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Training Industrial Engineering Students as Energy Engineers

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Early career engagement as a systems and logistics engineer by Department of Defense contractors, Avis Ransom, applied a bachelors in chemistry and MBA in the management and development of technology and in the application of engineering to address DoD requirements. Following 15 years of self employment as a business development consultant, she joined Morgan State University's School of Engineering. As Principle Investigator for a Department of Energy contract to transform the building services industry she works with a team to improve training and education for careers related to the high performance (energy efficient) building industry, develops related curricula, enhances career awareness and develops business strategies to help the industry transformation processes. She seeks to explore the postulate that the industrial engineering core competencies offer significant advantages when learning the complex set of skills and knowledge required to audit and analyze buildings for energy efficiency. As staff for the Dean of the School of Engineering, she develops projects, plans and implements strategies and develops and documents reports, newsletters and proposals.

Training Industrial Engineering Students as Energy Engineers

Introduction

Buildings consume approximately 40% [1] of all energy in the United States. Most buildings operate far less efficiently than their potential. In the U.S., industry alone accounts for about 31% of all energy used [8]. There are many benefits to making commercial and industrial manufacturing plants more efficient. One is to become more competitive in the international market resulting in the obvious domestic benefits. Another is the impact on the environment. Even a small increase in overall efficiency of U.S. commercial and industrial buildings would reduce the U.S.'s carbon footprint significantly.

Currently, the U.S. workforce is not adequately trained in the area of energy efficiency. The Department of Energy recognizes this fact and is attempting to remedy this with programs such as the Energy Efficient Buildings Hub and the continued support and recent expansion of Industrial Assessment Centers [2]. However at the present time, those providing "energy efficiency" services are typically either too technical in their approach such as researchers and professors; or possess inadequate analytical and design capabilities such as technicians and residential energy auditors. We need to concentrate on increasing energy efficiency in current and future industry and commercial operations.

To train an adequately skilled workforce [3] to address such a crucial need is the goal of our initiative. Having skills and knowledge in engineering fields combined with the ability to do engineering economic analyses, are extremely valuable. Energy engineers will both be able to define better solutions as well as present compelling cases to managers and owners to invest in retrofits, upgrades, maintenance and efficient operations in general.

The Need for Energy Engineers

According to the Environmental Energy Technologies Division of the Lawrence Berkley National Laboratory the importance of the energy efficiency services sector (EESS) to the U.S. economy is growing rapidly [3]. Climate changes, issues regarding energy supply, a desire and perceived security need for energy independence, and uncertain but rising energy prices have led to an increase in interest, funding and policies that support and promote energy efficiency in residential, commercial and industrial buildings. The federal government and a number of state governments have also valued energy efficiency as an economic recovery strategy [4].

As a result there has been significant growth in the energy efficiency services sector (EESS) in recent years. According to a 2010 study the growth is projected to continue and to accelerate over the next ten years increasing two-to-four-fold by 2020 to 220,000 person-years of employment in one scenario. A more aggressive scenario projects growth to reach 380,000 person years (representing as many as 1.3 million people) in the same time frame. Partially based on rate-payer initiatives and federal and state funded energy efficiency initiatives, resources to fuel these growths are currently on a solid path of growth [5].

The energy efficiency services workforce is subdivided into manufacturing and distribution;

planning and project management; consulting and auditing; construction and installation; evaluation, monitoring and verification; and operations and maintenance. Based on over 350 surveys of people in key positions like these the following key challenges to expanding the EESS workforce were revealed:

1. Shortage of management-level applicants with experience in energy efficiency
2. Shortage of experienced energy efficiency engineers, and
3. Limited awareness on the part of building and construction tradespeople and contractors that the energy efficiency services sector exists is poised to expand significantly, and their skills will be required [6].

If the workforce does not expand in line with the potential expansion of the building services sector the sector will not grow as projected. This sector not only includes residential and commercial buildings but also includes facilities related to industrial and manufacturing plants that are major sources of inefficient energy use.

