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Educating Students about Energy: A Practical Approach

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Abstract

Global energy usage is continuously rising with its adverse effect on the environment. Several governments have imposed new policies for design and implementation of energy efficient buildings and equipment. The value of energy efficiency in properly implemented construction standards is universally recognized as the easiest and most cost-effective way to help consumers save energy and money, make housing more affordable, and reduce air pollution. Buildings can benefit from the incentive and lower energy usage. Students graduating these days need to be educated about energy and energy management. A graduate course is developed to address the energy management, building efficiency evaluation and implementation of energy management principals. Furthermore, the graduate program in Engineering Technology at Purdue University Calumet developed a focus area in the energy with four required courses. Students in this course learn the principals of energy management and present a practical project. The project must apply the energy efficiency principals and examine different available potentials for further improvement and cost savings. The energy efficiency improvement needs auditing, mitigation, pinpointing the culprit, finding remedy, calculating the incentives, implementing the solution and measuring the energy usage. A real case study is presented to demonstrate the implementation of these principals. At the conclusion, assessment result is provided to demonstrate the effectiveness of this graduate course.

Introduction

Industrial and commercial buildings consume majority of energy. The energy consumption of industrial buildings is tied to the production line. Improving the efficiency of such buildings may need production line upgrade and equipment replacement. However, commercial buildings account for 19% of the energy consumed in the United States. The types of buildings that use more than two-thirds of that energy are office, retail, educational, health-care, lodging and warehousing. More than half the energy used by commercial buildings goes toward heating and lighting. Opportunities for commercial buildings include improving the operations and maintenance of existing buildings, and finding ways to deal with the split incentives that often occur between the bill-payers and the tenants of the building. Additionally, in many cases (particularly in schools and public buildings) capital is not always readily available for efficiency improvements. At a national level; energy inefficiency poses steep economic and environment threats. On a local level, increasing energy efficiency is important to small businesses for their continued success. On a more tangible level, improving energy efficiency can lower utility costs for buildings and operation of businesses. Due to decline in economy in recent years, tenants of large buildings have difficulties in paying their utility bills. To help stay attractive and relevant to potential new businesses, commercial buildings must stay cost-competitive with other markets. Incentives from utilities, local and federal governments provide opportunities to increase energy efficiency and lower energy usage costs of commercial buildings.
Industrial and commercial energy consumption can be divided into two major parts of Production and Operation. Production is the area with the largest energy consumption in the industrial sector which requires serious planning and control. The planner should plan the production processes so that they operate efficiently with minimal operating cost. Aaccording to

the International Facility Management Association about 25% of total industrial cost is the energy cost[1]. The main objective of the energy management is to reduce the total operating cost without compromising the safety and comfort. European governments have published guidelines to successfully integrate energy management without sacrificing the production, safety and comfort[2, 3]. In the United States, the Energy Star® is the largest program defining low-energy homes. Homes earning Energy Star® certification use at least 15% less energy than those without the certificates[4]. Maintenance also plays a crucial role in the energy consumption. Equipment shall be selected such a way to minimize maintenance and downtime. With a detailed maintenance program, power losses and cost increases can be avoided.[5-11].
Due to the importance of energy resource management; recently many schools started offering undergraduate or graduate level energy management courses. A new course is offered to address the need of energy resource managements with focus on practical projects. Students should have a technical foundation, basic understanding of engineering concepts and electro-mechanical systems to take this course. This course concentrates on five major components of Energy Resource Management: *Supply, Demand, Regulation, Environment and Government Subsidies.* Energy audits, energy economics, metering, performance contracting and financing with demand response, measurement, verification, equipment applications, and systems are also studied. An overview of alternative energy as well as the latest energy efficient lighting technology is given. The quantitative analysis of water, air, gas, electricity and steam is also given. This course presents the key concepts and methods of energy efficiency. It explores how energy is converted into useful services and the role of increased efficiency in providing those services with less energy. The different forms of efficiency improvements and conservation are introduced, drawing upon examples in transportation, buildings, and industry. Case studies of energy auditing, energy purchasing and conservation, maintenance and operation issues, code and standards applied in energy resource management are given.
This Energy Resource Management course is designed to bring a better understanding of methods and approaches related to identification, quantification and analysis of energy resource management opportunities. The objective of this course is to equip students with the concepts and analytical skills necessary to assess the viability of various components of Energy Resource Management, regulation and environmental issues in the context of a growing demand for energy.

