Session 2533

Energy Engineering: Development of a New Senior Elective Course

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Abstract

Energy engineering is a multi-disciplinary course encompassing thermodynamics, fluid mechanics, engineering economics, energy conversion and conservation, and pollutant emissions. This paper describes the development of an undergraduate elective course, energy engineering, in the Department of Mechanical Engineering at Lamar University. Both conventional and alternative energy resources are covered in the course. Design aspects of energy conversion devices such as gas turbines and photovoltaic cells and contemporary topics such as distributed power generation, Combined Heat and Power (CHP), and environmental impacts caused by energy generation and consumption are introduced in the course. The paper provides the contents of the course in details: textbooks, reference materials, course topics, web resources, computational tools, exams, and group projects. The results of the course outcome assessment based on student surveys are also provided.

Introduction

Energy affects the lives of everyone in so many ways, economically, technically, and environmentally. Thus, integration of energy and its many aspects such as energy conservation technologies and environmental impacts of energy generation, in the educational curriculum of science, technology, and engineering students is essential. In order to address this need, a new elective course, Energy Engineering, was developed and implemented in the Mechanical Engineering Department at Lamar University. The course was designed in order to demonstrate how knowledge from junior level thermal/fluid science classes could be used to design and develop energy systems. The course topics and contents were based on similar courses at other universities[1-3]. However, more emphasis was placed on the design procedure and calculations related to different energy systems in order to increase the design contents of the course as required by Accreditation Board for Engineering and Technology (ABET). Students were also encouraged to use web-based resources and computational tools to carry out analysis and design calculations. This paper describes the design and implementation of this new course, Energy Engineering, in details.

Course Description

Energy Engineering is a multi-disciplinary subject that encompasses thermodynamics, fluid mechanics, engineering economics, energy conversion, energy conservation, energy audit and management, and environment. The course is developed as an elective course for the senior undergraduate students but first-year graduate students are also allowed to take the course. At Lamar University, the prerequisites for the course are the completion of undergraduate fluid mechanics, thermodynamics, and heat transfer courses. The class is a 3-credit hour class with 3 hours of lecture time each week. The typical semester lasts for about 15 weeks so the total instruction time is 45 hours. The catalog description of the course is as follows:

> "This course deals with energy resources, energy conversion, and energy conservation. Topics covered include different types of energy resources and their uses, different types of energy conversion technology such as fuel cells, thermoelectric, and solar energy conversion, and energy conservation technologies such as pinch technology and cogeneration. Current status and future challenges of energy generation and conservation including critical issues such as air pollution, smog and greenhouse effects, and NO_x emissions will also be discussed."

The main objectives of the course are

- To provide an overview of different energy resources and their importance in energy generation
- To develop ability to evaluate, design, and analyze different energy generation technologies
- To explore current status and future challenges of energy generation and conservation technologies
- To introduce and discuss environmental impacts of energy generation

The curriculum for the course is therefore developed with a view of achieving these objectives satisfactorily.

Textbook

The main criteria for choosing the textbook is the depth and breadth of the topics covered in the book. The number of available books on energy and energy related books are large[4-12] but many of them are not intended for use as textbooks. The books suitable for use as texts, Principles of Energy Conversion by Culp[4] and Energy Conversion Systems by Sorenson[5], in the author's opinion are out of date as they were published in the late seventies or early eighties when the topic of energy was the main concern in the United States. In addition, Principles of Energy Conversion book is out of print. However, students need a textbook for their study and thus, Energy Conversion Systems by Sorenson was chosen as the text. To cover more contemporary issues such as CHP, the instructor utilized other books and technical papers.

