A COURSE ON ENERGY TECHNOLOGY AND POLICY

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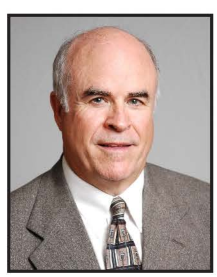
Rarely a day goes by that we do not read or hear a news item about energy issues. In April 2005 I was planning to teach a fall elective course on optimization (a course definitely oriented toward left-brained ChE students). I decided, however, that it was time to teach something different and introduce our students to the subject of energy from the chemical engineering perspective. Thanks to the flexibility of our department chair, I was allowed to change the course offered since both courses were electives. I also did a market survey of about 60 seniors who were enrolled in my process control class—to provide some stealth publicity (as it would be a new elective) and also find out how they would react to enrolling in such a course. While I received quite a few affirmative responses ("yes, I would be interested, but I am graduating in May"), there was useful feedback on items such as numbers of reports, exams, and presentations, as well as subject matter. I launched the course in fall 2005 and taught it again in fall 2006. It was an extremely positive experience for me, and, based on student evaluations, they liked the less-structured, more individualized course in contrast to the typical core ChE course.

Teaching an energy course was not a new experience for me, as I taught a course called *"Energy Policy and Technology"* in 1974 during the "first" energy crisis. One of my former students in that class (who rose to the position of VP at Amoco and BP) sardonically redubbed it *"Energy Policy, Technology, and Communism,"* as I was a "more liberal than average" professor at the University of Texas then, arguing that the free market would not provide adequate policy solutions to the looming energy crisis.

Now we are embroiled in the second energy crisis (or as someone suggested, the "second coming" of the energy crisis), but in many ways not much has changed about the proposed technological solutions to the energy challenge. I did want to make this second course offering more technical in nature, so I reordered the course title to "Energy Technology and Policy." Initial enrollment was 25 students, about half of whom were graduate students. One year later, enrollment grew to 40, including 10 graduate students, largely due to the popularity of the first offering. There was an interdisciplinary flavor to both classes, as several students from electrical, mechanical, and petroleum engineering were enrolled. This resulted in a broadening experience for the class because students brought different perspectives on subjects such as diesel engines, semiconductors, oil, and gas.



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TEXTBOOK

I selected a book that was not written by engineers or scientists, but would instead give more insight into the non-technical (economic/environmental/sociopolitical) aspects of the course, thus complementing the technically focused lectures. *The End of Oil* by Paul Roberts[1] offers excellent insights on Middle East politics and history, at least from the oil and gas perspective. The author also makes some interesting observations (ca. 2004) about why the liberation of Iraq should be viewed in strategic energy terms (vs. weapons of mass destruction). In *The End of Oil*, Roberts presents a balanced point of view on most different energy alternatives, although he does not present many details on biofuels. He makes three major proposals for energy policy changes:

(1) *Boost natural gas supplies as a 30-year bridging fuel.*

(2) *Implement a carbon tracking system to facilitate coal gasification and carbon sequestration.*

(3) *Launch a significant effort to reduce oil and gas consumption in the United States.*

Roberts also does not believe the laws of supply and demand will be an orderly solution to energy shortages, although I know some economists would disagree (but those are equilibrium rather than dynamic market viewpoints). He does not over-hype some of the new energy alternatives, and his views on the potential "hydrogen economy" are sound ones, in my opinion. He also provides some calculations designed to estimate the true cost of various fuels vs. nontraditional alternatives. One other advantage of this book was its inexpensive price of $10 (paperback). This gives students a break from the $130 books offered by mainstream publishers that I impose on them in courses such as process control and optimization.

As it appears the second energy crisis will last longer than a few years (probably forever), a number of new books that have been published recently were subsequently added to the reading list for the second offering in fall 2006. Other books, such as References 2 and 3, are possible principal textbooks, but their level of presentation was not a good match for chemical engineers as they are more oriented to nuclear power and fossil fuels than desired. Another key reference is *Coal Processing and Pollution Control*,[4] a book I wrote in 1983. Because this book is out of print, I scanned six chapters and posted them on the Web, much in the spirit of the Google library project (less controversial because I am the author). It is interesting that much of the coal technology presented in this book is still appropriate today, although much of the economic information is no longer meaningful in terms of absolute costs. This book was published shortly after the end of the first energy crisis, a victim of bad timing. It is still, however, a useful resource today.