The course will focus on the fundamentals of energy auditing and Energy Resource Management with respect to the physical principles of operation, design, manufacturing and purchasing of various technologies for energy. Traditional engineering science is integrated with the practical issues of manufacturing, cost and market analysis, and policy considerations to provide a complete picture of the engineering and development of modern Energy Resource Management.

In order for the students to really appreciate the management of energy and its impact on the energy bill, practical projects must be implemented in the course. These projects can demonstrate the available utility incentive methods as well as other energy management programs. Gas and electric companies are offering energy saving incentive programs for replacing existing equipment with new energy efficient ones. Students with good technical foundation and basic understanding of engineering concepts can take this course.

Oil Subsidies

The largest U.S subsidies to fossil fuels are attributed to tax breaks that aid foreign oil production, according to research done by the Environmental Law Institute in partnership with the Woodrow Wilson International Center for Scholars. The study, which reviewed fossil fuel and energy subsidies for Fiscal Years 2002-2008, reveals that the lion's share of energy subsidies supported energy sources that emit high levels of greenhouse gases.

The research demonstrates that the federal government provided substantially larger subsidies to fossil fuels than to renewables. Fossil fuels benefited from approximately $72 billion over the seven-year period, while subsidies for renewable fuels totaled only $29 billion. More than half the subsidies for renewables—$16.8 billion—are attributable to corn-based ethanol, the climate effects of which are hotly disputed. Of the fossil fuel subsidies, $70.2 billion went to traditional sources—such as coal and oil—and $2.3 billion went to carbon capture and storage, which is designed to reduce greenhouse gas emissions from coal-fired power plants. Thus, energy subsidies highly favored energy sources that emit high levels of greenhouse gases over sources that would decrease our climate footprint.

The U.S. energy market is shaped by a number of national and state policies that encourage the use of traditional energy sources. These policies range from royalty relief to the provision of tax incentives, direct payments, and other forms of support to the non-renewable energy industry. "The combination of subsidies—or 'perverse incentives'— to develop fossil fuel energy sources, and a lack of sufficient incentives to develop renewable energy and promote energy efficiency, distorts energy policy in ways that have helped cause, and continue to exacerbate, our climate change problem[12].

Learning Outcomes and Methods of Evaluations or Assessment

Students after successfully completing of this course should be able to perform the following tasks as shown in Table-1.

Table 1: Course Outcomes

Perform auditing and economic analysis of conventional and non-conventional energy sources, seasonal variations and availability.
Apply management control and maintenance systems of energy resources.
Assess sustainability of high performance green and renewable energy.
Understand boilers, fired systems, cogeneration and HVAC systems.
Realize ground source heat systems.
Recognize lighting and electrical management.
Comprehend natural gas purchasing and thermal storage.
Know codes and standards.
Identify utility de-regulation and energy system outsourcing.
Grasp energy security risk analysis methods.
Handle financing Energy Resource Management projects.

Topics Addressed

The following topics are covered in the course:

- The Evolution of Energy Resource Management
- Implementing a Strategic Energy Efficiency Program
- Why Energy Efficiency Programs Fail-Road Blocks to Success
- Justifying, Selling and Funding Energy Programs and Projects – The Language of Accounting and Economics
- Procurement and Energy Bill Analysis
- Energy Audits and Instrumentation
- Building Envelope
- Electrical Systems
- Heating Ventilating and Air Conditioning Systems (HVAC)
- Lighting
- Motors and Drives
- Boilers and Steam
- Maintenance
- Building Commissioning
- Developing a Master Energy Efficiency Plan-Bringing it all together

A design project is given to students to utilize the above topics. Usually, within the first three weeks of the semester, the outline of the project is discussed to allow sufficient time for the students to configure the logistics for successful completion of the project.

