Development of a course in energy management for engineering and technology programs

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Abstract

The energy management field is experiencing significant growth, due to the restructuring of the utility industry, the building automation, and increasing demand for energy services. There is a growing need for engineers with skills in energy, environmental, and facilities management. This paper presents the development of an undergraduate course in the area of energy management and industrial energy systems. The objective of this course is to study energy management methods, procedures and functions as performed in modern residential, commercial and industrial facilities. "Energy management" is a broad term that has a number of different meanings. However, energy management is about managing available resources and equipment to make the most efficient use of energy. Courses with "energy management" in their names or descriptions often cover broader environmental and economic issues as well the implementation of practical solutions. Energy Studies and Energy Management are all about how to make best use of our present and future energy sources, by addressing critical economic and environmental issues, by considering the technical, economic and social factors, affecting energy demand. Our course is focusing more on technical and engineering aspects of energy management, rather than environmental or economic aspects. The course aims are to train students to use process integration methods and analysis and optimization tools necessary for identifying and designing efficient industrial energy systems that contribute to sustainable development. The paper describes our efforts and challenges, course contents, pedagogical approaches to enhance student comprehension of the concepts involved. The course goals and objectives are to provide students with methods, tools and procedures to identify the cost-optimal mix of different energy technologies to satisfy a given energy demand in most efficient way.

Introduction, Fusion Green Manufacturing into Engineering and Technology Programs

Energy is a vital source of economic development. To meet the global needs of economic growth there is a dramatic increase in the demand of energy. Unlike the developed countries the developing countries are struggling to meet the increasing demands of energy. Hence different energy management systems and models are adopted to fulfil the needs of the growing economy. Today economies, both developed and developing ones face a two-fold energy challenge in the 21st century: meeting the needs of billions of people who still lack access to basic, modern energy services while simultaneously participating in a global transition to clean, low-carbon energy systems. Both aspects demand urgent attention, because of the access to reliable, affordable and socially acceptable energy services is a pre-requisite to alleviating poverty and meeting other societal development goals and because of emissions from developing countries are growing rapidly and are contributing to environmental problems that put the health and prosperity of people around the world at grave risk.

Historically, humanity's use of energy has been marked by four broad trends: (1) rising consumption and a transition from traditional sources of energy (e.g., wood, dung, agricultural residues) to commercial forms of energy (e.g., electricity, fossil fuels); (2) steady improvement in the power and efficiency of energy technologies; and (3) a tendency (at least for most of the 20th century) toward fuel diversification and de-carbonization, especially for electricity production; and (4) reducing pollution emissions[1-16]. These trends have largely been positive. However, the rate of technology improvement has not been sufficient to keep pace with the negative consequences of rapid growth in energy demand. The task, then, is not so much to change course as it is to accelerate progress, especially toward increased energy efficiency and lower-carbon emissions. This would have many concurrent benefits for developing countries in terms of reducing pollution and improving public health, making feasible a broad expansion of access to basic energy services and laying the foundation for more competitive industries and future economic growth. Moreover, to the extent that sustainable energy policies promote the development of indigenous renewable-energy industries, they will have the additional benefit of creating new economic opportunities, reducing countries' exposure to volatile world energy markets and conserving resources for internal investment by curbing outlays for imported fuel.

Energy management, sustainability energy conservation and efficiency can be taught in many disciplines, including, but not limited to: design, engineering, manufacturing, technology, and management[1-14]. Either we are focusing here on the issues related to development of the energy management or industrial energy course, will also outline how sustainability and energy management might be integrated into the curriculum from perspectives of courses and students' research and projects. At the course level, examples of how to integrate the concepts and applications of sustainability into existing material will be discussed. The current situation and the demand for a sustainable and efficient use of energy knowledge are more and more required and expected by employers. Sustainable development is a contemporary issue for everyone to embrace, especially engineers, engineering technologist, architects, designers, manufacturers, etc. Sustainable development is common practice in most of the developed countries; however, the concept has not been mainstreamed into engineering education within the U.S[4-12]. Several U.S. engineering societies have made declarative statements about their commitments to sustainable development[5-12]. Students who at least have some knowledge of sustainability related to their discipline can be winners in obtaining careers in the new green jobs market. While green energy jobs are found across all industries, the most likely place to find them are in renewable energy, industrial energy systems, green and eco design and energy management. Green energy jobs involve any of the following activities:

1. Energy generation from renewable energy sources
2. Manufacturing of goods used in renewable power generation, construction, and installation of energy and pollution management systems
3. Engineering and consulting services in support of the activities above