There is a wide distribution of job types and skill levels required to support the projected growth potential. Meeting the growing needs of the EESS will require 2-year and 4-year college education, on-the-job training, apprenticeship programs, certificate programs and workshops. In addition to the jobs that require energy engineers, the trainers for most of the other jobs will require personnel with 4-year degrees. However in 2008 only 28 four-year colleges and universities stood out that offered programs in architecture, engineering, policy, planning or interdisciplinary programs that were directly relevant to EESS. At that time they were generally filled to capacity. According to that study:

> *Finding energy engineers, even at entry-level positions, is difficult for the EESS. There are very few energy-specific engineering degrees offered, there is no recognition of energy efficiency as a discipline in occupational and census data on engineering and the types of engineers sought by the EESS (engineers with good foundation in thermodynamics and fluid dynamics with good communication skills to talk to end users) are among the most highly valued in the engineering field* [9].

In 2011 the Department of Energy released for review and comment, job task analyses for six job types that have or are undergoing significant change due to energy efficiency demands. They are:

1. Commercial Building Energy Auditors
2. Commercial Building Energy Modelers
3. Commissioning/Retro-Commissioning Authorities
4. Energy/Sustainability Managers
5. Facility Managers
6. Operating Engineers/Building Technicians

A careful review of the knowledge, skills and abilities identified for these jobs when compared to a number of existing college programs have significant overlap with multiple disciplines including engineering. Engineering programs in new disciplines require years for development and funding is seldom available to support such undertakings. Space is also a limiting factor for the creation of a new program, especially one with a demand whose growth rate is still being determined.

Curriculum Design for Energy Engineers

Given the immediate and growing need and constraints mentioned above, two possible solutions exist for the highest levels of professional education and training, both of which are suggested in the literature. One is modified educational programs using as the starting point the optimum existing program. A second is the infusion of energy efficiency into the curricula of a wide variety of educational programs that already develop many of the requisite basic skills and knowledge needed in EESS, although these programs are currently without exposure to energy efficiency applications.

The first option, starting a new curriculum, requires an extensive administrative initiative. It would necessitate entering a bureaucratic maze involving obtaining both internal and external permissions and approvals which usually take years to complete with no guarantee of final approval. Furthermore, budget and funding requirements for such an endeavor makes it very unrealistic considering the current economic and political conditions of the state, country, and the world. The second option is less cumbersome and more attractive in lieu of the problems faced with the first option. This is the option we have undertaken.

Selecting Proper Discipline

The School of Engineering (SOE) at Morgan State University (MSU) has four degree granting departments; Electrical and Computer Engineering (EE), Civil and Environmental Engineering (CE), Industrial and Systems Engineering (IE), and Transportation and Urban Infrastructure Studies (TUIS). Another relevant asset at Morgan is the new state-of-the-art facility housing the Center for the Built Environment and Infrastructure Studies (CBEIS), which was constructed next to the Engineering School. CEBIS houses the School of Architecture and Planning (AP), and departments of Civil Engineering (CE), and Transportation (TUIS). This interdisciplinary Center is involved in energy efficient design of residential and commercial buildings. One of its primary focuses is the next generation of energy efficient infrastructure and construction.

Among the considered disciplines, Industrial engineering (IE) holds great promise as the basis for developing a workforce skilled in science, engineering and business aspects of energy efficiency. Industrial Engineers have the requite skills set and can easily adapt the additional skills to lead as energy engineer analysts for commercial buildings particularly with manufacturing components. The core curriculum, with minor changes in emphasis, already contains the major factors needed by energy engineers focusing on commercial ventures with manufacturing components. IE's are trained to have strong process, planning, manufacturing, and economic analysis skills that are needed for such a discipline.