Design Project

The design project constitutes a major part of the student's grade. The students will apply the learned principles and the attained knowledge of the components and subsystems to design and complete a working Energy Resource Management project. The students are required to prepare the design of an Energy Resource Management to meet a certain requirements. The students are to perform calculations, computer simulation, components selection, and cost analysis. The final report shall provide the auditing, optimum design, cost analysis, and maintenance program while meeting the design requirements.

Assessment and Grading

Homework assignments, in-class exercises and quizzes will be used throughout the semester to assess comprehension in an incremental manner. Mid-semester and the final exams will be used to assess the student total knowledge comprehension. Students must rely on both knowledge and comprehension for the application phase. They should be able to apply principles or concepts to new situations. Students are expected to demonstrate problem-solving techniques and work independently on their own. They should show competency in analysis, synthesis, and evaluation of a given problem. The final class design project is used to assess this phase. Homework and quizzes values 20%, two tests 40% and the final class project 40% of the grade. Table 2 shows the result of the student assessment and Table 3 gives the result of student performance in one semester.

Table 2: Student Assessment Result

Energy Resource Management					
Student Assessment of Student Outcomes					
Proposed ABET Criterion Satisfied: a, b, d, f and g					
	Semester: Fall 2012				
Student Outcomes (Matched to ABET a,b,d,f, and g)	**Student Feedback (Composite Target Score = 3.00)**				
	Excellent (4)	**Good (3)**	**Acceptable**	**Pass (1)**	**Composite**
a. As a result of this course, my ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities can be rated as,	9	3	2	0	3.50
b. As a result of this course, my ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies can be rated as,	10	4	0	0	3.71
d. As a result of this course, my ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives can be rated as,	11	2	0	1	3.64
f. As a result of this course, my ability to identify, analyze, and solve broadly-defined engineering technology problems can be rated as,	13	0	1	0	3.86
g. As a result of this course, my ability to apply written, oral, and graphical communication in both technical and nontechnical environments, and an ability to identify and use appropriate technical literature can be rated as,	10	1	2	1	3.43
Instructor Comments: The composite score exceeds the target score that is set at 3.00 on the scale of 4. Hence the course met the specified criteria and no action is needed at this time.	Number of Responses: 14				

Table 3: Course Embeded Assessment of Student Performance

Energy Resource Management												
Semester: Fall 2012			**Instructor:**									
	Course Embedded Assessment of Student Performance						**Student Evaluation (%)**					
Course Objective	**Assessment Tool 1**	**Score (%)**	**Assessment Tool 2**	**Score (%)**	**Assessment Tool 3**	**Score (%)**	**E**	**G**	**A**	**P**	**NA**	**Composite**
1.Evolution of Energy Resource Management	Homework	78	Exam-1	75	Project	80	10	1	2	1	0	**3.4**
2. Selling and Funding Energy Programs, Accounting and Economics, Procurement and Energy Bill Analysis	Homework	79	Exam-1	70	Project	70	9	2	1	1	1	**3.2**
3. Energy Audits and Instrumentation, Building Envelope	Homework	74	Exam-1	75	Project	72	8	3	1	2	0	**3.2**
4.Electrical Systems, Heating Ventilating and Air Conditioning Systems (HVAC), Lighting, Motors and Drives	Homework	82	Quizzes	75	Exam-2/Project	77	7	5	2	0	0	**3.4**
5.Boilers and Steam, Maintenance, Building Commissioning	Homework	80	Exam-2	70	Exam-2/Project	85	8	1	3	2	0	**3.1**
6. Developing a Master Energy Efficiency Plan-Bringing it all together	Quizzez	75	Eam-2	73	Project	81	6	6	1	1	0	**3.2**
Number of Responses: 14 The course content was delivered through in-class lectures The Course Assessment Target Score is 70%. No corrective actions were needed, since in all categories, the target scores were met.												