There is increasing motivation to incorporate concepts of sustainability, energy efficiency and management into the undergraduate engineering and technology curricula. The Accreditation Board for Engineering Technology, Inc. (ABET), requires that graduates be able "to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability”[3,4]. There are several initiatives to promote the sustainability of engineered systems and energy efficiency, while still improving the quality of life, looms more immediate. Not only accreditation boards and professional organizations but many major corporations are concerned with sustainable development to reduce costs and liabilities and to create products that help improve the quality of life here and abroad. One of the steps in developing the curriculum was to assess the availability of educational and training programs available to students. It was found that not too many institutes were offering courses and/or training programs that were related to the energy efficiency, sustainability, green design and renewable energy fields. Schools with undergraduate engineering programs are working to include sustainability and sustainable design into their curricula[6-12]. The methods for doing so can be subject-, problem-oriented, can be based on case studies, or could be part of a capstone experience. Sustainability can also be an opportunity to satisfy the general education component of ABET criteria.

In our green manufacturing project, a two-level approaches was taken in our curriculum changes to incorporate sustainability, green, sustainable design and renewable energy subjects. A first level such topics, subjects and problems were introduced by the faculty involved in this project in their courses, where it is appropriate. Projects for the senior deign project capstone course sequence were proposed and directed by the investigators. Limited financial support was also provided, via grant funds for these senior design projects. At second level several courses on green manufacturing, sustainability, industrial energy systems, and renewable energy technology were proposed, developed or underway to be developed. However, the efforts to integrate sustainability, green manufacturing, renewable energy into our curricula have met with some resistance in problems related to 1) adding new courses or integrating instruction in sustainability, green design, industrial energy systems and renewable energy contexts into already tight engineering technology curricula, 2) the faculty inter-disciplinary expertise necessary to teach new sustainability, green design or renewable energy topics, 3) the resistance to revising existing senior design project courses, and 4) new laboratory infrastructure[6-12]. The green manufacturing, renewable energy technology and sustainability skills and knowledge are required to meet the following objectives, including energy efficiency and management, sustainable planning and design, sustainable and green manufacturing, and renewable energy sources such as biomass, biofuels, solar power, and wind energy. These components are selected because they represent green technologies highest potential impact in our areas. Development of a workforce skilled in these areas is essential toward sustaining a green economy in these regions. Several interdisciplinary, sustainability-related courses have been proposed, developed, offered or are underway to be developed in the course of this project. A life cycle engineering and environmentally responsible design and manufacturing seminar is also proposed to be part of the endeavor. Although these courses have created a quite high level of awareness among our students, they are not required of all students, and no pervasive sustainability theme has been established in our curricula. The authors believe that more information and real-world learning experience will be required in each curriculum to incorporate a sustainability theme. However, care should be taken and new innovative strategies should be explored.

Our approaches taken for our curriculum changes to incorporate sustainability, green design and renewable energy subjects consist of the following steps. First such topics were introduced by the faculty involved in this project in their courses, where it is appropriate. Projects for the senior deign project capstone course sequence were proposed and directed by the project investigators.

Limited financial support was also provided, via grant funds for these senior design projects. At second level several courses on green manufacturing, sustainability, industrial energy systems, and renewable energy technology were proposed, developed or underway to be developed. However, the efforts to integrate these topics into our curricula have met with some resistance in problems related to: 1) adding new courses or integrating instruction in sustainability, green design, industrial energy systems and renewable energy contexts into already tight engineering technology curricula, 2) the faculty inter-disciplinary expertise necessary to teach these new topics, 3) the faculty resistance to revising existing senior design project courses, and 4) new laboratory spaces and infrastructure[26-32]. The new courses related to this projects include: 1) Renewable Energy Technology; 2) Industrial Energy Systems; and 3) a future course on Green Manufacturing and Clean Technology. First course was offered several times since Spring 2011, while the second one was first time offered in Fall 2014 quarter. The last one is planned to be offered, as an elective special topics course during Summer 2015 quarter[6-9].

Energy Management Systems

Energy is and has been an indispensable component of and a key requirement for human existence/activities. Many of the conflicts that have bedeviled humanity can be linked directly or indirectly to energy acquisition. There is a direct correlation between the economic wellbeing of a nation and the per capita energy consumption. Consequently, the world today is witnessing a paradigm shift regarding acquisition and control of energy resources. Industrial, power, energy and manufacturing companies all over the world are realizing that the energy and sustainability issues are very critical for the competitiveness and survival of their business. This awareness has created a renewed focus on energy as a manageable input. The high price volatility, tough global competition and high energy demand are forcing companies to review their energy consumption patterns and finally adopt energy management systems. There are so many market influences that will drive the growth and demand of energy management including the desire to reduce cost of energy inputs, satisfy the increasing sustainability demands from supply chain partners, consumers, stakeholders and their band image.

