Alternate Energy Systems—A New Elective?

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Abstract

Experiences with a technical elective course, ME 4353/6353 Alternate Energy Systems, are delineated. Alternate Energy Systems (AES) was devised for senior and beginning graduate students in mechanical engineering (ME) and presents a first-order introduction to the plethora of alternate energy technologies now considered as available, viable, or promising. The AES course covers basic principles, economic considerations, application potentials, and advantages and disadvantages of a variety of alternate energy technologies. The course topics, contents, and goals are discussed in detail in the paper. After two offering, the AES course meets the stated purpose of the course and has become a popular elective even though the workload and effort required are significant.

Background

Virtually all mechanical engineering (ME) programs make use of technical electives to provide students with depth or breath in an undergraduate ME curriculum. Many of these technical electives explore traditional topical subjects such as finite element analysis or HVAC systems, but some such as composite materials or nanotechnology, provide introductions to new or emerging areas of mechanical engineering. Technical electives with titles such as energy conversion or direct energy conversion have provided exposure to selected energy conversion systems and principles. However, deregulation of electricity and natural gas, widespread use of decentralized generating plants, emerging new energy technologies, added stress on the national electrical grid, uncertainty about energy availability (especially in the international arena after 9/11), and mounting environmental concerns have increased the diversity of sources and technologies used to satisfy residential, commercial, industrial, and transportation energy requirements. All of the above suggest that the time has come for a course that examines principals of many alternate energy sources and integrates the presentations with the energy and economic realities of the twenty-first century. This paper explores experiences with such a new technical-elective course, ME 4353/6353 Alternate Energy Systems, at Mississippi State University (MSU).

Course Description

Alternate Energy Systems (AES) was devised for senior and beginning graduate ME students and presents a first-order introduction to the plethora of alternate energy technologies
now considered as viable or promising. The AES course covers basic principles, economic considerations, application potentials, and advantages and disadvantages of the following alternate energy technologies:

(1) active solar  
(2) passive solar  
(3) photovoltaic  
(4) hydroelectric  
(5) wind  
(6) gas turbine  
(7) cogeneration  
(8) CHP (Cooling, Heating, Power)-Buildings  
(9) fuel cell  
(10) geothermal  
(11) OTEC (Ocean Thermal Energy Conversion)  
(12) biomass  
(13) municipal solid waste  
(14) nuclear fission  
(15) nuclear fusion  
(16) others.

Web-based resources are included in all topics considered. The purpose of the course is not to examine in detail each technology, but rather to provide an introduction and assessment and the salient features of the diversity of energy systems available as well as to understand how each alternative fits in the energy and economic mixes of options available.

Course Details

The objectives of the Alternate Energy Systems (AES) course are to develop an understanding of the following:

(1) quantitative attributes, especially efficiencies, of different energy systems,  
(2) availability of different energy sources,  
(3) physical principles of different energy systems,  
(4) design/selection/economic/environmental issues and energy sources,  
(5) sources of information on alternate energy systems  
(6) relationship between source and site energy.

An underlying goal of the AES course is to provide students with an overview of energy usage in the contemporary world. In addition to the technical contents of the course, the energy consumption, end-point energy usages, and energy availability in the United States are previewed. Course closure is a five-to-ten minute report by each student on an energy system/technology or example not discussed in class. The technical part of AES is divided into
three segments: (1) solar energy, (2) turbomachinery-based systems, and (3) other systems. Such
a division of topics may seem unusual, but division into renewable and non-renewable fragments
the coverage of fundamentals principles. The course summary outline with lecture days, quizzes,
and other activities is given in Table 1. A more detailed examination of each of the major
segments in Table 1 follows.

A textbook is not available, so at the first class meeting students are warned that many
handouts will be used and are asked to prepare a loose-leaf notebook so the handouts can be
ordered (for use in homework and on quizzes). Extensive use of handouts has not been a
problem, although a textbook would enhance the course. The reference list contains an abridged
selection of textbooks and web sites that were helpful in the course.

Table 1. Alternate Energy Systems Summary Outline

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number of Days</th>
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<tbody>
<tr>
<td>Course Introduction/Energy Summary</td>
<td>3</td>
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<tr>
<td>Solar Energy Systems</td>
<td>12</td>
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<tr>
<td>Turbomachinery-based Systems</td>
<td>14</td>
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<td>Other Energy Systems</td>
<td>9</td>
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<td>Student Reports</td>
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<td>Quizzes</td>
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<td>Total</td>
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</table>

Course Introduction and Energy Summary in the US

The course introduction essentially tells the students what will be covered in the course,
what the expectations are, and how the grades will be determined. Senior and graduate students
in ME have generally expended so much effort in mastering the mathematics and principles of
various topics that they often neglect to assimilate the “big picture.” The Energy Information
Administration (EIA) of the US Department of Energy (DOE) provides a yearly summary of
energy usage by sectors in the US. The EIA web site contains an excellent graphic summarizing
the energy flow\textsuperscript{1} in the US. This graphic, reproduced as Figure 1, immediately grabs a student’s
attention and set the tone for the remainder of the course.

