the problems and identify the possible solutions (Figure 5). Following this approach, the course will include sets of problems. Each problem will include a problem representation, a multi-layered conceptual model of the systems being analyzed, a computer-aided workbook, and a case library of similar analyses. Relevant technical knowledge in the course will include topics such as: introduction to energy management, fundamentals of industrial systems analysis and design, heat transfer, fluid mechanics and electrical science, boilers, furnaces, motors, lighting, HVAC, compressed gases, electrical energy management, insulation use and design, waste reduction, performance of building envelopes, alternative energy sources, energy policy and codes, economic analysis, energy auditing, and national energy security and reliability. In essence, this learning-through-doing approach exemplifies a number of contemporary learning theories, including anchored instruction, case-based reasoning, and problem-based learning.

Students in the course will also be exposed to the Missouri IAC activities through industrial visits, seminars and presentations.

Figure 4. Screen Example: Audit Case



The course to be delivered through MU Extension and MU Continuing Education to practitioners in the field will be a self-instructional course that de-emphasizes the conceptual components of this course, focusing instead on the processes and similar cases in order to familiarize the practitioners with the mechanisms of energy analysis. In addition, the online performance support system will help an industrial organization if and when an energy audit is appropriate.

Figure 5. Learning Assessment Criteria

Rubric/Criteria for a final audit report

A. Problem identification
4. All energy problems in each energy system are identified
3. All energy problems in some of the energy systems are identified; some energy problems in each energy system are identified
2. A Few energy problems in some of the energy systems are identified
1. None of the energy problem is identified

B. Data analysis
3. All required data are collected and analyzed correctly
2. Some required data are collected and analyzed correctly
1. Data are collected but not correctly analyzed

C. Recommendation generation
3. Energy problems are solved by appropriate and practical recommendations
2. Energy problems are solved by appropriate but impractical recommendations
1. There is no recommendation generated or recommendation is irrelevant to energy problems

D. Correctness of energy saving calculations
4. Provide correct calculation of energy savings and payback years
3. Provide calculation of energy savings and payback year but not precisely correct
2. Energy saving and payback year are provided without concrete reason
1. No or incorrect energy saving and payback year are provided

As an aid to teaching, training and auditing, a computer-aided audit workbook has been developed 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, data collecting tools, procedures of analysis and calculation, and worksheets to support task execution and project management. Other notable features include links to other resources, the experts/expertise database, and a specially developed worksheet for calculating organization-wide energy consumption. With the completion of the necessary steps, the workbook provides templates for generating final recommendations and report. 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.

Student Involvement

Up to date, both undergraduate and graduate students have been successfully involved with the center's work - graduate classes through group projects, and senior undergraduate classes through Capstone projects. In addition to engineering, students majoring in physics, biochemistry and management have also been involved in the effort. In addition to industrial energy audit, these students have tackled many activities such as:

- Promotion of awareness, including the development of informational brochure on energy and productivity efficiency and waste reduction, which has been sent to a large number of industrial organizations in the state.
- Demographical analysis of industrial organizations in the state in regard to energy consumption, and development of a database containing the key information and the key statistics which have been very valuable in our campaign of awareness promotion.
- Development of the computer-aided energy audit book, initially as training and auditing tool for IAC students, but potentially also a tool that can be made available to the general manufacturing organizations to promote best practice.
- Experts/Expertise Base. This database lists and provides links to details of faculties with interests and experiences in various areas of energy efficiency and conservation, from all the major universities within the State of Missouri. The experts are grouped according to their area of expertise and their institution, and database is searchable accordingly to provide contact details and more detailed information. Through a link this database is incorporated within our computer-aided audit workbook, making it a useful on-line tool if any additional and/or specialist help is required by a client during an energy audit.
- Formation of the MU Student Energy Conservation Society, intended to help in promoting awareness of energy efficiency and IAC activities, both within the student population and in the community at large.

Conclusion

Although a new IAC center, Missouri Industrial Assessment Center's state-wide networking effort is believed to be novel and timely. Our approach, based on an extensive

network of stakeholders, has already been proven to be beneficial to all concerned. In this case, outreach, research and educational activities are truly and seamlessly integrated.

We are now able to offer a comprehensive package of services regarding industrial system improvements. The state energy managers and engineers have made use of their experiences to help train the center students. The industrial partners interject a "voice of the manufacturing client/customer" into the process of initiating, reviewing and making recommendations to the curriculum development effort to be carried out by the center, to assure that the results meet the needs of industry and the community. The MU Extension also utilize its educational and training network to help the center's training effort, including facilitating a series of energy seminars across the state. The MU Student Society of Energy Conservation helps promoting awareness of energy efficiency and waste reduction through presentations, seminars, and workshops, for the university and school (high/middle) student population in the region, and through its newsletters and articles.

Through these efforts, we now have a platform and network that provide our students and clients with excellent learning and consulting opportunities about industrial energy efficiency both within the university and in the community, benefiting from the expertise, experiences and resources brought in by the university faculty, the government agencies and the industries.

Acknowledgement

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