AC 2007-3099: PROJECT-BASED PEDAGOGY TO ENHANCE TEACHING AND LEARNING IN ENERGY AND THE ENVIRONMENT FOR HONORS STUDENTS

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Project-based Pedagogy to Enhance Teaching and Learning in Energy and the Environment for Honors Students

Abstract

The paper presents a project-based teaching pedagogy for an honors level freshman course on energy and the environment. In addition to class lectures and discussions, students select from among a menu of energy-related topics for their project. The projects cover various aspects of the in-class discussions on energy fundamentals, renewable energy, fossil fuels, environmental impact, and energy policy. Each student prepares a 30 minute presentation on their topic to be given in class. The key criteria are for the lecture and data presented to be substantially different from the in-class lectures, up-to-date, and extend beyond the US (i.e., internationalized or globalized). Students are expected to be the experts on the topic after completing and presenting their project. Sample student topics include: wind, geothermal, hydroelectric, solar, biomass, ocean and tidal energy, coal, petroleum, natural gas, oil shale and tar sands, electric power, fuel cells, environmental impact of energy, energy supply and demand, materials for energy applications, and the 2005 US Energy Act.

The class, over a two year period 2005-2006, has shown a remarkable level of growth, excitement and interest of students. The presentations followed by questions and answers have shown enhanced teaching and learning of students. Student evaluations have indicated the project to be one of the key aspects of the course students liked most. It was concluded that project-based pedagogy significantly enhances teaching and learning.

Introduction

To meet the ever increasing energy demand, the nation and the world need a well trained and diverse workforce to develop process, utilize and manage both conventional and renewable energy sources in an environmentally safe and economically viable manner. Unfortunately, many of the academic programs that provided such workforce (e.g., chemical engineering) have redirected their focus to the health or bio-related areas leaving many energy producing and consuming industries with a high average technical workforce age and growing workforce demand. There is also renewed emphasis on the development of alternative sources of energy to conventional fossil fuels. The increasing demand for energy and trained energy workforce calls for innovative methods to increase enrollments and graduation rates of students in energy-focused disciplines.

Penn State University has significant resources and expertise in energy especially within the College of Earth and Mineral Sciences (EMS) through the departments of Energy and Geo-Environmental Engineering (EGEE), Material Science and Engineering and Geosciences as well as the Energy Institute (EI). The EMS College, in collaboration with other Colleges, is uniquely positioned to assist in this area of national importance: energy. The EGEE Department, for example, is committed to educating the student body at Penn State with regard to energy and energy concerns. This department is currently
educating 4,000 students per year in energy outside of our departmental majors, compared to less than 300 four years ago. In particular, the education of non-science students in energy is vital to the national debate on energy and security.

The high enrollments were achieved with dedicated faculty through innovative teaching styles and interactive learning objects. Two of the popular general education courses that have contributed to the education of the large number of students on energy are EGEE 101 Energy and the Environment and EGEE 102 Energy Conservation. The innovative approaches used in these classes have attracted higher representations of minorities (19% in “Energy & the Environment”) and women (56% in “Energy Conservation”). The regular sections of these classes typically have enrollments of 100-200 per section. However, the honors sections of these classes are limited to 20-30 per section. This allows more group discussion and interaction as well as individual projects and presentations by students. This paper covers aspects of the honors sections of the two classes taught by the authors; in particular the honors section of EGEE 101 Energy and the Environment taught by the lead author in Fall 2005 and 2006.

**EGEE 101H: Energy and the Environment**

This course satisfies the general education natural science requirement of Penn State University. It is typically taken by non-science majors as most science majors would have already satisfied this requirement with required courses in chemistry, physics and biology. However, a significant number of science-based majors still take this course. The course has no prerequisites and is offered in the Fall and Spring semesters.