The Industrial Engineering program at MSU is an ABET accredited program with several tracks, one of which is the energy concentration. Energy research at MSU already has an established track record in energy applications with several million dollars in grants through NSF and DOE. The MSU IE Department is currently involved in research of more efficient uses of energy in large commercial and manufacturing buildings. In the past, due to lack of interest, this concentration had a limited number of students involved. However, with the new emphasis on efficient use of energy, many students have indicated strong interest in pursuing the energy concentration. Students following this track choose their elective courses from among several possible course offerings. Among these are interdisciplinary courses that are offered by: electrical engineering on power generation and energy; courses centered on construction and efficient building design through School of Architecture and Civil Engineering; and Industrial Engineering courses in energy use, distribution, and analysis.

The infusion of energy efficiency into the Industrial Engineering curricula not only does not need any additional permission or lengthy approval process, but it is most suited to take advantage of strengths currently available within the program. It further integrates the strengths and knowledge available within several other disciplines in an interdisciplinary approach to develop and train energy engineers of the future without compromising the essential requirements of the industrial engineering field.

This will provide a working blueprint for expansion into a full-fledged educational program for an energy engineer of the future.

Skills and Knowledge Requirements

U.S. Department of Energy has identified an extensive set of skills and knowledge base requirements for an energy engineer. There are four basic themes among the above requirements:

1. Communication and organizational skills: including interpersonal, writing and oral, management and teamwork.
2. Energy auditing skills: including the ability to setup test and measuring devices, calculate energy use and identify and implement energy savings plans.
3. Scientific knowledge of energy generation and use: including understanding the concepts of energy generation, heating and cooling principles, familiarity with electro-mechanical analog and digital devices to implement, monitor, and control them within a planned project.
4. Having a 'system' view about energy: considering not just economic short term gains but a holistic approach considering the environment and sustainability in the projects.

Similarly, "Industrial engineering is concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems." [7]

Although there is correlation between the skills and knowledge required by the energy engineer and the IE curriculum, there are additional skills and knowledge requirements that do not necessarily exist in traditional IE curriculum. Four major categories of 'skill/knowledge' requirements and 'traditional IE' exposures and our suggestion to strengthen these 'skill/knowledge' sets are delineated in the Table 1.

Table 1. Skills and Knowledge Set		
Skill/Knowledge	Traditional IE	Courses to Compensate
Understanding architectural and construction specifications	Good understanding of drafting, familiarity with CAD and solid Modeling software but limited to mechanical parts	A course developed by construction management of the School of Architecture
Understanding electrical motors and power generation	Familiarity at the level of physics electricity, with additional exposure in manufacturing processes	A course in electrical engineering especially developed for non EE's
Understanding the concepts of heating, cooling, and air conditioning	Good exposure in physics and thermodynamic courses but at general level	Additional exposure through courses for energy concentration
Ability to perform energy audit, monitor and control energy use	Good knowledge of using measuring equipment and software knowledge to perform analysis	Additional modules included in the current courses in thermodynamics and manufacturing processes

The skill and knowledge set which already exist in industrial engineering curriculum that benefits an energy engineer can be classified into the following 5 categories:

1. Knowledge and skills in implementation, assessment, evaluation, and analysis of projects
2. Familiarity with technical aspects of the energy related projects of industrial nature
3. Technical knowledge and ability to work with measurement instrumentation and software
4. Optimization, statistical, and simulation knowledge to find the most efficient solutions
5. Manufacturing processes and product design knowledge to understand the energy requirements in production facilities

An extensive detailed table of 'Energy Engineer Tasks, Knowledge, Skills and Abilities v.s. MSU Courses' is presented in Appendix A.

IE Curriculum at MSU

ABET accredited Industrial Engineering program at MSU consist of 134 credits in four categories, general education requirements (49), science and mathematics (30), industrial engineering courses requirements (46), and concentration requirements (9).