Other recent books that have appeared include those by Smil[5] and Tester, et al.,[6] published by MIT Press, and a book on the methanol economy[7] that covers a broad range of topics. All of these books have certain strengths that could be valuable in an energy course for chemical engineers depending on the technical emphasis of the course. For example, the Tester, et al., book would be suitable for a graduate course on energy and sustainability.

COURSE STRUCTURE

Table 1 gives a list of the topics covered in the course. The breadth of energy alternatives is one reason the course is appealing to chemical engineers. Because of my previous involvement in creating synthetic fuels from coal, I had a predisposition toward covering that material, but several student evaluations at the end of the course indicated that they wanted less coverage on coal (perhaps because they do not subscribe to coal as the main answer to the current energy crisis). One advantage to teaching an energy course on the University of Texas campus is that there are quite a few energy experts in fields of interest to chemical engineering. Guest lecturers on geology of oil and gas, the oil business and extraction techniques, energy projections (from a former Assistant Secretary of the U.S. Department of the Interior), solar energy, nuclear power, and energy and the environment (climate change) were scheduled. Private sector presentations included the hydrogen

TABLE 1
Energy Course Topics

	Guest Lecturer/Affiliation
1. U.S. Energy Supplies/Origin and Occurrence	L. Long (UT Geology)
2. Oil Exploration and Production	W. Fisher (UT Geology) L. Lake (UT Petroleum Engineering)
3. Coal Extraction, Combustion, Gasification, Liquefaction	
4. Fuel Cells, Hydrogen Economy, Sustainability	D. Austgen (Shell Hydrogen) J. Siirola (Eastman Chemical)
5. Recovery of Oil Shale/Tar Sands	
6. Energy and Transportation	
7. Nuclear Power	L. Draper (Amer. Electric Power, retired) S. Biegalski (UT Mechanical Engineering)
8. Solar Energy, Wind Power	G. Vliet (UT Mechanical Engineering) J. Hoffner (CSG)
9. Biomass Production and Conversion	
10. Energy Conservation	
11. Climate Change and Energy Utilization	D. Allen (UT Chemical Engineering)
12. Energy Policy and Technology	

TABLE 2
Energy Crisis—A True/False Quiz

1. The first energy crisis in 1974 occurred because of a shortage of oil production capacity.
2. The U.S. should sign the Kyoto Treaty (on CO_2 emission) even though it treats China and developing countries more favorably than the U.S.
3. Global warming due to human (anthropogenic) caused greenhouse gas emissions is occurring and its impact is evident and is measurable today.
4. Hydrogen is the best non-polluting fuel to use (burning it yields H_2O), so we should convert to a hydrogen-based economy.
5. Continuing massive oil imports will eventually destroy the U.S. economy.
6. Drilling and producing oil and gas in the Arctic National Wildlife Refuge (Alaska) will significantly reduce our need for oil imports.
7. Gasoline is more expensive today than in 1975 (in constant dollar terms).
8. The United States has enough fossil fuel supplies (oil, gas, coal, shale) to meet its own energy needs.
9. OPEC controls the price of oil.
10. The invasion of Iraq was partly driven by a need for stability in and access to oil supplies, comparable to other justifications (weapons of mass destruction or Saddam Hussein's reign of terror).
11. At a high enough price for fuel, (e.g., \$80/bbl oil) over a 20 year horizon in the future, potential energy supplies will be plentiful, including solar and biomass.
12. U.S. Government policy should encourage conservation and constrain consumption through increased taxation of gasoline (e.g., \$2.00/gallon vs. \$.20).
13. Americans will be willing to give up their love affair with personal autos and explore (and use) mass transportation.
14. Massive use of hybrid autos and outlawing SUVs are the best near-term solution for reducing oil consumption.
15. Fuel cells will largely replace internal combustion engines in autos by 2035.
16. The use of nuclear energy for electric power production in the U.S.A. can increase from 20% to 30% by 2025.
17. World oil production will reach a maximum in the next four years and then start declining irreversibly.
18. A worldwide growth rate of 2% in energy use is small enough that we don't have to worry about energy supply/demand imbalances.
19. The politically expedient solution to the energy crisis is short-term comfort for ourselves vs. agreeing to some inconveniences and price increases on behalf of our grandchildren. Would our culture vote for a candidate who told us we needed to make major sacrifices in our lifestyle and economic well-being?
20. Investment in new energy technology will have the same beneficial impact on the U.S. economy as information technology and computing in the past 20 years.
21. New advances in technology and engineering ingenuity will increase electrical efficiency, combustion efficiency, and provide a plethora of personal energy sources, thus raising our standard of living even higher.
22. The next major war will be fought over access to energy supplies.

