Educating The Next Generation Of Energy-Savvy Workforce

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ABSTRACT

This paper reports a problem-based learning model for the training of university students in the area of industrial energy efficiency, and discusses its context, contents, and the results from its implementation. The impact has been significant, with hundreds of university graduates trained and many of them now working in industry, leading their organization's energy efficiency initiatives.

Keywords: Energy Efficiency; Engineering Education; Energy Management; ISO50001

INTRODUCTION

The needs are obvious. To help reduce greenhouse emissions and be a responsible citizen, an industrial company 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 (Wu, 2009, Bunse et al., 2011; EPA, 2011; Carrico & Riemer, 2012). There have been plenty of real life cases to support the claim that "energy efficiency is a source of energy" (Giacone & Mancò, 2012). A good example is the case of Dow: significant reduction of energy intensity has been achieved globally in its network of manufacturing facilities during the past two decades (DOE, 2012; See Figure 1). Also, it is evident 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. However, in reality companies are often faced with obstacles such as 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 institutionalized operational procedures and standard to set the energy efficiency program in the facilities; and, in some cases, resistance to changes recommended by science related to climate change (Chai & Yeo, 2012; Kounetas, et al., 2011; Wu, 2007).

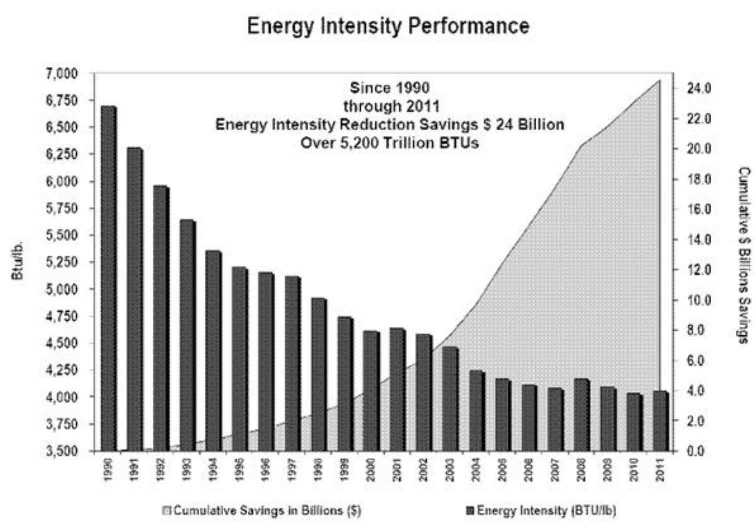

Figure 1 (DOE, 2012)

In essence, companies in the real world need assistance to overcome the obstacles. The education and training of the next generation of energy-savvy engineers and professionals is *the* key in a systematic approach to help the industrial sectors to effectively initiate and implement energy efficiency programs. This paper reports an experimental-learning based model for the training of university students in the area of energy efficiency, and discusses its context, contents, and the results from the last decade of its implementation. It describes how such a systematic effort has been carried out at the University of Missouri (MU), through the Missouri Industrial Assessment Center (U.S. Department of Energy, IAC Program) in the MU College of Engineering, which logically integrates the university, the state agencies, the MU Extension, and the major utilities in the state, to achieve its educational goals.

The impact of this initiative has been significant. More than 500 MU students have been trained in the concepts and techniques of industrial energy efficiency, with many of them now working in industry, leading their organization's energy efficiency initiatives. For example, one of our graduates is leading a multi-national manufacturing organization's global effort to institutionalize best practices in energy efficiency at its 150 manufacturing sites with an estimated potential saving of $50M annually, and our former Lead Student is currently a state energy manager and part of the state government energy team (Wu, Ponte, & Pinthuprapa, 2013).