The main objectives of this course are to:

- provide basic understanding and appreciation of energy and environmental concerns
- analyze energy consumption patterns
- discuss various energy resources that power the modern society
- examine energy conversion processes
- explore interrelationships between energy use and industrial progress and environmental consequences
- discuss sustainable future energy alternatives and conservation methods

The course is typically broken into four units:

Unit 1: Energy fundamentals that covers forms and uses of energy, supply and demand, and energy conversion and efficiencies

Unit 2: Nuclear and renewable energy that covers nuclear energy and such renewable options as wind, geothermal, hydropower, ocean and tidal, solar, biomass, and hydrogen and fuel cells.

Unit 3: Non-renewable energy- coal, petroleum, natural gas, oil shale and tar sands

Unit 4: Environmental impact that discusses the environmental and health and safety impacts of non-renewable and renewable energy options.

A sample schedule for a course that meets twice a week for 75 minutes per class session is shown in Table 1.
Table 1: Sample EGEE 101H Class Schedule

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Unit</th>
<th>Topic(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>1 (Energy Fundamentals)</td>
<td>Introduction to Energy; Forms of Energy; Uses of Energy; Energy Efficiency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supply and Demand</td>
</tr>
<tr>
<td>4-7</td>
<td>2 (Renewable Energy)</td>
<td>Wind and Geothermal; Hydro, Ocean, Tidal; Solar; Biomass; Fuel Cells; Nuclear Energy</td>
</tr>
<tr>
<td>8-11</td>
<td>3 (Fossil Fuels)</td>
<td>Fossil Fuels Overview; Coal; Petroleum/Crude Oil; Natural Gas; Oil shale &amp; tar sands</td>
</tr>
<tr>
<td>12-15</td>
<td>4 (Environmental Impact and Project Presentations)</td>
<td></td>
</tr>
</tbody>
</table>

In the honors section class, in addition to the enhanced interaction and open discussions on the topics, each student is required to develop expertise in one subject area of the class. Students are required to prepare a 30-minute PowerPoint presentation (20 minutes presentation and 10 minutes question and answer session) on their project topic and to deliver it in class. The presentation is evaluated by their peers and the instructor. An electronic copy of the presentation is submitted through a drop box in the course management site (ANGEL) that is accessible to all students. The quality of the student document and presentation material is judged especially on how current or up-to-date the data/information is and the extent or level of internationalization/globalization of the data (i.e., how far the data presented goes beyond the US and incorporates information/data on the rest of the world). Typically the project is weighted 20% of a students overall grade. As the instructor and student presentations are accessible to all students, they are responsible for all material covered by the instructor and students for all exams including the final exam. This encourages students to attend class and participate in the class presentations and discussions.

Sample topics or projects that students have previously chosen from are given in Table 2.

Table 2: Sample EGEE 101H Student Project Topics

16. Materials for energy applications 17. Electric power 18. Other

Students are expected to make presentations that are substantially different from the class lecture notes provided online to all students. They may however expand on the lecture notes provided in ANGEL, if available, and focus in their presentations on such topics as:
• The cause or source of the energy
• The reserves and resources of the energy
• The mechanism/technology for conversion of the energy
• Production rate
• Consumption/usage rate (e.g., total and per capita) relative to other sources of energy
• Specific applications or uses of the energy and their percent distribution
• The historical trend in cost and usage
• Historical setbacks or accidents on its production and usage
• Future of the energy source
• Societal or environmental impact
• Relation of the supply and demand to population and industrialization
• Personal statement or impression/summary after completing the project and developing expertise on the specific topic studied.

Students are encouraged to consult with the instructor as much as possible and to strive to be the expert and most current and reliable resource for information on their topic. The project based learning is to promote independent thinking and analysis, creativity, and the organization and presentation of thoughts and material learned.

Sample Student Projects/Presentations

Sample student project presentation on the 2005 US Energy Act is given at the end of the paper in Figure 1. Also shown in Figure 2 is a project on Biomass/Bioenergy. A summary of some of the personal opinions/conclusions provided after their research is given in Figure 3. Before each presentation, students were given an evaluation sheet shown in Table 3 to evaluate their peers on the project and presentation.

Student Evaluations of Projects and Course

Shown below are the mean values of the student’s feedback reported at the end of the course in Fall 2005 semester on a scale of 1 to 7 with seven being the highest score.