TABLE 3
Grading Policy—Energy Technology and Policy

(1) Two written reports plus literature portfolio (40%) – specific topics selected by students
(a) research on selected energy technology
(b) government-regulatory issues
(2) Two ten-minute oral reports presented by each student (10%) based on the above written reports
(3) Homework assignments involving energy calculations (10%)
(4) Midterm exam (20%) (take-home)
(5) Final exam (20%) (take-home)

economy (from a VP at Shell Hydrogen), the solar panel business, sustainability (Jeff Siirola from Eastman Chemical), and a former CEO from American Electric Power (who spoke on the theme, "would I build a nuclear power plant today?"). Student evaluations indicated that they enjoyed hearing from different speakers rather than just from the course instructor. I found the speakers very informative, and engaged them in discussions and debate after the typical obligatory PowerPoint presentations. I encouraged the students to participate in such discussions, but did not want to impose a requirement on their participation (*e.g.*, you have to ask one question in class every three weeks). It took a few weeks to get the fluid, engaged environment I was seeking, but it did occur. I added a few more guest speakers for the second offering, such as in CO_2 sequestration.

One of the effective ways to get the class talking during the first week of class was to have them participate in a true-false quiz on energy (see Table 2). I have used this quiz in teaching several older adult groups with success, and have found that participants immediately react and share their viewpoints and impressions with others in the class. A number of questions are loaded with a political viewpoint, so the true or false answer depends on your politics. Because the students do not formally take the quiz and submit the answers, this is not too threatening, even in the home state of President Bush. As each question can lead to a separate discussion, I find that we are unable to cover all of the questions in the first class meeting, and some questions are saved for later in the semester. In these discussions it is interesting to gauge how well-informed students are on energy matters, since very few of them read a daily newspaper.

The grading structure for the course is given in Table 3. As mentioned earlier, it is a course where

TABLE 4
Take-Home Exam—Energy Course

1. It is 2025, and coal is now being gasified around the U.S.A. to produce synthetic methane, which is replacing dwindling supplies of natural gas. A company has access to a large coal reserve in Wyoming, 1100 miles from an industrial site in Texas that needs the gas. The President of the company must decide on the least cost strategy to transport the energy between Wyoming and Texas, using the following two scenarios:

   (a) make pipeline quality gas from the coal in Wyoming, then transport the gas by pipeline to Texas. Assume the coal has a heating value of 10,000 Btu/lb.

   (b) Ship the coal by rail to Texas, and then gasify the coal at the industrial site in Texas.

   You have been hired as a consultant to help the President decide. What will be the cheaper transportation option between (a) and (b)? Provide supporting calculations.

2. If a hydrogen economy develops in the future, there will be a need for increased transport of hydrogen by pipeline.

   (a) In comparison to natural gas, it appears that hydrogen (with a heating value of one-third of CH_4) would cost three times as much per 106 Btu to transport. However, the physical properties of H_2 may be such that pressure losses are quite low, thus reducing costs. Explain.

   (b) What are the added safety issues that must be addressed in H_2 pipelines? Note that H_2 pipelines exist and operate in Texas today.

3. It has been suggested in news sources that the production of ethanol from corn in the Midwest U.S. is a net energy loss, in that more energy may be required to produce one gallon of ethanol than is available in the ethanol itself. Research this topic and determine if this statement is correct or not. You may take into account energy requirements to grow the corn.

4. Building and home lighting directly affects our economy. As a nation, we spend approximately one-quarter of our electricity budget on lighting – or more than $37 billion annually. An incandescent light bulb is highly inefficient because it converts only a small amount of the electrical energy into light; the rest is converted to heat. In spite of this inefficient conversion of energy, the relatively inexpensive purchase price of incandescent bulbs when compared to fluorescent lighting accounts for their popularity among consumers.
   A 75W (1220 lumens) bulb that is assumed to have the shape of a sphere has a diameter of 6 cm and a surface temperature of 250°C (when the light is turned on). The surrounding room air temperature is 25°C. Heat transfer calculations indicate that the incandescent bulb has a heat loss of 65W compared to 20W for the fluorescent bulb. The 75W incandescent bulb has a 750 hour life, while the 17W (1200 lumens) fluorescent bulb averages 10,000 hours before failing. Find out the cost of both bulbs from a local supplier and calculate the rate of return for replacing the equivalent of 20 75W lights (typical house), which are turned on an average of 4 hours/day.