Review of the course and student assessment reveals that students perform satisfactorily. Any of the objectives having an average below 3.00 needs to be addressed and changes must be implemented. At this time no action is needed. Out 14 students registered for the course; only two were undergraduate and one female student. Traditionally very few female students attend engineering graduate schools.

Utility Incentive Programs

Gas and Electric companies in the United States have on-going incentive programs for residential, commercial and industrial customers. Depending on the time of the year and locations, the incentive programs may vary. Customers must work closely with the utility companies to submit applications, calculation, cost, drawings, specification, contractor name and credentials, and other relevant required material for the final approval. The process can be done on-line or through mail. Usually, the utility companies assign a project manager for each project to assure the smooth completion of the project. The highlights of the incentive programs for one gas and one electric company are shown in Tables 3 and 4 respectively. The detail of these programs and their application form can be found in their website [13, 14].

Table 3: Brief Highlight of a Gas Company Incentive Program

2,500 - 7,500 Therms saved / year = $0.75 / Therm saved
> 7,500 Therms saved / year = $1.00 / Therm saved
Maximum project incentive: $500,000 per project or 50% of the total project cost, whichever is less
Maximum total incentive per site: $500,000 per year (June 1, 2013 - May 31, 2014)
Minimum project payback: 1 year
Projects must save a minimum of 2,500 Therms per year to be eligible

Table 4: Brief Highlight of an Electric Company Incentive Program

All lighting projects are expected to comply with the Illuminating Engineering Society of North America (IESNA), recommended lighting levels or the local code. New T8/T5 Fluorescent Fixture with Electronic Ballast specifications.
1. A Pre-Approval Application is required. Manufacturer's specifications for new fixtures, lamps and ballasts must accompany Pre-Approval and Final Applications.
2. Incentives are only available for new fixtures. New fixtures must consist entirely of new components and be unopened at time of purchase.
3. T8/T5 lamps must have a CRI ≥80.
4. Ballasts must meet the following specs:
• High frequency (≥20 kHz)
• Power factor (PF) ≥0.90
• UL or ETL listed
• Warranted against defects for 5 years
5. Ballasts for 4-foot lamps must have total harmonic distortion (THD) ≤20 percent at full light output.
6. For 2- and 3-foot lamps, ballasts must have THD ≤32 percent at full light output with new T8/T5 Fluorescent Fixture with Electronic Ballast.
Replacement of an existing exterior lighting system with a new lighting system containing T8/T5 fixtures with T8/T5 lamp(s) and electronic ballasts.
Reduction in connected Watts $0.40 per Watt reduced
Maximum incentive is $150 per installed fixture.

Practical Project

A 29,000 square foot warehouse near Chicago is selected for this project. The warehouse is used for packaging and storing food. Clients for this company vist the warehouse on regular basis to check the quality of the packaged food and electric power and lighting is a key factor. The warehouse had a variety of ineffeciet, noisy and sometimes non-functional light fixtures such as 12 foot T12, Mercury Vaspor 400W, Metal Halite 400W, and 4 foot T12. These light fixtures consumed excessive amount of energy without providing sufficient lighting. The students are to evaluate existing lighting system check the available incentive programs, provide calculations and find right part replacement. Table 5 lists the quantity, individual power consumption, total power for each light fixture. The old light fixtures are replaced by 6-lamp T5 fixtures. T5 fluorescent lamps have a higher luminous efficacy than T8 or T12 lamps. Luminous efficacy indicates how much light a lamp generates from the energy it consumes. The higher the value, the more energy efficient the lamp is. The luminous efficacy of T5 lamps is about 100 lm/W, while those of T8 and T12 lamps are only about 80 lm/W and 70 lm/W respectively. The T5 costs almost double T8 lamps.T8 lamps are more cost effective than the T5 and normally recive better incentives from utility companies. However, the building owner preferred T5 lighting. T5 light fixtures are bighter than T8 lights and provide light closer to daylight than T8. In the following table, the total incentive is ,calculated to be $6,160. The total cost of the project is almost double the incentive amount. The customer will save more in the incoming years due to lower electric bills. The Return On the Investment is (ROI) is provided below.