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, Missouri Industrial Assessment Center (MoIAC) (http://iac.missouri.edu) has the objectives to:

- 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

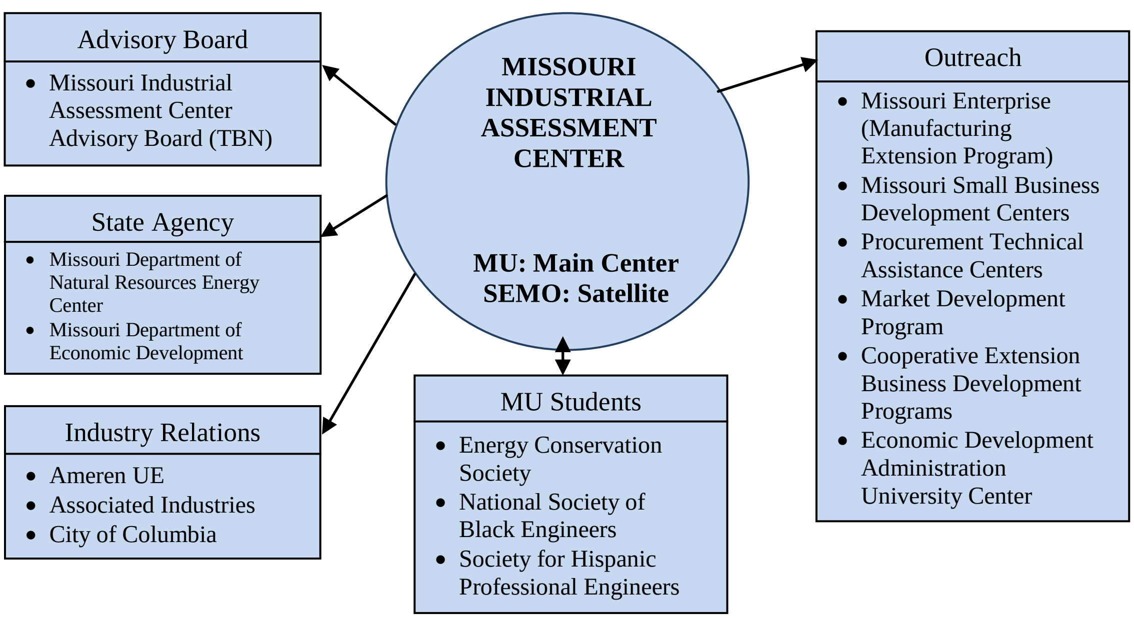

Figure 2

The overall structure of Missouri IAC is summarized in Figure 2 (Wu, 2009). The integration of activities between the MoIAC and its partners is logical and seamless. This network will be extremely effective in helping the MoIAC to accomplish its mission in student education, as well as in outreach, research and development. *State*

Agencies: Working side-by-side on various initiatives, the MoIAC team and the state energy managers and engineers have developed an extremely fruitful working relationship. *Manufacturing Extension Partners (MEP) Program:* This is also a well-established and productive partnership that will provide our students with valuable experience involving an extended range of skills and considerations. *Industry Partnerships through MU Extension and Technology Resource Center (TRC) at SEMO:* MU Extension's Business Development Programs assist more than 15,000 Missouri companies each year. *Statewide utilities:* The major state and local utility providers have agreed to partner with the MoIAC: Ameren UE (largest utility in state), the City of Columbia, Kansas City Power and Light, Springfield City Utilities, and the Missouri Public Utilities Alliance which represents over 120 Municipal utilities across the state. *Student Organizations:* The MU Student Society of Energy Conservation, the NSBE, and the SHPE will collaborate with and complement the MoIAC activities.

CURRICULUM DEVELOPMENT

Education and training has been one of the key elements of MoIAC operation, and the center has had a particularly significant impact in this regard. Its state-wide framework provides a strong foundation for the education and promotion of energy efficiency in the university student population. Integration of activities between the center and its partners are logical and seamless, so that the activities and goals in both academic education and practical experiences can be directly supported or supplemented. The center has incorporated industrial energy efficiency topics in all MU classes related to manufacturing systems design and operation, at the junior, senior, and graduate levels. Working with industrial sponsors, many senior capstone (two semester project)/MSc projects have been carried out in the area of energy efficiency analysis and implementation. More than 500 MU students have been trained in the concepts and techniques of industrial energy efficiency, with many of them now working in industry, leading their organization's energy efficiency initiatives.