Solar Energy Systems

Solar energy has traditionally been a part of many courses examining energy conversion
topics or renewable energy sources. The solar energy coverage in the AES course is much less
detailed (and shorter) than in a solar-energy engineering course, but all fundamentals are covered.
References 3-13 are used in this segment of the course. As can be seen from the reference list,
extensive use is made of information from the web. Table 2 presents the topics covered in the
solar energy segment of the course.

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\textsuperscript{1}The energy flow in the US.
Table 2. Solar Energy Systems Segment Topics

1. Radiation heat transfer review
   spectral characteristics
   spectrally-dependent $\alpha$, $\varepsilon$, and $\tau$
   energy balances

2. The sun
   geometry: azimuth, attitude, declination
   sunpath charts
   solar insulation: hourly, monthly, yearly with geometry
   NREL data

3. Active solar
   solar collector principles
   commercially available solar collectors
   solar collector analysis, performance, and economics
   f-chart method
   TRNSYS

4. Passive solar
   the Greeks
   passive solar principles
   examples and economics
   ENERGY-10
Table 2. Concluded

5. Photovoltaic
   principles
   quantum limitations
   efficiencies
   commercial availability
   costs

Turbomachinery-based Systems

Turbomachinery based systems include familiar and widely-used technologies such as hydroelectric and wind as well as the somewhat newer combustion turbine systems, especially in what the U. S. Department of Energy calls the CHP-Buildings (Cooling, Heating, and Power-Buildings) configurations. With increasing emphasis on decentralized, or local, generation of electricity and with the increasing demand for peaking electricity, dedicated (non-CHP-Buildings) combustion turbines are also increasing dramatically in number and importance. The energy transfer process in rotors is the connection between all turbomachinery-based systems and is covered as the first primary topics in this segment of the course. References 7, 9, 10, and 14-25 are used in this segment of the course. Table 3 presents the topics covered in the turbomachinery-based systems.

Table 3. Turbomachinery-Based Systems Segment Topics

1. Energy transfer in rotors
   conservation of angular momentum
   the Euler pump equations (torque, power, and change in head)
   velocity triangles
   impulse and reaction
   applications
2. Hydroelectric
   national and international examples
   Kaplan, Francis, and impulse turbines
   “dimensional” specific speeds and device suitability
   hydroelectric system analysis
3. Wind
   survey of types
   actuator theory and maximum power extraction
   wind energy power coefficients
   system components
   commercial availability and examples
   economics
Table 3. Concluded

4. Combustion turbines (Gas turbines)
   isentropic efficiencies
   cycle analysis and heat rate
   Solar, GE, and Siemans examples
   Micro-turbine (Capstone) example

5. Utility billing structures
   electricity: energy and demand
   gas: energy
   examples of commercial bills and rate schedules

6. CHP-Buildings
   introduction
   baseline efficiencies of various devices
   analysis of commercial utility bills for CHP-Buildings suitability

Other Energy Systems

Alternate energy systems certainly include technologies not classified either as solar or turbomachinery based. The course was split into these segments to permit congruent coverage of fundamental principles, so the category “Other” is devoted to alternate systems not in the first two categories. This is an artificial distinction, but it has worked well in the AES course at MSU. The Other Energy Systems segment of the course is more qualitative and less quantitative than the first two segments. In general the sequence is to present an energy source, preview systems to harvest the energy, discuss the potential of the energy source, assess status of the technology, and critically examine the economics and barriers (technical, economic, political, and social). References 9, 10, 16, 23, and 26-32 are used in this segment of the AES course. As with the other segment, web-based sources are extensively used, and the students are warned to be critical of un-reviewed/marketing-oriented material so prevalent in company, organization, and individual web sites. No homework problems were assigned in this segment, rather the student reports (discussed in the next section) were due immediately after the segment. Table 4 presents the topics covered in the “Other Energy Systems” category.