Table 5: Calculated Electrical Incentives for a Warehouse Lighting Near Chicago

Description	**Quantity**	**Watt**	**Total Watt**	**Calculation**
Metal Halite	30	450	13,500	
T12/2 Light Tube	116	180	20,880	
Total Wattage of Old Equipment				34,380
T5/6 Light Fixtures	59	320	18,880	
Total Wattage of New Equipment				18,980
Total Wattage Difference				15,400
Incentive Per Watt	$0.40			**$6,160**
ComED Incentive One Time	**$ 6,160**			

The above project was implemented to receive the incentive. Figures 1 through 4 show technicians from a contracting company are removing the old light fixtures and installing the new 6-lamp T5 light fixtures. A copy of the incentive check received by the owner is shown in Figure 5 as proof of the practicality of this project. The new lighting system provided uniform bright and comfortable lighting with substantial annual energy saving. In this type of project usually, the building owner pays roughly half of the total fixture installation.

Payback Calculation

Implementation of energy management techniques requires capital investment and how quickly the savings will cover the investments can be attained with simple payback calculation. It determines at what point this will occur through the realized energy savings. Although simple payback does not take into account compounded savings, discount rates, inflation rates, or replacement costs, it is a very easy, commonly used, and it is a useful tool. Projects with paybacks less than 3 to 5 years should be implemented. Projects with paybacks greater than 10 years are generally not cost effective.

Total power consumption between old and new fixtures: 15,400 Watts
The warehouse operates 12 hours during the weekdays and 6 hours on the weekends for 50 weeks per year.
Total hours of operation per year = 50x5.5x12 = 3,300 Hours
Total kWh saved per year = 15,400 x 3,300/1,000 = 50,820 kWh
Saving per year = 50820 x $0.1/kWh = $5,082
Total cost of project = $12,500
Incentive amount = $6,160
Net Project Cost = 12500 – 6,160 = $6,340

It will take a little more than one year (6,340/5,082 *12 = 15 Months) to recover the cost of investment. The customer will save $5,082 per year after the 15 months of operation.

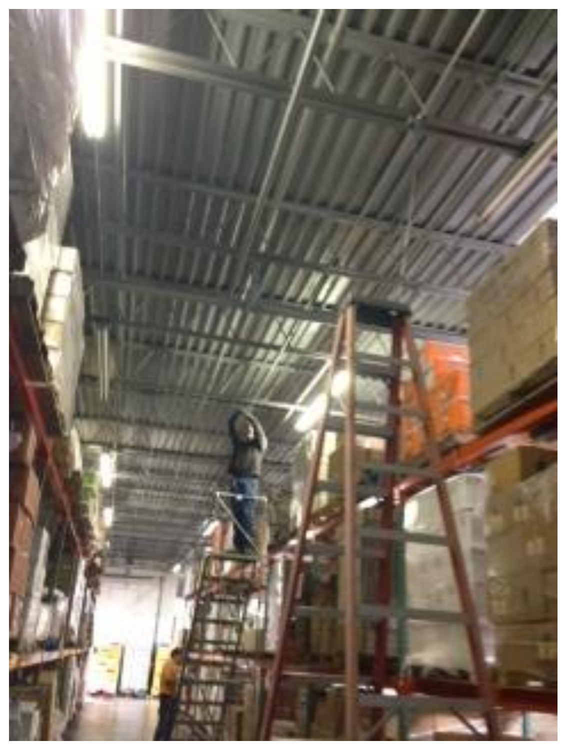
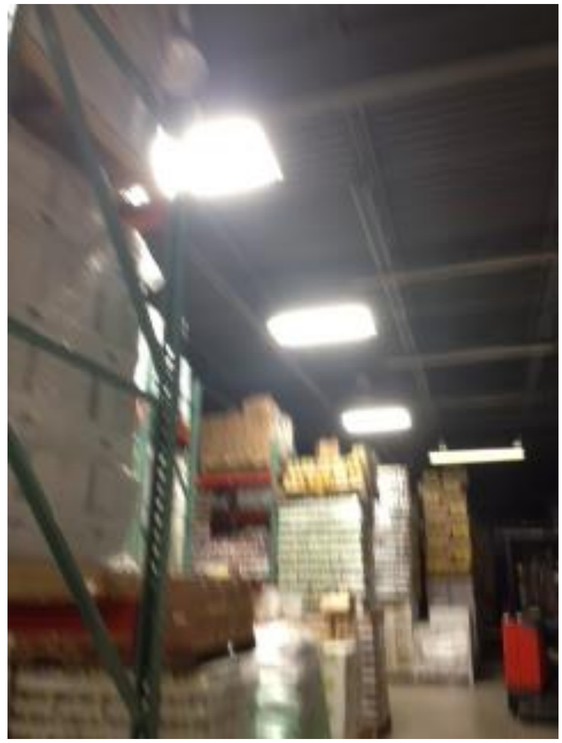