One of the main resources for the course materials is the World Wide Web (WWW) as so much information is freely available in WWW. For example, Department of Energy (DOE) publishes an annual outlook on energy[13, 14] and the entire report is made available to the public on the DOE web site (http://www.eia.doe.gov/oiaf/aeo/). Similar reports are available for download from the web sites of British Petroleum (BP)[15] (www.bp.com) and Internal Energy Agency (IEA) (http://www.worldenergyoutlook.org/weo/pubs/weo2002/weo2002.asp)[16]. The main advantages of the learning materials acquired from the web are that they are free and they cover up-to-date information on the consumption and production of energy, current status of energy generation systems and technologies, and future challenges to be expected in different areas of energy generation and consumption.

Course Content

The course consists of four parts: energy resources, energy conversion, energy conservation, and environmental impacts of energy generation. In the first part of the course, two types of energy resources are covered in details: non-renewable and renewable energy resources. Non-renewable energy resources discussed in the course include petroleum, coal, natural gas, and nuclear while renewable energy resources are solar, biomass, wind, geothermal energy, and hydro. For each energy resource, the following topics are discussed:

- Current and future availability
- Production and consumption
- Advantages and disadvantages
- Technical and economic challenges
- Current and future uses
- Environmental impact

The main resources for studying patterns of energy consumption and production in the US and the World are the Annual Outlook of Energy (AEO)[13] report published yearly by the Department of Energy (DOE), and World and US Energy Statistics[15] published yearly by British Petroleum (BP). The report from BP is extremely useful for demonstrating energy consumption and production by fuel, by country, and by region as the entire data from the report is available as a Microsoft Excel file. The textbook includes enough coverage for non-renewable energy resources but lacks materials for renewable energy resources. Thus, instructor made use of materials from other texts [6, 7, 17, 18] for coverage of renewable energy resources.

One of the main difficulties in this part of the course is that energy resources have different forms (gas, liquid, solid) and different units associated with them. For example, the unit for petroleum (oil) may be in terms of barrels of oil, barrels per day, thousand barrels per day, tonnes of oil, million tonnes of oil equivalent (Mtoe), and million Btu (British Thermal Unit). The students therefore found it difficult to understand many different units as well as convert one unit of energy resource to the other, especially for energy resources in different forms (gas, liquid, solid). The ability to do these conversions is essential in this course in order to compare and evaluate energy consumption and production patterns of different countries, and to compare different types of power plants utilizing gaseous, liquid, and solid fuels. Here, WWW provides the solution in the form of freely available online conversion calculators for use by students. The two conversion calculators, one from the website of BP[15] and the other developed by the author and two students[19], are used by the students for this part of the course.

The second part of the course is about the energy conversion processes for different energy resources discussed in the first part. The energy conversion devices covered in the course include internal combustion engines, steam and gas turbines, photovoltaic cells, wind turbines, geothermal heat pumps, fuel cells, and microturbines. Most of these devices are based on thermodynamic principles so the first law analysis of power cycles was reviewed in this part of the course. For each energy conversion device, the following topics were covered:

- Basic thermodynamic principles and analysis
- Advantages and disadvantages
- Current technical status and future challenges
- Environmental impact

In this part of the course, first law analysis of energy conversion devices is necessary to predict the performance of these devices. A quick and easy way to carry out the first law analysis is necessary in order to facilitate the learning and understanding of students. CyclePad program[20] was introduced to the students in their thermodynamic class and students are already familiar with the program. Therefore, it is used as the main computational tool for analysis and design of conventional energy systems such as gas turbine and combined cycle systems. For example, specifications for an actual combined cycle system of Siemens Westinghouse were taken from the company website[21]. Students used CyclePad program to predict the performance of the system, and the results were compared with those given by Siemens Westinghouse. Close agreements were found and students felt confident using the program to carry out the design in the latter part of the course.

In addition, web-based resources were also used to develop design activities in this portion of the course. For example, a design sheet from Florida Solar Energy Center[22] is used to design a residential solar heating system. Web-based materials are also extremely useful as supplemental materials when covering new energy generation devices such as fuel cells and microturbines as only a few books[23-25] are available on these topics. Students were also encouraged to use the web sites of the manufacturers as these web sites provide up-to-date information and materials.