The energy concentration allows students to take three courses among the following list of courses:

1. IEGR390: Industrial Data Acquisition Systems
2. IEGR405: Advance Energy Conversion Systems

3. IEGR414: Heat Transfer and Industrial Applications
4. IEGR439: Energy and Environmental Management Issues
5. IEGR499: Special Topics in Energy

Furthermore, all industrial engineering students take a course called 'Senior Design' that is an independent study culminating all their training into a project that for those in energy concentration will be in the energy field.

Enhancement and Modifications of the Curriculum

Having the existing ABET accredited IE program, three levels of enhancements and modifications are implemented.

Level 1: Incorporating energy related themes and modules into the current courses

This would allow students to become familiar with the terminology and concepts. It also includes developing lab modules for appropriate courses. An example of such an effort was conducted in the fall semester of 2012 in IEGR363: Manufacturing Processes, an IE core course. The course was conducted as a theme-based class having the theme, 'efficient energy use in manufacturing'. The course also had a hands-on laboratory that included modules in energy auditing.

Level 2: Development of interdisciplinary courses

This would allow the skills needed for energy engineers to be gained. These courses are:

a) Power and Energy use and auditing offered by electrical engineering department.
b) Smart Building Technologies and Design: developed through the school of Architecture under its design and construction division.
c) Sustainable Manufacturing Facilities, a course developed by joint effort of Industrial and Civil engineering departments.

Level 3: Development of laboratories for hands-on training and research

This would train students in the best practices for energy audits. We have started procuring the initial equipment including: blower door, infra-red camera, thermometer, multi-meter, moisture meter, CO2 meter, and ammeter. Some mentioned equipment was used during the fall 2012 student training. The new equipment and laboratories will complement and enhance the current advanced energy laboratory. A list of equipment and capabilities of this lab is provided in Appendix B

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Appendix A

Energy Engineer Tasks, Knowledge, Skills and Abilities v.s MSU Courses			
TASKS	**Industrial Eng.**	**Electrical Eng**	**Civil Eng.**
Identify energy savings opportunities and make recommendations to achieve more energy efficient operation.	CM	CM	CM
Manage the development, design, or construction of energy conservation projects to ensure acceptability of budgets and time lines, conformance to federal and state laws, or adherence to approved specifications.	CM	W	CM
Conduct energy audits to evaluate energy use, costs, or conservation measures.	CM	W	CM
Monitor and analyze energy consumption.	CM	CM	CM
Perform energy modeling, measurement, verification, commissioning, or retro-commissioning.	CM	S	CM
Oversee design or construction aspects related to energy such as energy engineering, energy management, and sustainable design.	CM	W	CM
Conduct jobsite observations, field inspections, or sub-metering to collect data for energy conservation analyses.	CM	W	CM
Review architectural, mechanical, or electrical plans and specifications to evaluate energy efficiency or determine economic, service, or engineering feasibility.	CM	W	CM
Inspect or monitor energy systems including heating, ventilation and air conditioning (HVAC), or daylighting systems to determine energy use or potential energy savings.	CM	CM	CM
Evaluate construction design information such as detail and assembly drawings, design calculations, system layouts and sketches, or specifications.	CM	CM	CM
Prepare and deliver reports and presentations of findings, recommendations and business case analyses for retrofits, upgrades, energy efficient process modifications.	W	W	W

KNOWLEDGE	IE	EE	CE
Engineering and Technology — Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.	S	S	S
Mathematics — Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications	S	S	S
English Language — Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar.	S	S	S
Building and Construction — Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.	CM	W	S
Physics — Knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic and sub- atomic structures and processes.	CM	S	CM
Design — Knowledge of design techniques, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models.	CM	CM	CM
Mechanical — Knowledge of machines and tools, including their designs, uses, repair, and maintenance.	CM	CM	CM
Administration and Management — Knowledge of business and management principles involved in strategic planning, resource allocation, human resources modeling, leadership technique, production methods, and coordination of people and resources.	CM	CM	CM
Computers and Electronics — Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.	CM	S	CM
Economics and Accounting — Knowledge of economic and accounting principles and practices, the financial markets, banking and the analysis and reporting of financial data.	CM	CM	CM