The need to manage energy for manufacturing companies to reduce the energy input cost is not the only driver of the need of energy management. The global need to save energy is the most important concept in this regard. Acquiring sufficient energy economically, safely and cleanly is important for the manufacturing companies. It is a sign to show the level of development for countries. Companies are influenced are attracted towards the new technologies not only to minimize the energy input but also to gain sustainability[10-15]. An energy management system (EMS) is a system of procedures, methods and computer-aided tools used to monitor, control, analyze, assess and optimize the use and performances of industrial, commercial and residential energy systems and in industrial processes. EMSs are also often commonly used by individual commercial entities to monitor, measure, and control their electrical building loads. Energy management systems can be used to centrally control devices like HVAC units and lighting systems across multiple locations, such as retail, grocery and restaurant sites. EMS can also provide metering, sub-metering, and monitoring functions that allow facility and building managers to gather data and insights to make more informed decisions about energy activities across their sites. In a slightly different context EMS can also refer to a system in an organization to achieve energy efficiency through well laid out procedures and methods, and to ensure continual improvement, which will spread awareness of energy efficiency throughout an entire organization. It can also refer to a computer system which is designed specifically for the automated control and monitoring of those electromechanical facilities in a building which yield significant energy consumption such as heating, ventilation and lighting installations. The scope may span from a single building to a group of buildings such as university campuses, office buildings, retail stores networks or factories. Most of these energy management systems also provide facilities for the reading of electricity, gas and water meters. The collected data can then be used to perform self-diagnostic and optimization routines on a frequent basis and to produce trend analysis and annual consumption forecasts. The EMS course offers a diverse selection of technical training and career development opportunities for individuals who are interested in improving energy system performance or working in the energy industry.

Course Description, Objectives, Goals and Content

Energy courses have always been the core requirement for all the concentrations within the Industrial Technology program. Over the years, our department has been reviewing the employment trends as it relates to energy and power concentration. In an introductory course for industrial energy systems and sustainability, there should be a balance between breadth and depth of coverage. There is a need for breadth that provides an understanding of the complexity and system's nature of sustainability tempered by the realization that a full understanding of each of the issues that is a part of that complexity cannot be developed in one course. Full treatment of specific issues must be remanded to later courses in the curriculum. The benefits of the one-course approach can be summarized as:

- Course designed with a specific focus on energy management and energy efficiency in industrial processes;
- Multiple aspects of sustainability, energy efficiency and energy management are integrated throughout the course;
- No need for cross-departmental coordination of section offerings;
- No prerequisites, except standard physics and calculus courses.

The energy management systems course was first offered in Fall 2014 quarter as a 3 credit hour special topics course, due to the new course approval administrative procedures. It comprises of 10 lectures, one class project/case study, one field trip to a local energy company, two research oriented take home tests, and a final examination. Since the course is open to people with diverse technical backgrounds, emphasis is placed more on application and concepts rather than the core technical engineering principles. The course aims are to train students to use process integration methods and tools necessary for identifying and designing efficient industrial energy systems for a sustainable development. The course addresses use of methods to identify the cost-optimal mix of different energy technologies to satisfy a given process energy demand. Technical energy systems encountered in the course include electrical, thermal, and mechanical energy systems.

The objectives of this course are to enable the student to understand the fundamentals of energy supplies and uses, and how energy can be used more efficiently in buildings and industries, a comprehensive review basic energy related sciences. Other objectives are to enable the student to understand the methods of energy management in homes, institutions, businesses, large buildings and industrial facilities and processes, as well as the realistic potential of renewable energy sources, and to develop overall energy awareness and an efficiency ethic which can be used to help themselves and the organizations they work for. The course is a combination of classes and real assessment projects with hands-on site assessment of at least two real industrial companies to introduce the student to the fundamentals of the concepts and systems in energy efficiency. Another objective of this course is to familiarize the students with the application of standards and codes such as NEC, NEMA, IEEE and IEC for building and industrial electric and energy systems. Concise lab and project reports, clearly describing all conclusions and comments are also required during the course. This is a multidisciplinary course and in consequences we included required and recommended textbooks in the syllabus, as well as additional tutorials prepared by the instructor. The required and recommended references for this course are: Capehart B.L. et al, Guide to Energy Management, Doty, S. and Turner, W.C., Energy Management Handbook, Morvay, Z. and Gvozdenac, D., Applied Industrial Energy and Environmental Management, and Putman, R.E. Industrial Energy Systems: Analysis, Optimization and Control[13-16].