Different types of energy conservation technologies were discussed in the third part of the course. Some of the energy conservation topics covered are cogeneration or Combined Heat and Power (CHP), trigeneration, waste heat recovery, and pinch technology. For each energy conservation technology, the following topics are discussed:

- Second law analysis
- Advantages and disadvantages
- Current technical status and future challenges
- Environmental impact

Many conservation technologies are based on second law analysis and heat recovery. Since CyclePad program does not include the second law analysis, another web-based tool developed by the author and two students[17] was used in this art of the course. Some of the web resources used by the instructor include the cogeneration reports by the European Association for the Promotion of Cogeneration (Cogen Europe)[26] and the articles from the web site of the Chemical Engineers' Resource Page[27].

Environmental Impact

In this section, the discussion is focused on different pollutants, and how energy generation and consumption affect emissions of these pollutants. The pollutants to be discussed include NO_x, SO_x, CO, CO_2, particulate matters (PM), Volatile Organic Compounds (VOC), and CFCs. Effects of these pollutants on the environment in the form of smog, acid rain, global warming, and ozone hole are discussed. For each pollutant, the following topics are covered in details:

- Origin and chemistry
- Sources
- Environmental and health impacts
- Current remediation techniques and technologies
- Future challenges

The main focus of the discussions is on the sources of each pollutant and the technologies for remediation, reduction, and elimination of these pollutants. The materials from the text are outdated for this part of the course and WWW provides many resources especially from the web sites of DOE and Environmental Protection Agency (EPA).

Outcome and Assessment

The following is the list of outcomes expected from the course:

1. Explain different types of energy resources and their uses for energy generation.
2. Describe the advantages and disadvantages of different energy resources.
3. Discuss and compare different energy generation technologies, their advantages and disadvantages.
4. Do calculations on different energy conversion technologies to evaluate their performances.
5. Understand environmental impacts of each type of energy conversion.
6. Discuss current status of energy generation and conservation technologies.
7. Explore future challenges of energy conversion and conservation.

The assessment methods for the course consist of assignments, exams, and group projects. The weekly assignment covers 20% of the total grade, and two exams and two group-projects cover 80% of the grade. There are two exams for the course. The duration of each exam is 90 minutes and each exam is worth 20% of the total grade. The first exam covers energy resources and energy generation and the second exam covers energy conservation technologies and environmental impact.

The use of group projects in engineering provides cooperative learning environment for students to gain teamwork skills. Thus, two group projects were assigned in this course. The first project involves designing a power plant to generate electricity for a city. Each student group is assigned different energy generation systems such as a coal-fired steam power plant, fuel cell, and natural gas-fired combined cycle. Each group designs its power plant and provides estimates on the capital and operating costs of the plant. For the second project, each group chooses a contemporary topic related to energy generation and prepares a technical report on the chosen topic. Some topics chosen are distributed energy generation, trigeneration, and waste heat recovery.

At the end of the course, a student survey was conducted in order to assess whether the students have achieved the expected outcomes. Ten students took the class in Spring 2002 and the results of the student survey were given in Fig. 1.