   For extra credit (5 pts) verify the heat loss of 65W mentioned above for an incandescent bulb using appropriate heat transfer calculations.

oral and written communication skills are emphasized, but also provides students an opportunity to integrate knowledge they have acquired in other engineering courses. Students should know how to perform economics calculations as well as do efficiency analysis using energy balances and thermodynamics. I find that most of today's students do not retain much information from their previous courses, so revisiting key concepts in an energy context is useful.

While chemical engineering students are exposed to various energy topics, such as distillation, in previous courses, they do not understand how these topics relate to macroscopic energy issues in the United States or the world. Rarely are students conversant with order of magnitude information like how many Btu's are in one standard cubic foot of natural gas [answer = 1000] or how many Btu's can be liberated by condensing one pound of steam [answer = 1000]. I place a high value on being able to perform approximate calculations quickly because it is valuable for discussions with your supervisor or the plant manager later in your career.

A take-home exam format, which allowed students to research certain types of information (most use Google and Wikipedia), was used exclusively and worked well. Each take-home exam required about 10 hours of work, so it had the advantage of considerable depth compared to the typical one-hour exam. See Table 4 for the take-home mid-term exam used in fall 2005.

A typical homework assignment is given in Table 5. As most energy solutions depend on economics, it is important to reinforce student background in this aspect. All energy conservation applications involve spending capital funds in order to achieve energy savings. As example, I recently upgraded my air conditioning system to a 14 SEER unit, which can be justified based on reduced cooling costs and various tax and rebate incentives (see problem 2 in Table 5).

The final exam included somewhat similar problems to the midterm, but I also included a question that was intended to assess how much views on energy might have been influenced by the class (see Table 6). It was interesting to see how many students developed more passionate views on energy conservation, the problems

TABLE 5
Homework—Energy Economics

1. A synthetic methane plant from coal is to be constructed at a cost of $4 billion dollars. It requires 14,000 tons/day of coal (10,000 Btu/lb) and will produce 130 MMSCF/day of synthetic methane. What is the thermal efficiency? What is the cost of coal in the produced methane ($/MMBtu)? What is the equivalent fixed cost of the plant capital cost in $/MMBtu? Assume that the plant operates 320 days per year.

2. New air-conditioning units have an EER of about 13. If a new AC unit costs $3,000 after a City of Austin rebate, what is the payback on replacing an AC unit with an EER of 9? Assume existing cooling costs of $1,200 per year (May–September) with the current unit.

TABLE 6 Final Exam Question
You have been appointed the U.S. energy czar. Discuss your personal view of what changes (or not) should be made in the U.S.A. energy mix in 2025 (when you are over 40!). Assume that the amount of oil and gas available for energy use would be the same or less than in 2005. Rank relative increases on a percentage basis; recognize that some technologies may take longer to develop. Use 2005 usage levels as your baseline. You can choose to reduce oil imports in the scenario developed.
(a) solar
(b) nuclear
(c) fuels from biomass
(d) energy conservation
(e) coal
(f) tar sands
(g) oil shale
(h) hydrogen
(i) other
Comments: Write one page summarizing your ratings.

of using coal, etc. This question was graded on how well the students substantiated their views (*i.e.*, many possible correct answers).

One of the important points students need to understand is the growing size of the energy demand, largely due to the economic development of China and India. Even a 2% annual global growth rate can, over 30 years, dwarf what appear to be measurable increases in energy supplies due to improved technology. One case in point is the Arctic National Wildlife Refuge (ANWR) debate in the United States. The net addition of this resource to oil supplies in the United States will only amount to one year's increase in the global energy demand. An interesting video on the Web by Chemistry Professor Nathan Lewis of Caltech ("Scientific Challenges in Sustainable Energy Technology," <http://nsl.caltech.edu/energy.html>) lays out a compelling picture of the energy options in 2050 after available oil and gas supplies decline. Lewis opines that in 50 years massive efforts in solar energy will be required to prevent greenhouse gas buildup and to keep the U.S. standard of living the same. Students in today's classes will still be around in 2050 to see what happens; professors like me will not be here then, but our children and grandchildren will. Students also need to understand that the U.S. public does not have a rational view of their responsibility to share the burden of energy consumption. The American transportation dependence (addiction?) on imported oil is perhaps the most significant problem faced in the near term. Other notable examples include opposition to wind energy in Massachusetts and general resistance to new nuclear power plants almost everywhere. The philosophy of many citizens has moved from NIMBY ("not in my backyard") to BANANA ("build absolutely nothing anywhere near anything"). This attitude will obviously need to change in the near future.