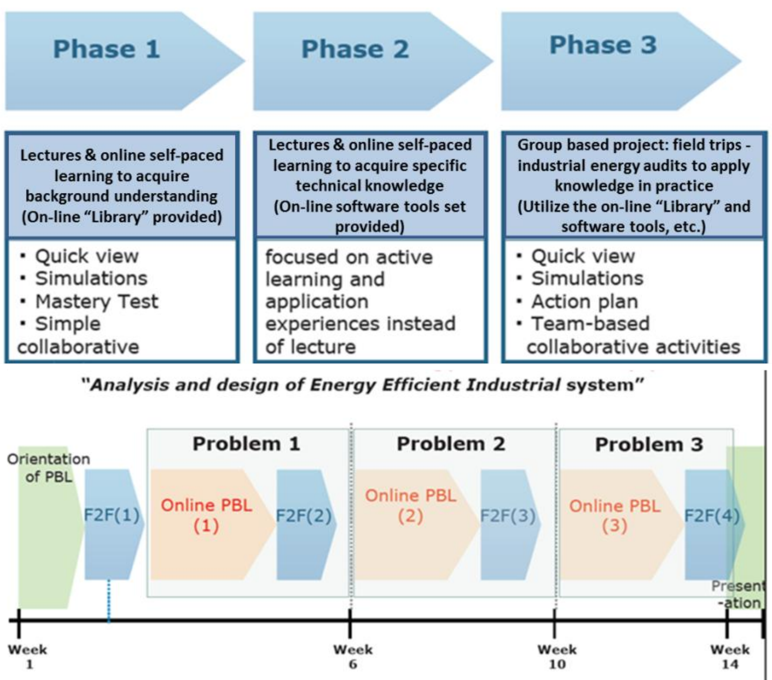

Figure 3

A number of classes in the area of industrial energy efficiency has been developed and delivered and a minor degree has been introduced in the MU College of Engineering. In particular, a three credit-hour class *Analysis and Design of Energy Efficient Industrial Systems* has been 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. Based on this, three innovative options have been developed: 1) a three-credit-hour senior undergraduate/first year graduate course 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 management.

STRUCTURE AND CONTENTS

As a problem-based learning (PBL) course, it is designed to support the kind of diagnosis-solution problem solving required to carry out a competent initiatives related to energy efficiency (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. A PBL course provides an intensive, interactive, and experiential learning environment that is more effective for the students to gain such skills. Since industrial energy efficiency efforts involve a large number of documents and multitude of concepts, analysis, and decisions, an effective means is needed to support the tasks involved.

Following the structure outlined in Figure 3, the class topics are as summarized in Table 1. It consists of three main topic groups:

- Background knowledge of energy efficiency and management
- Technical knowledge of best practice in industrial energy efficiency
- Site project – energy assessment project involving real manufacturing/industrial organizations

Table 1

Week	Topics
1	Course introduction
2	Introduction to energy management system
3	Overview to ISO50001
4	Production systems improvement and energy efficiency **Assignment 1**
5	Intro. To heat transfer and thermodynamics
6	Basics of electricity, lighting, and motors
7	Steam and its applications
8	Intro to heating and cooling
9	Compressed air system and best practice
10	Energy transmission and storage -- **Test 1**
11	**Spring Break**
12	Site project
13	Site project --- **company assessment report 1**
14	Site project
15	Site project
16	Site project --- **company assessment report 1**
17	**FINAL EXAM**