Table 4. Other Energy System Topics

1. Fuel cells
   basic operation
   types of electrolyte
   examples and availability
   economics and potential
Table 4. Concluded

2. Geothermal (including ground-source heat pumps)
   basic principles
   availability
   status and economics

3. OTEC (Ocean Thermal Energy Conversion)
   basic principles
   availability
   problems
   status and economics

4. Biomass
   applications
   availability and limitations
   problems
   status and economics

5. Municipal Solid Waste
   applications
   availability and limitations
   examples
   status and economics

6. Nuclear fission
   nuclear physics
   reactor physics, neutrons, moderators, and reactivity
   light-water reactors, types, and examples
   Chernobyl
   outlook

7. Nuclear fusion
   allure
   nuclear physics
   containment
   research and status
   timeline?

Student Reports

At the start of the course, each student is assigned a report on an alternate energy systems not covered in class. Timelines for selection, instructor approval, and the preliminary outline are established at that time. PowerPoint must be used in the presentations, and the reports are made the last week of classes. Student presentations have been the best segment of the course. Individually or in groups of two or three, the students have exhibited great interests and have expended considerable efforts in this segment. Individual students or groups have visited alternate energy sites located near MSU, have contacted companies for information and materials, have made extensive use of web resources, and generally picked interesting, unique
topics of interest to fellow students (and to the instructor as well!). Some sample topics are provided in Table 5.

Table 5. Examples of Topics for Student Reports

1. The Red Hills Lignite Generating Plant
2. The Caledonia Combustion Turbines Plant
3. The Grand Gulf Nuclear Power Plant
4. Photovoltaic Usage on Off-shore Drilling Platforms
5. Passive Solar Examples on the MSU Campus
7. Energy Usage in the Florida Solar Energy Test Houses
8. Low-head Hydro for Residential Uses
9. Solar Powered Sail Boat
10. The Status of Fuel Cells for Residential Use

Four periods were required for the student presentations. Each presentation was followed by a question period with class and instructor participation.

Course Assessment

The best course assessment mechanism is the ABET course assessment developed by the instructor after each offering. The ABET assessment narrative is reproduced in the following paragraph, and the ABET summary table is presented as Figure 2.

The formal ABET AES narrative for the Fall Semester 2001 is as follows: ‘Students in this class mastered the material with an overall assessment of “G.” The first two segments of the course, “solar” and “turbomachinery-based”, were quantitatively oriented while the third segment, “other” (geothermal, OTEC, fuel cells, biomass, nuclear), was more qualitative. In the first two segments, students benefited from reviews on radiation heat transfer, fluid mechanics, and cycle analysis. The students this semester had some difficulties in mastering cycle analysis of gas turbines and energy transfer in turbomachines. The turbomachinery energy transfer applications, especially the construction of velocity triangles, gave the students trouble. This was not unexpected as this topic is traditionally difficult to master. Using utility bills from the MSU Industrial Assessment Center (IAC) in the cogeneration application portion peaked the interest of students and should be continued. The students adequately mastered, assessed as “G” to “E,” the areas of emphasis in the “other” segment (geothermal, OTEC, fuel cells, biomass, nuclear). A more quantitative coverage of the “other” topics is needed and should be expanded the next offering. The student reports, oral reports on an alternative energy system topics or examples not covered in class, were excellent. All student presentations were acceptable and many showed much effort and thought. Although some fine-tuning in the “other” segment will be done the next offering, no major changes in topics or modes of presentation are needed based on this assessment.’
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<th>T 3</th>
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P—Poor, F—Fair, S—Satisfactory, G—Good, E—Excellent
t—Test, HW—HomeWork, R—Report, F—Final

![Figure 2. ABET Assessment for AES (Fall 2001)](image)

## Conclusions

After two offering, Alternate Energy Systems meets the stated purpose of the course and has become a popular elective even though the workload and effort required are above average for a technical elective. Because of the variety of topics covered, the students do not become saturated or bored with an individual topic. The division of AES into three segments [(1) solar energy, (2) turbomachinery-based systems, and (3) other systems] is unusual, but student reaction has been good.

## References

1. [www.eia.doe.gov/aer/diagrams/diagram1.html](www.eia.doe.gov/aer/diagrams/diagram1.html)

2. [www.eia.doe.gov/oiaf/earlyrelease](www.eia.doe.gov/oiaf/earlyrelease), (Contains annual energy outlook.)


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27. www.ifc.com. (Contains information on the PC25 fuel cell.)

28. www.id.inel.gov/geothermal and www.eren.doe.gov/geothermal. (DOE geothermal energy web sites.)


31. www.solidwaste.org/wtedescr. (Contains Spokane solid waste plant information.)


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