SKILLS	IE	EE	CE
Reading Comprehension — Understanding written sentences and paragraphs in work related documents.	S	S	S
Critical Thinking — Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.	S	S	S
Active Listening — Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.	S	S	S
Complex Problem Solving — Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.	S	S	S
Monitoring — Monitoring/Assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.	S	CM	CM
Speaking — Talking to others to convey information effectively.	S	S	S
Writing — Communicating effectively in writing as appropriate for the needs of the audience.	S	S	S
Active Learning — Understanding the implications of new information for both current and future problem-solving and decision-making.	S	S	S
Judgment and Decision Making — Considering the relative costs and benefits of potential actions to choose the most appropriate one.	S	CM	CM
Mathematics — Using mathematics to solve problems.	S	S	S

ABILITIES	IE	EE	CE
Written Comprehension — The ability to read and understand information and ideas presented in writing.	S	S	S
Deductive Reasoning — The ability to apply general rules to specific problems to produce answers that make sense.	S	S	S
Oral Comprehension — The ability to listen to and understand information and ideas presented through spoken words and sentences.	S	S	S
Inductive Reasoning — The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).	S	S	S
Problem Sensitivity — The ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing there is a problem.	S	S	S
Oral Expression — The ability to communicate information and ideas in speaking so others will understand.	S	S	S
Speech Clarity — The ability to speak clearly so others can understand you.	S	S	S
Information Ordering — The ability to arrange things or actions in a certain order or pattern, according to a specific rule or set of rules (e.g., patterns of numbers, letters, words, pictures, mathematical operations).	S	S	S
Written Expression — The ability to communicate information and ideas in writing so others will understand.	S	S	S
Near Vision — The ability to see details at close range (within a few feet of the observer).	S	S	S

CM- Course needs modifying
S – Courses are satisfactory
W – Will be addressed in a workshop
N – New course needed

Appendix B

Locations of Physical Facility and Size: Morgan State University, Center for Advanced Energy Systems & Environmental Control Technologies (CAESECT)

Lab #1: Rm. 105, Advanced Instrumentation Lab, William Donald Schaefer Engineering Building, Area: 1200 sq. ft

Lab #2: Rm. 146, Industrial Technologies Lab, Mitchell Engineering Building, Area: 600 sq. ft

Lab #3: Rm. 119, Advanced Energy Systems Design;/Fabrication Lab, Mitchell Engineering Building, Area: 240 sq. ft

Lab #4: Rm. 340, Advanced Computational Fluid Dynamics (CFD) Simulation Lab, William Donald Schaefer Engineering Building, Area: 600 sq. ft

Laboratories Facilities

Combustion Process Testing Equipment:

Swirling Fluidized Bed Cold Model (6" ID)
Swirling Fluidized Bed Hot Model (10" ID)
And Swirling Fluidized Bed Prototype (16" ID)
Advanced Real Time Gas Analyzer

Laser-Based Particle Image Velocimetry (PIV):

Flow imaging / visualization and measuring of velocity profile capabilities using double-pulsed technique

3-D Phase Doppler Particle Analyzer/Laser Doppler Velocimenter (PDPA)

Capabilities of measuring the size and velocity of spherical particles, and liquid droplet size and velocity

Biofuel Testing Equipment:

Biofuel Testing Reactor
Unit: ModelC491/23001
Computerized Emission Analyzer
Gasoline/Diesel Engine Test Beds
Engine Test Station with Dynamometer

Solar Energy Testing Facility:

Lab scale solar tower
Solar receiver

Solar Fuel Cell Lab Testing Equipment:

Solar panel,
Reversible fuel cell,
Digital multi-meter

Fuel Cell Testing Equipment:

PEM Fuel Cell,
Electrolyte,
Anode & cathode beakers

HVAC Testing Facilities