The system concept of energy management, structured problems-solving, continuous cycle of improvement, and the newly established ISO 50001 standards (ISO, 2012) are the main focus of the first topic group. In MoIAC, we have been preparing ourselves, our partners, and our students for the ISO 50001 standards for the past two years. In the industrial sectors, it is well understood 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, 2002, 2013). This cycle of continuous improvement is the foundation of the ISO 50001 (ISO, 2012). In order to become compliant with the new standard, organizations need approaches and tools to help with: 1) education and training of personnel; 2) planning and execution of energy efficiency projects, including planning, data collection and analysis, identification of opportunities, detailing and justifying recommendations, implementation tasks; and 3) institutionalization of best practices in the organizational and operational structure, including analysis and investigation of an organization’s specific needs, identification of best practices guides and operational procedures, and documentation. We have developed technical presentation and materials for our students such as: “ISO 50001: Web-Based Framework for the

Institutionalization of Industrial Energy Efficiency." The structure and functionality of our web-based tool can play a key role in achieving the teaching goals and our effort and results to date have been reported (Wu, 2011).

Relevant technical knowledge in the course include topics such as (Doty & Turner, 2009): 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. Based on real-life cases, for each area, problems are provided and the students are required to analyze the problems and identify the possible solutions. Some of such problems are listed in Figure 4. Each problem will include a representation of the systems being analyzed, and a case library of similar analyses, as illustrated by the example given in Figure 5.

Description
Utilize Higher Efficiency Lamps And/or Ballasts
Eliminate Leaks In Inert Gas And Compressed Air Lines/ Valves
Use Most Efficient Type Of Electric Motors
Install Compressor Air Intakes In Coolest Locations
Utilize Energy-efficient Belts And Other Improved Mechanisms
Reduce The Pressure Of Compressed Air To The Minimum Required
Insulate Bare Equipment
Use More Efficient Light Source
Install Occupancy Sensors
Analyze Flue Gas For Proper Air/fuel Ratio

Figure 4

AR 8: Install Steam Turbine to Waste Water Boiler for Electricity Generation

Estimated electricity usage savings = 3,140,012 kWh annually
Estimated electricity usage cost savings = $110,214annually
Estimated electricity demand savings = 4742 KW-Months annually
Estimated electricity demand cost savings = $41,923 annually

Estimated Implementation Cost = $150,000
Simple Payback Period 1.2 years

Existing Practice and Observation

The facility uses outside boiler for waste water treatment, rated at 100 HP with a gas input of 3.35 MMBtu per Hour. Water is boiled until the contaminants are solidified and left to be disposed. The steam generated through the process is completely and directly disposed outside.

Recommended Action

A large amount of heat is wasted through the direct disposal of the entire steam generated by this boiler. It is recommended that a steam turbine be installed to generate electricity. The result will be simply a conventional thermal power station. This will contribute in reducing the electricity consumption and demand and utility costs.

Analysis

In the following, we provide analysis to illustrate the potentials involved, with data and assumptions based on data gathered during our visit and the subsequent communications with the company. By knowing the temperature and pressure of the steam produced, the power that can be generated from this steam can be calculated. Steam thermodynamic properties charts were used to calculate the enthalpy of the steam:

h_{steam} = Enthalpy of the steam at the specified pressure and temperature
h_{steam_out} = The enthalpy of the steam exiting the turbine (assuming the pressure is the same as the outside pressure).

Now, the work generated by the steam is:

Work = $v\_steam^{\cdot} \times ϱ \times (h_{steam}\text{-}h_{steam\_out})$

$v\_steam^{\cdot}$: The volumetric flow rate of the steam exiting the boiler.
ϱ : Density of the steam exiting the boiler: 0.535 kg/m^3

As an example, for output temperature of the steam at about 215 F, the power that can be produced by the turbine each m^3/second of steam will be about:

Work = $1\frac{m^3}{sec} \times 0.535\frac{kg}{m^3} \times (2674\frac{kj}{kg} - 2500\frac{kj}{kg})$ = 150 kW.
……….

Figure 5

Finally, the site visits and company related projects are a very valuable learning element for the students. This provides a unique opportunity for the students to relate classroom learning with real-world problem-solving. As an aid to teaching, training, and auditing, a computer-aided audit workbook provides a complete guide to the processes, tasks, and outcomes of an energy assessment (Figure 6. Workbook available on-line at: http://iac.missouri.edu/webtool/flowchart/flowchart.html). 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.