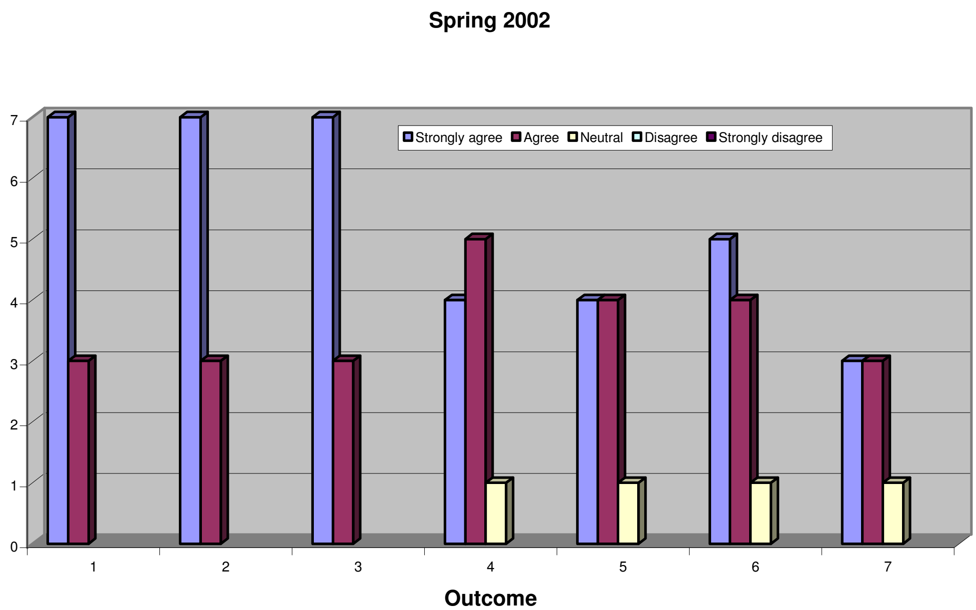

Figure 1 Results of Student Survey for Spring 2002 Semester

Based on the results of the student survey in Spring 2002, some improvements were implemented in the course contents, coverage, and resources. In addition, more web resources were used in many parts of the course and computational tools were incorporated into the course before the class was offered again in Spring 2003. This time, 20 students took the class and much better outcome for students' learning has been achieved. Figure 2 shows the results of the student survey for the Spring 2003 semester. However, the result for the outcome 7 remains similar. This can be attributed to the relatively short time devote to the materials related to outcome 7. In the next offering of the course, more time will be allocated for materials related to outcome 7 to improve the course.

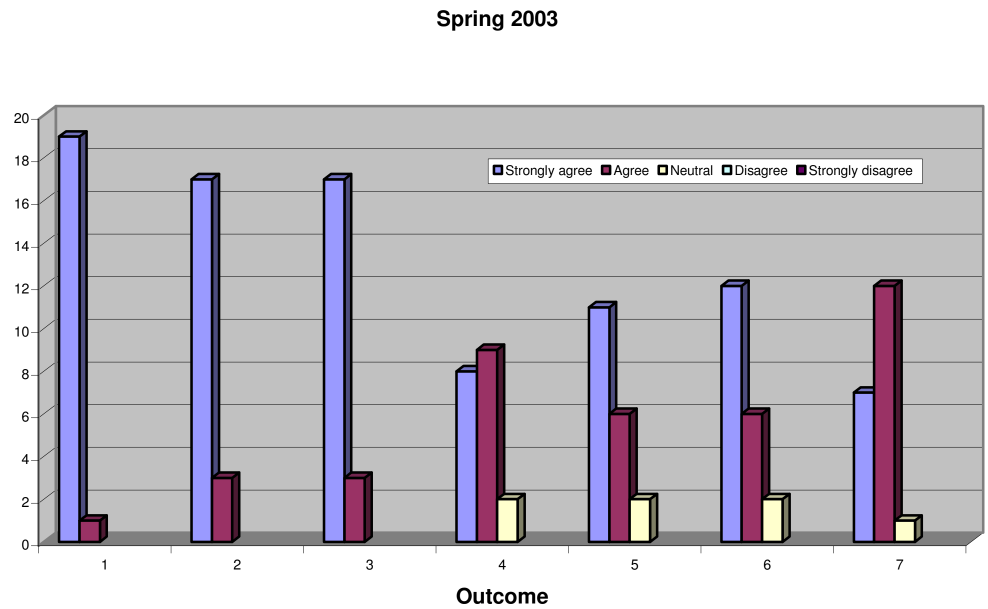

Figure 2 Results of Student Survey for the Spring 2003 Semester

Conclusions

This paper discussed the design and implementation of a new senior elective course, Energy Engineering, in the Department of Mechanical Engineering at Lamar University. The paper provides the contents of the course in details: textbooks, reference materials, course topics, web resources, computational tools, exams, and group projects. The results of the course outcome assessment based on student surveys are also provided.