The class is planned for 10 weekly lectures of 4-hour each which represent 11 weeks on a regular quarter. This represents a normal quarter or can be adapted to summer sessions; this class is recommended for both scenarios. Lectures are considered to be classes that are given completely by the instructor or a specialist of the topic being taught. Two laboratory sessions on the major renewable energy systems are embedded in this course. The last section of each lecture (each divided in three major section: resources, system components and characteristics, and design) will focus on the design of the different products and/or systems that produce energy from renewable resources. This allows the students to understand how these products are made so they can understand further on how they are manufactured. The class will be evaluated thru two exams in order to assess the level of the student understanding of the course materials. The course is broken down into 10 modules. Brief details of three modules are described below. The course contains the following topics:

Week/Module 1: Introduction to Industrial Energy Systems Energy, Energy Management, Techno-economic Optimization of Resources in Industrial Equipment and Energy Systems.

Week/Module 2: Fundamentals: Units: Finance, Electrical, Thermal; Standards and Policy, Energy Bills, Energy Audits, Savings Analysis, Managing Energy Resources with the Corporate and Plant Information Technology System

Week/Module 3: Energy Conversion Equipment Characteristics; Understanding Energy Bills, Economic Analysis and Life Cost Cycle

Week/Module 4: Lightning; Mid-term Exam Review

Week/Module 5: **Mid-term Exam; Energy**; Heating, Ventilating, and Air Conditioning

Week/Module 6: Boilers and Steam Distribution Systems; Industrial Energy System Optimization Methods and Strategies; Optimization of Size and Design Parameters; Influence on the Environment.

Week/Module 7: Control Systems and Computers; Controls, Measurement, Verification, Modeling

Week/Module 8: Energy Systems Maintenance; Insulation; Economics of Energy Conversion in Industrial Energy Systems;

Week/Module 9: Motors, Compressed Air Systems, Energy Management Systems (EMS), Data Analysis

Week/Module 10: Smart Grid, Alternative Energy Sources, Green Buildings; Final Exam Review

Week 11: Final Exam; Project Presentation

Pedagogical approach and the unit structure were designed and envisioned to make and a gradual transitions for the objectives and applications of each topics to the methods, tools used and advanced applications. Several examples are included were included in each unit from simple applications to usually case studies of the unit subjects. Students were strongly encouraged work and solve in teams for home-works, assignments and case studies. Examples, problems and case studies were selected from required and recommended textbooks, as well as from the references or from the literature. A review of previous unit is included at the beginning of each unit/module. At the end of each module a short 10-min. quiz is given to the students to test their understanding of the materials presented in that unit. Each module consists of an 1) introduction and unit description; 2) theoretical development, and 3) problems and case studies. The case studies are designed**: *1) to reinforce and support unit/module theoretical development; 2) to emphasize the importance of corroborating the results of measurements and data analysis with the objectives of energy management problem and application; 3) to expose the students to tools, methods and practice used in energy management and industrial energy systems*** [17,18].

Sample of Course Units

Module 2: **Fundamentals**, **Energy Audit Process and Methods**

An important design aspect of any commercial or industrial facility is the development of an adequate energy management program. One of the most the important component is to conduct an energy audit. An energy audit is examining the ways energy is currently used in that facility and identifies some alternatives for reducing energy costs. The audit goals are:
• identify the types and costs of energy use,
• understand how that energy is being used, and maybe wasted,
• identify and analyze alternatives such as: improved operational techniques and/or new and more efficient equipment that can substantially reduce energy costs, and
• perform an economic analysis of the alternatives and determine the most cost-effective one.