Figure-1&2 Technicians Removing Old T12/8foot Light Fixtures



Figures 3&4 Six-Lamp T5 Light Fixtures Installation

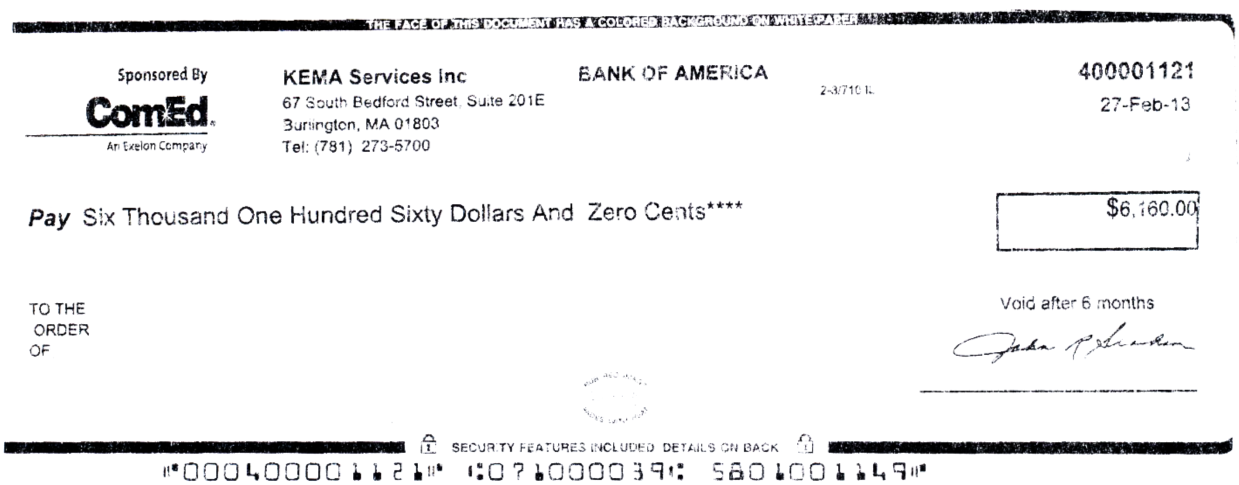


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Figure 5: A copy of the incentive check received by the building owner that idicates the practicality in-class project.

Summary

A new graduate course on “Energy Resource Management” with focus on practical project implementation was developed, offered and assessed. Different traditional methods of assessment such as homework, quiz and test were used. However, the true measure of the material comprehension was shown via practical project implementation. A real project for lighting replacement, cost calculation, incentive utilization and payback calculation was implemented. The students with strong understanding of the course subjects easily finished the project but students even with good test scores and limited comprehension struggled through the project. Project implementation requires a very close industry collaboration and accurate planning. The instructor must coordinate the students' activity with industry, contractors, suppliers and utility companies to guarantee the smooth completion of the projects. The instructor needs to prepare the list of potential projects and their availability before the beginning of the semester. The above project completed very successfully due to good forward thinking and planning. This course will be offered in spring 2014 again. A heating and cooling system upgrade utilizing the incentive program is intended as the class project.

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