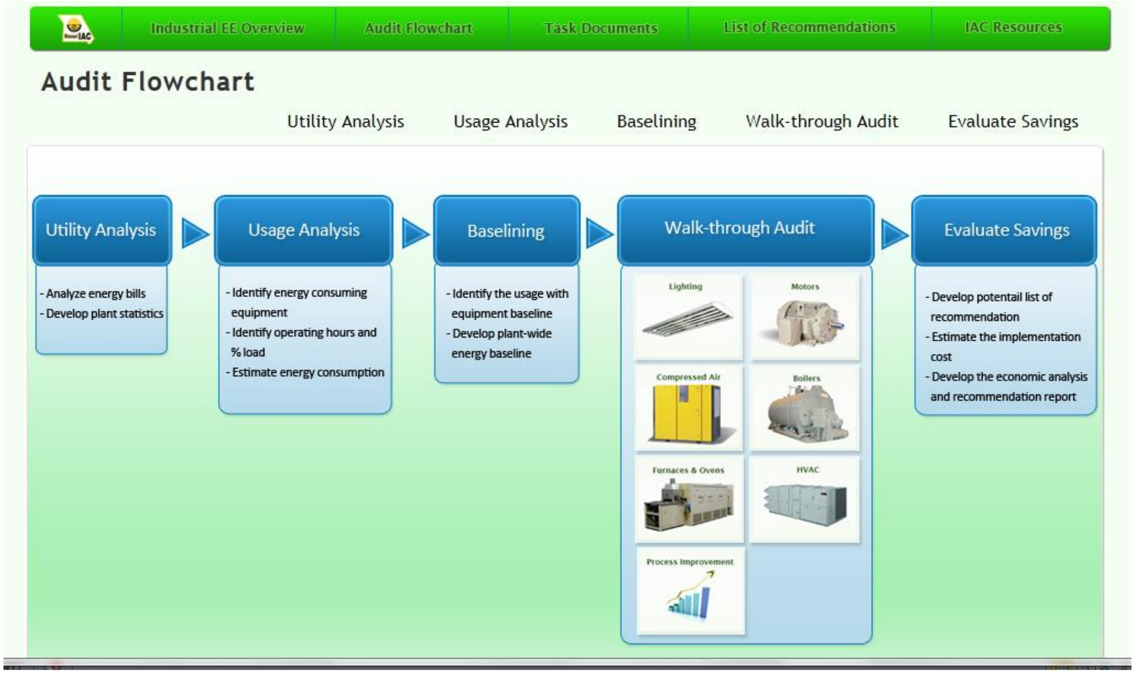

Figure 6

SUPPORTING MATERIALS

To help achieve its goal, a comprehensive collection of teaching materials have been gathered/developed and provided to the class, including:

- An on-line library of reading materials, such as books, technical publications, best-practice tip-sheets, study guides, etc., covering all of the topic areas as outlined in the syllabus.
- A computer-aided framework has been developed to help with the learning, adaptation, and institutionalization of best practices in energy efficiency within an industrial environment, see the sample page shown in Figure 7. Its contents follows logically the key stages of a continuous cycle of improvement (which is the foundation of the newly established energy management standard ISO50001 (ISO, 2012)). The concept of task-centered approach is adopted to provide the basis for the development of this computer-aided framework to incorporate all the procedures, processes, and tasks along the cycle of continuous improvement. The workbook utilizes 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 tables, procedures of analysis and calculation, and worksheets to support task execution, project management, and documentation. It is structured in a user-friendly and practical way, intended to support:
    - Interactive learning and training, by providing learning materials and best practice guides and resources in a focused way.
    - Application in actual energy improvement project.
    - Working data/tool sheets that can be populated for data collection and task execution.
    - All of ISO50001 requirements in organization, personal, task planning, task execution, and documentation.
- A collection of software tools.