This module addresses the three phases of an energy audit: preparing for the audit visit, facility survey and implementing the audit recommendations. The module outline consists of:

- Introduction, Energy Audit Purpose, Goals and Objectives
- Preparing Energy Audit; Types of Energy Audits
- Tools for Energy Audit, Facility Inspection & Evaluation
- Energy Management Opportunities;
- Energy Audit Report; Case Studies, Implementing Audit Recommendations
- Summary

Module 5: **Lighting**

The lighting system provides many opportunities for cost-effective energy savings with little or no inconvenience. In many cases, lighting can be improved and operation costs can be reduced at the same time. Lighting improvements are excellent investments in most commercial businesses, lighting accounting for a large part of the energy bill (30-70% of the total energy cost). Lighting energy use represents only 5-25% of the total energy in industrial facilities, but it is usually cost-effective to address, lighting improvements are easier to make than many process upgrades. While there are significant energy-use and power-demand reductions available from lighting retrofits, while lighting level standards of the Illuminating Engineering Society (IES) should be followed to insure worker productivity and safety. Inadequate lighting levels can decrease productivity. Most of the lighting retrofits are increasing productivity, and most likely to appeal to employees, clients and guests, having a positive impact on the facility, business reputation, prices and sales. A lighting retrofit program can be a win-win proposition for the business owner and the employees as it can improve morale, safety, and productivity while reducing life-cycle costs. Module/lecture provides a brief description of lighting systems, characteristics, and retrofit options. The module outline, objectives and goals are:

1. Learn and understand of lighting systems & components, their performances and characteristics
2. Understand the importance improving lighting system efficiency and energy usage for residential, commercial and industrial facilities
3. Lighting System Types and Characteristics: a) Lighting System Components; b) Lamp Types, Ballasts; and c) Luminaires/Fixtures
4. Lighting System Needs & Requirements
5. Maintenance, Lighting System Surveys and Monitoring
6. Regulatory Issues, Potential EMOS Identification
7. New Technologies & Approaches
8. Summary and Conclusions

Module 9: **Motors, Compressed Air Systems, and Process Energy Management**

Often, energy management is simply a matter of managing the energy required for lighting and space conditioning. In large industrial facilities, energy management is more complex, involving large motors and controls, compressed air systems, industrial insulation, complex combustion monitoring, steam distribution, significant amounts of waste heat, etc. Facilities offering large energy management opportunities are industrial ones, manufacturing plants, large office and commercial operations, and government institutions such as schools, hospitals and prisons. In generally they have specialized industrial, commercial or institutional processes that incorporate many of the concepts covered in other modules/lectures. These processes require in-depth evaluations to determine the appropriate energy-saving measures. In this module we first discuss the motors and controls, since they form an integral part of most industrial processes. Next, compressed air systems and air compressors are discussed since they are major suppliers of process energy. Finally, several case studies of process energy management opportunities are presented. The module outline consists of:

- Introduction
- Motors, Drives and Control; Adjustable Speed Drivers
- Compressed Air Systems, Components and Control
- Energy Process Improvement Methods
- Case Studies and Examples
- Summary & Conclusions

Student Assessment

Questionnaire		**Score**
Q1	Are the course topics challenging and interesting?	
Q2	A team project will be useful to you?	
Q3	It will useful to add a laboratory component to future INDE 420 (4 credits version of this course)?	
Q4	Have you learn more than expected with the course?	
Q5	Please, provide an overall evaluation of the course.	

Table 1 Questionnaire for the evaluation of the industrial energy systems course.

There were 20 students enrolled in the course, form engineering and technology programs. Generally, students expressed their desire to have more projects and practical experience, case studies, that will involve the use of software packages that are more popular in the energy industry. At the end of the quarter, all students have been requested to answer (with a five point scale: 1-very poor, 2-poor, 3-satisactory, 4-good and 5-very good) an anonymous questionnaire as shown in Table 1. According to the results, the new industrial energy system course received a 4.2 (and 0.95 standard deviation), on 5.0 point ratings, for all academic years when the course was offered, compared with an average rating of 3.4 for the all courses and years at our technology program. The results from the students' feedback have been extremely positive. The majority of students felt also that such projects enhanced their understanding of the theoretical materials and made the course more interesting.

Conclusions and Future Work

It is the responsibility of engineering and technology faculty to remain current in their discipline, which includes the new knowledge of sustainability and how it relates to their discipline. Faculty should be able to bring this knowledge to their teaching, research and service. Engineering and technology students must to be ready to face global challenges today and tomorrow. They must understand how to work and solve problems in a global world. Are you prepared to teach your students how to solve global challenges in a sustainable way?

This paper describes the development of industrial energy systems course for engineering and technology programs. The ever increasing importance of energy efficiency and management and the critical role it continues to play globally provided the incentive for development of the course. The course objectives and details of the material covered in the course are presented in this paper. Overall, based on the student feedback and evaluation, the development of this course can be judged to be successful. New materials, including new software, projects/case studies and laboratory experiments will be added in future while the present content will be continuously improved and modified to keep abreast with technological developments. With the knowledge acquired in this course, the graduates (future engineers and technologists) are in a better position to manage energy utilization in a more optimal and efficient manner.

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