1. Overall quality of the course: 6.00
2. Overall quality of the instructor: 6.33
3. Clarity of the instructor’s presentations: 5.83
4. Instructor's willingness to help students make progress: 6.17
5. Instructor's skill creating a climate conducive to learning: 6.17
6. Adequacy of the instructor’s knowledge of the subject matter: 7.00
7. Instructor’s preparation for class: 6.67
8. Course organization in terms of logical arrangement of material and activities: 6.67
9. Instructor's skill in encouraging students to think: 6.50
Typically comments and responses to three specific questions asked students at the end of the course included:

a. What did you like most about the course?

   **Student presentations; independent research projects;** small class size and interactions; wide range of interesting topics; learning new materials; great instructor; online notes; the professor; in class demonstrations; fun, friendly and interesting learning environment; puzzles, homework and exam format

2. What did you like least about the course?
   Tediuous/lengthy homework; fast pace sometimes; too much material (but interesting); no book; math and equations; exam format

3. What suggestions do you have for improving the course?
   More movies/films, videos, and in class demonstrations; have textbook; less homework; less math; make it more challenging

Some of the comments sound contradictory. This reflects the mix and wide range of backgrounds of the students. In particular, non honors students are allowed to register for the course after registration of honors students. Clearly, however, the positive experiences far outweigh the negative experiences in terms of number and intensity.
Summary and Conclusions

In summary, through project-based pedagogy, teaching and learning in an energy and the environment general education course were enhanced as evidenced by student evaluations. The class, over the two year period 2005-2006, showed a remarkable level of growth, excitement, and interest of students. Student presentations showed enhanced teaching and learning. Student evaluations and comments indicated the project to be the part of the course students liked and enjoyed most. The approach enabled students to develop expertise in an aspect of energy and the environment, through project-based pedagogy, while learning from the professor and peers. In particular, the course structure enabled a broad range of topics such as the 2005 US Energy Act and aspects of some topics that would not have been covered in class to be researched and presented by students. This significantly broadened the depth of knowledge gained by students and the overall effectiveness of the course.

References:

1. College of Earth and Mineral Sciences, Penn State University
Figure 1. An Example of Student’s presentation on 2005 Energy Act

**Energy Policy Act of 2005**

- The bill was signed on August 8th, 2005 by George Bush.
- It is the first National Energy Bill in over a decade.
- "It's an economic bill, but... it's also a national security bill." - George Bush

**Background Information**

- The Energy Policy Act of 2005: "To ensure jobs for our future with secure and reliable energy."
- [http://energycommerce.house.gov/108/0235_EnergyPolicy_Act/Table%20of%20Contents.PDF](http://energycommerce.house.gov/108/0235_EnergyPolicy_Act/Table%20of%20Contents.PDF)
- Sponsor: Rep. Joe Barton
- Passed in the House 275 – 156
- Passed in the Senate 74 - 26

**Background Information cont.**

- It is a huge document and addresses wide ranging issues. Topics range from promoting hydrogen fuel cells to what type of firearms are security personnel allowed to carry at nuclear power plants.

**The Energy Bill and Renewable Energy**

- Establishes a goal of having 7.5 percent of energy use by the Federal government come from renewable energy by 2013.
- Renewable Energy Security Act: Provides financial assistance to homeowners who make their homes more energy efficient. The amount will not exceed $3,000 per home or 25% of the cost.
- For 2006 there is $150 million in the budget for this initiative.

**Hydroelectric**

- The Energy Bill provides monetary incentives for hydroelectric power generation.
- Hydro power facilities will receive 1.8 cents for every kilowatt hour, and no facility will receive more than $750K in a year.
- Efficiency improvement payments: If a facility increases efficiency by at least three percent, they are entitled to incentive payments.
- Facilities will receive up to 10% of the cost of the improvements and not more than $50K.
Biomass

- Improved Biomass Use Grant Program:
  - Research and development costs associated with increasing the use of biomass energy will be subsidized partly by the government.
  - Grants are available up to $50K, and the total amount for each project between 2008 and 2015 is $50 million.
  - Grants of $20 per “green ton of biomass” are also available to people who use biomass to produce electricity, substitutes for petroleum products or transportation fuel.