Earlier I commented on how today's students do not normally make it a habit to read a daily newspaper. I felt that students needed to read on a regular basis to see how energy issues are discussed in public forums, by politicians, or by other thought leaders. Hence, one of the other requirements in the class was for students to collect one article per week of general relevance to energy from a newspaper or national magazine, either print-based or on the Internet. At the end of the semester the students submitted a list of articles plus a short overview of each one. While many students voluntarily will read energy articles, there are always some students who need to be coerced.

STUDENT PRESENTATIONS

Student presentations were a cornerstone of the course. I wanted students to make individual choices on which energy issues they would study in-depth. Table 7 gives a list of the projects selected in fall 2005 after discussions with the instructor. Students were required to give two talks, one on technology (about halfway through the semester) and the other a policy

TABLE 7 Student Energy Project Areas
conservation of crude oil (fuels vs. chemical feedstock)
heavy oil gasification
oil shale utilization
wind power
hydrogen technology
LNG (liquefied natural gas)
oil importation effects on economy
energy conservation in wastewater purification
environmental impact of auto mobile technology
fuel cells and hydrogen technology
personal auto use and conservation
photovoltaic technology for solar energy
nontraditional hydrocarbon sources (hydrates)
energy efficiency and conservation (green building)
effects of lifestyle choices on energy use
developing a positive image of nuclear energy
energy usage in developing countries
sources of hydrogen
wind energy and power generation
nuclear fusion technology
electric vehicles
ethanol production
biodiesel production
carbon dioxide reduction

The students also held an "American energy idol" contest to select the best talks.

presentation, which was given toward the end of the semester. Both presentations were accompanied by a written report. The policy assignment required them to review existing government policies (mostly U.S. focused) and then propose modifications to these policies. The topics in Table 7 were fairly general, and in the fall of 2006 most projects were more specific (usually negotiated between faculty and student based on his/her interest).

One problem created by so many presentations is how to schedule them without taking away a large amount of time from the lecture activities. A few extra class sessions were scheduled for the technology presentations so that there was a reasonable fit with the topics scheduled. This aspect of the course turned out to be a pleasant surprise, namely that students were able to teach each other. The quality of the presentations was quite good, so I found I did not need to cover the same material. For example, two student presentations on wind energy seemed sufficient, so I did not cover this topic. The students also held an "American energy idol" contest to select the best talks. I then posted the student presentations

TABLE 8
Guidelines for 10-Minute Talks

1. Why is this issue or technology important to the energy situation?
2. What is the technical background? What are the technological challenges?
3. What is the economic feasibility?
4. What are the government policy issues?
5. Use 10 slides or less.

TABLE 9
Selected Lecture Notes and Presentations on the Course Web Site
<www.che.utexas.edu/course/che379&384/index.html>

1. U.S. Energy Supplies/Origin and Occurrence
- a. Energy prices, supply, and demand
- b. Geology of oil and gas
- c. Energy true-false quiz
- d. Global energy situation
- e. Global energy overview to 2050
- f. Oil importation effects on U.S. economy
- g. China energy consumption
- h. Energy economics

2. Oil Exploration and Production
- a. The oil business
- b. Crude oil trading
- c. Heavy oil issues
- d. LNG transporting and storage
- e. Methane hydrates
- f. CO_2 sequestration

3. Coal Combustion, Gasification, Liquefaction
- a. Coal reserves and properties – Chapter 2[4]
- b. Coal extraction – Chapter 3[4]
- c. Coal transportation – Chapter 4[4]
- d. Coal preparation and cleaning
- e. Coal carbonization
- f. Coal gasification – Chapter 7[4]
- g. Coal liquefaction – Chapter 8[4]
- h. Coal combustion – Chapter 9[4]
- i. Environmental impact