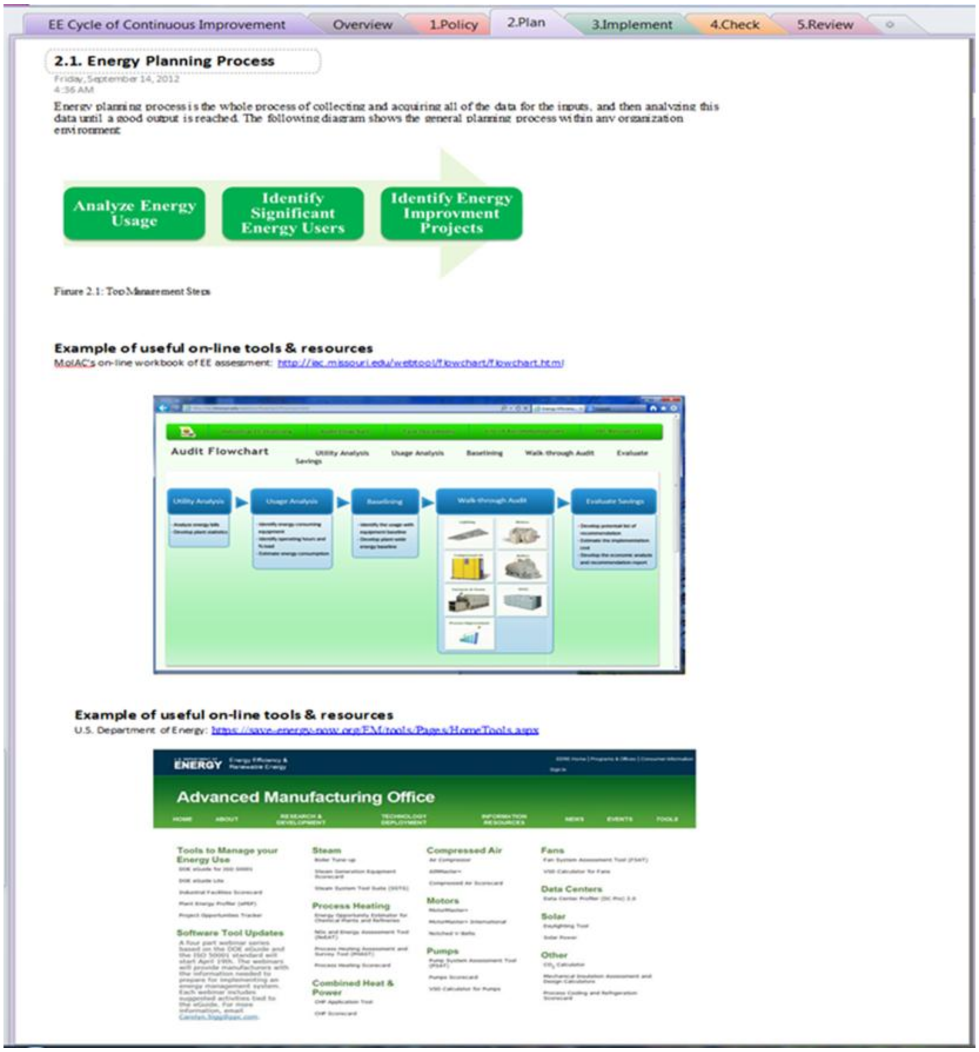

Figure 7

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 assessment, 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.
- 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.

- Collaboration with state government agencies. 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 feedbacks from the attendee organizations are extremely positive. Many students have actively participated in these workshops.

CONCLUSION AND FUTURE WORK

The impact of this initiative has been significant. More than 500 students have been trained in the concepts and techniques of industrial energy efficiency, with many of them now working in industry, leading their organization's energy efficiency initiatives.

Our approach, based on an extensive network of stakeholders, has proven to be very 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 companies 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. We plan to carry out future evaluation to assess the long term impact of such efforts in the industries.

AUTHOR INFORMATION

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