Geothermal, Solar, Wind and Ocean Energy

- Over the next five years, $30 billion is being devoted to renewable energy.
  - $10 billion of that amount is devoted to funding solar energy.
  - $10 billion of that amount is used in the production of hydrogen and ethanol.
  - Grant funding is available for studying ocean and wave energy.
  - State and local governments that construct buildings that utilize renewable energy are entitled to grants up to 40% of the costs of installation.

The Energy Bill and Fossil Fuels

- Over the next five years, $2.9 billion is going to be used to fund a number of initiatives related to fossil fuels.

Coal

- The Clean Coal Power Initiative is the main piece of legislation concerning coal.
  - Goals by 2020:
    - reduce 50% of sulfur dioxide
    - cut emissions of NOx to 0.5 lbs per million Btu
    - reduce mercury emissions
    - increase thermal efficiency of coal to nearly 60%.

Coal cont.

- Funding Coal Technologies:
  - Low-sulfur technologies are available to firms which operate power plants while use coal gasification and produce or power-intensive of power.
  - Funding opportunities are available for petroleum coke gasification projects.
  - $1 million towards researching electron scrubbing technology to reduce sulfur emissions.
  - Overall, in the next five years, $1.4 billion will be spent on coal technology R&D.

Petroleum and Natural Gas

- Expected life capacity of the Strategic Petroleum Reserve from 700 million barrels to 1.4 billion barrels.
- Cells for an increase in petroleum refining capacity.
  - Refineries are expected to have refining capacity expanded by 2010.
  - Strategic expansion of refining capacity by investing in the production of biofuels.
  - Some but not all states are reducing refining activity in the area and unemployment.
- Encourages the prohibition of offshore drilling in the Great Lakes and if the Finger Lakes.
Petroleum and Natural Gas cont.
- In the next five years, $460 million will be allocated to studies concerning exploration, gas hydrates, reservoir life, transportation, ultra clean fuels and environmental research.
- $50 million is going to be allocated specifically towards the Ultra-Deepwater and Unconventional Natural Gas and Other Petroleum Research fund.
  - The latter provides subsidies to companies which engage in deepwater exploration.

Nuclear Energy
- Over the next five years, $2.05 billion has been set aside for R&D, commercial application, engineering, security, and waste storage associated with nuclear energy.
- Nuclear Power 2010 Program:
  - A roadmap which promotes engineering and designing new nuclear plants and encourages new nuclear plants to be built.

Hydrogen Fuel Cells
- The bill allocates money for “research and development on technologies relating to the production, purification, distribution, storage, and use of hydrogen energy, fuel cells, and related infrastructure.”
- With the goal of “commercialize the use of hydrogen for transportation, electricity, industrial, commercial, and residential applications.”
- Establishes an interagency task force composed of more than 8 government agencies with the goal of promoting the use of hydrogen fuel cells.

Hydrogen Fuel Cells cont.
- Funding: The Energy Bill calls for $1.05 billion over the next five years and for additional money for 2011 through 2020 allocated specifically for development of the hydrogen supply.
- Funding: Calls for $650 million over the next five years for development of fuel cell technologies, plus additional money for 2011 through 2020.

The Energy Bill and Transportation
- By 2015, the automobile industry should be able to sell hydrogen powered vehicles in the “mass consumer market.”
- This also involves the construction of infrastructure to support hydrogen vehicles, including refueling stations, hydrogen production facilities, transmission of hydrogen and viable storage.

The Energy Bill and Transportation cont.
- Hybrid Vehicles: The bill encourages production and consumption of hybrid vehicles in a number of ways
  - There are various tax credits ranging from $3K to $4K for fuel cell vehicles
  - $1K to $4K for fuel efficient cars
  - $400 to $2,400 for hybrid vehicles that reach a certain fuel efficiency
The Energy Bill and Transportation cont.