4. Recovery of Oil Shale/Tar Sands
- a. Shale oil
- b. Shale and tar sands

5. Fuel Cells, Hydrogen Economy, Sustainability
- a. Hydrogen as a fuel (Shell Hydrogen)
- b. Hydrogen storage technology
- c. Sources of hydrogen and hydrogen economy
- d. Fuel cell technology
- e. Sustainability in the chemical and energy industries
- f. Membrane separation of hydrogen

6. Energy and Transportation
- a. Electrical vehicles
- b. Auto engine efficiency improvements
- c. Plug-in hybrids

7. Nuclear Power
- a. Nuclear power
- b. Fusion power

8. Solar Energy, Wind Power
- a. Solar energy
- b. Photovoltaic – solar cell
- c. Wind energy

9. Biomass Production and Conversion
- a. Ethanol
- b. Bio-diesel

10. Energy Conservation
- a. Effects of lifestyle choices on energy use
- b. Energy conservation measures
- c. Developing countries
- d. Green buildings

11. Climate Change and Energy Utilization
- a. CO_2 emission reduction technology
- b. Carbon cycle
- c. What causes climate change?

12. Energy Policy and Technology

TABLE 10 Video Content for An Energy Course
"An Inconvenient Truth"—Paramount
"Who Killed the Electric Car?"—Sony
"Renewable Energy"—Modern Marvels (History Channel)
"Mega Oil Complex (Tar Sands)"—History Channel
"Coal Cowboy"—60 minutes (CBS)
"The Power of the Sun"—UCSB, Department of Physics

on the course Web site, which had the advantage of making the Web site a substantial resource. The guidelines for the presentations were fairly minimal (see Table 8).

The course Web site contains a significant amount of content and is not password-protected. In addition to student presentations, it includes the instructor's lectures (many on coal) and book chapters, guest lectures, exams, and the homework. Table 9 gives the URL and an outline of the lectures on the existing Web site; the coverage has become quite extensive over two semesters. Several other presentations totally apart from the course are also posted there. There are also a number of excellent videos on energy that are reasonably technical (see Table 10).

The notion that students can help develop content for a course is not a traditional view (vs. instructor-developed content or a textbook). Recently Boettcher[8] discussed this phenomenon, relating the idea to the "active learning" movement. In the acquisition of knowledge by the student, giving a lecture on a given topic promotes learning by the student at a higher level than lectures that involve interaction between professor and students or multimedia software. Learners can effectively learn content when they build their own knowledge in an interactive environment. Boettcher suggests that today's generation of students want to be doers, and active dialog with other students in a class is a very desirable activity. Posting student content on the Internet gives a higher level of value to the student contributions, which certainly resonated with the students in the class, and it also gives them a stronger self-identity. I also used student solutions to the homework and exam problems and posted them on the course Web site. In some cases, if several alternative approaches to an open-ended problem were submitted, it was beneficial for the students to see multiple solutions. Boettcher[9] proposes that as much as one-third of the content of many graduate courses could be student-generated. The questions then arise as to how much of this content will be stored for the indefinite future. There is a limit to the number of student presentations that can be posted when the class grows to more than 30 students, but I have not reached any conclusions yet.

It is clear that students today feel the world energy dilemma is much more palpable to them. In informal polls of students in the class, the belief that global warming is occurring and is caused partially by human activities has increased from about 50% to 90% between 2005 and 2006. Students also are recognizing that their individual actions have an impact on both energy usage and the environment. Two sample comments at the end of the class are shown below.

- *"This class will affect what articles I read, how I vote, what kind of home I will look for, and probably what kind of car I will own for the rest of my life."*
- *"I bought a Prius because I don't think I could get a car that wasn't as fuel efficient as possible after taking your class. I picked my sister up from her high school and there were three Hummers in the parking lot!"*

These kinds of comments, which transcend the technical content in the course, make teaching this course very rewarding.

CONCLUSIONS

Clearly the emerging energy situation in the United States puts chemical engineering at the forefront of the large research and education effort that will need to be undertaken during the next 20 years. Chemical engineering undergraduates and graduate students should be literate on energy alternatives and the interconnection of technology, economics, environment, and government policy. The course I am teaching and the associated Web site will hopefully influence the knowledge base of chemical engineering students, and I encourage other departments to consider adding similar courses either as regular courses, seminars, or campuswide offerings (where students outside engineering are enrolled).

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