Bibliography

1. Hutzel, W. J., "Energy Conservation in Thermal Power Courses," Proceedings of the 2002 ASEE Annual Conference and Exposition, Montreal, Canada, 2002.
2. Schumack, M., "Incorporation of an Energy Conservation Theme into Thermal Science Courses," Proceedings of the 2002 ASEE Annual Conference and Exposition, Montreal, Canada, 2002.
3. Hodge, B. K., "Alternate Energy Systems A New Elective," Proceedings of the 2002 ASEE Annual Conference and Exposition, Montreal, Canada, 2002.
4. Culp, A. W., "Principles of Energy Conversion", 2nd Edition, McGraw Hill, 1991.
5. Sorenson, H. A., "Energy Conversion Systems," John Wiley & Sons, 1983.
6. Berinstein, P., "Alternative Energy: Facts, Statistics, and Issues," Oryx Press, 2001.
7. Hazen, M. E., and Hauben, M., "Alternative Energy," Delmar Learning, 1996.
8. Ristinen, R. A., and Kraushaar, J. J., "Energy and the Environment," John Wiley & Sons, 1998.
9. Thumann, A., and Mehta, D. P., "Handbook of Energy Engineering," 5th Edition, Fairmont Press, 2001.
10. Elliott, T. C. (Editor), "Standard Handbook of Powerplant Engineering," McGraw Hill, 1997.
11. Thumann, A., "Plant Engineers and Managers Guide to Energy Conservation," Fairmont Press, 2002.
12. Turner, W. C., "Energy Management Handbook," Prentice Hall, 2001.

13. “Annual Energy Outlook with Projections to 2020,” Department of Energy Report, 2002. http://www.eia.doe.gov/oiaf/aeo/
14. “International Energy Outlook 2002,” Department of Energy Report, 2002. http://www.eia.doe.gov/oiaf/ieo/
15. “Statistical Review of World Energy” British Petroleum, 2002. http://www.bp.com/home.do
16. “World Energy Outlook 2002,” International Energy Agency Report, 2002. http://www.worldenergyoutlook.org/weo/pubs/weo2002/weo2002.asp
17. Markvart, T., “Solar Electricity,” John Wiley & Sons, 2000.
18. Manwell, J., McGowan, J., and Rogers, A., “Wind Energy Explained: Theory, Design and Applications,” John Wiley & Sons, 2002.
19. S. Appanaboyina, R. Sreenivasa and K. Aung, “Development of Web-Based Tools for Energy Engineering,” *Proceedings of the 2003 ASEE Annual Meeting & Exposition,* Nashville, Tennessee, 2003.
20. CyclePad, Qualitative Reasoning Group, http://www.qrg.ils.nwu.edu/projects/NSF/Cyclepad/aboutcp.htm.
21. http://www.siemenswestinghouse.com/en/plantrating/index.cfm, Siemens Westinghouse, 2003.
22. http://www.fsec.ucf.edu/solar/apps/sdhw/gp10sizing.pdf, Florida Solar Energy Center, 1992.
23. Larminie, J., and Dicks, A., “Fuel Cell Systems Explained,” John Wiley & Sons, 2000.
24. Hoogers, G., “Fuel Cell Technology Handbook,” CRC Press, 2002.
25. Hamilton, S. L., “The Handbook of Microturbine Generators,” Pennwell Publishing, 2003.
26. http://www.cogen.org, European Association for the Promotion of Cogeneration (Cogen Europe), 2002.
27. http://www.cheresources.com/transition.shtml, Chemical Engineers’ Resource Page, 2003.

Biography

KENDRICK AUNG is an assistant professor in the Department of Mechanical Engineering at Lamar University. He received his Ph.D. degree in Aerospace Engineering from University of Michigan in 1996. He is an active member of ASEE, ASME, AIAA and Combustion Institute. He has published over 50 technical papers and presented several papers at national and international conferences.