- Establishes a grant program which allocates money to municipalities that participate in pilot programs that utilize new transportation technology
- Other programs take aim at reducing engine idling, encourage bicycle usage, aviation fuel conservation, railroad efficiency, and fuel cell school buses

The Energy Bill and Pollution

- Part of the Coal initiative sets aside money for reducing pollution associated with burning coal
  - In 2006: $300 million for pollution control equipment for controlling mercury, NOx and SO2, and particulates (more money is set aside for following years)
- Other methods for reducing pollution involve making the products we use more energy efficient (Energy Star Products)

Global Impact of the Energy Bill

- "Save America Free Act of 2005" - Sets up a commission which will try to develop an energy policy for the US which would make it possible for North America to be "energy self-sufficient" in 20 years.
- $10 million over the next two years to set up the commission

Global Spending on Energy R&D in 2004

- US: $2,880 Million
- Germany: $460 Million
- Japan: $3,963 Million
- UK: $566 Million
- Canada: $263 Million
- Turkey: $59 Million

Source: https://www.eia.gov/totalenergy/data/monthly/energy-technology.php

My Personal Opinion

- I think that the US Energy Bill is very important for the country. We are not far from an energy policy that will provide energy reduction more efficiently and increase energy efficiency. I think it addresses a key concern which is energy dependence on foreign sources of energy. Two key issues are hydrogen fuel cells and nuclear technology. I think that these two sources of energy are the future of our country.

My personal Opinion cont.

- Restarting the nuclear power industry will supply the necessary power to the industry and NOX and SO2 are the key pollutants which will arise in the increasing use of energy. This is particularly important because we already possess the nuclear technology and we are comfortable with it which makes it safer in the long run.
- Instead of hydrogen, we possess the technology to produce hydrogen fuel cell cars, but I feel as if the infrastructure to support hydrogen energy is still at least 20 years away. I feel that the funding towards hydrogen supply and infrastructure is a step in the right direction.
My personal Opinion cont.

- There is one issue that I have with the energy bill. It is the very small amount of energy that is actually being given over to the public. I would like to see more energy being given out to the public as well as more money being put into renewable energy. However, it is also true that the energy prices are still high and are expected to rise as a result of the high cost of providing energy companies and record levels of oil and natural gas prices. I think that it is necessary for Congress and the Bush administration to work together to bring down energy prices and provide more energy to the public.

Bibliography


Questions?
Figure 2. A Student’s Presentation Illustrating the Depth of Research

**Bioenergy/ Biomass: Biofuels**

**Biomass**
- Biomass includes all living and recently living organic matter (plants, animals, etc.).
- Can be used to produce fuels, power, and chemicals.
- Why should we care about Biomass?

**Importance of Biomass/Bioenergy**
- It's a Fully Renewable Resource.
  - Compare to Fossil fuels (Non-Renewable Energy Source)
- Generates No Net Greenhouse Gases.
  - CO₂ released from combustion of biomass is balanced from the CO₂ captured during biomass growth.
  - Zero net release of CO₂ during the cycle of Biomass.

**Importance of Biomass/Bioenergy**
- Biomass can be converted directly into liquid fuels (diesel).
- Biomass is the only renewable energy source for making alternative fuels for transportation.
- Current demand for fossil fuels is unsustainable in the long run.
- Major problems with fossil fuels:
  - Air pollution, health problems, global warming, addition to foreign oil, domestic security.

**Current Contribution of Bioenergy in the United States**
- U.S. 2005:
  - Renewable Energy Total: 6%
  - Bioenergy: Biggest contributor to Renewable Energy
    - 47% of Renewable Energy
    - Bioenergy = 2.9% of U.S. 2005 Energy Consumption

**Biorefinery**
- Biorefinery processes: Biofuels, Bioproducts
- Biomass feedstock
- Conversion Processes
- Biorefinery
- Biofuels
- Bioproducts
Biopower

- Biomass Fuelled Power Plants
  - Combustion of biomass produces electricity, heat, and process steam for:
  - Paper Mill and 2 neighboring towns
  - Image of a power plant

Bioproducts

- Chemicals and chemical products from biological sources (instead of petroleum)
  - Adhesives
  - Plastics
  - Solvents
  - Paints
  - Dyes, Pigments, Ink
  - Many more products
  - Image of products

Biofuels

- Biomass can be directly converted into liquid fuels (Biofuels)
  - Helps meet transportation energy needs
  - Burns cleaner than gasoline
  - Reduces air pollution
  - Decreases dependence on foreign oil
  - Are biodegradable
  - Image of a biofuel plant

  Two most common Biofuels
  1. Bioethanol
  2. Biodiesel

Bioethanol

- Ethanol: A 2-Carbon Alcohol
  - Same chemical that’s in beer and wine
  - Produced by fermentation of any biomass high in carbohydrates
  - Image of a bioethanol production process

  Bioethanol:
  - Derived:
    - Chemicals added to make it unfit to drink (Methanol, acetone, etc)
  - Derived from renewable biomass materials (corn, sugar, etc)

Bioethanol (continued)

- Can be used as either:
  - Alternative Fuel
    - E100: Pure Ethanol
      - easiest to fill up
      - Lower cost
      - Major decrease in greenhouse gases (CO2, etc)
      - Horsepower increased by about 5%*
    - E85 Blends: (85% Ethanol, 15% gasoline)
      - May increase maintenance costs
      - Horsepower increased by about 5%*
  - Additive to Gasoline
    - Boosts Octane #: (Ethanol O.N. = 108-109)*
      - Reduce emissions of CO and other smog-forming pollutants
    - E10 Blends: (10% Ethanol, 90% gasoline)


General Motors Flex Fuel Vehicles

- "Fuel Green, Go Yellow" Campaign: Uses both made from corn
  - Image of a flex fuel vehicle
  - "Energy independence? The answer may be growing in our backyard"
Currently, GM has 1.5 million Flex Fuel Vehicles on the road in U.S., as of 2006, 5 million Flex Fuel vehicles owned.

**Current Flex Fuel Vehicles**
- **Chevrolet**
  - Express 2500 (2005-2008)
  - Express 3500 (2005-2008)
  - HHR (2007-2008)
- **Chrysler**
  - 300 (2005-2008)
- **Dodge**
  - Dakota (2005-2008)
  - Durango (2003-2008)
- **Ford**
  - F-150 (1997-2008)
  - Expedition (2002-2008)
  - Excursion (2000-2005)
- **GMC**
  - Sierra Denali (2000-2005)
- **Hyundai**
  - Santa Fe (2002-2008)
- **Isuzu**
  - Ascender (2003-2007)
- **Jeep**
- **Kia**
  - Sorento (2003-2008)
  - Sedona (1999-2001)
- **Land Rover**
  - LR3 (2006-2008)
- **Mitsubishi**
  - Endeavor (2004-2008)
  - Outlander (2003-2008)
- **Nissan**
  - Armada (2004-2008)
  - Maxima (2003-2008)
  - Pathfinder (1999-2001)
  - Quest (2003-2008)
  - Sentra (2000-2008)
- **Plymouth**
  - Breeze (2000-2001)
  - Voyager (1999-2001)
  - Villager (1999-2001)
- **Subaru**
  - Forester (2002-2008)
  - Tribeca (2006-2008)
- **Toyota**
  - Sequoia (2001-2008)
  - Tundra (2000-2008)
  - Highlander (2001-2008)
  - Sequoia (2001-2008)
- **Volvo**
  - S60 (2000-2008)
  - S80 (2000-2008)

*Data from National Ethanol Vehicle Coalition*

**States in the U.S. with E85 Filling Stations**
States in yellow contain E85 stations.
Interactive Map on [http://www.energystar.gov/ia/about.html](http://www.energystar.gov/ia/about.html) about the location of individual filling stations

**Bioethanol Stats**
- In 2004, the use of ethanol as a fuel reduced the emissions of greenhouse gases in the U.S. by about 2 million tons.
  - Equivalent of taking 1 million cars off the road.
- In 2005, annual production of ethanol in U.S.: 3.25 billion gallons.
- 2005 Renewable Fuels Standard:
  - Mandates annual U.S. ethanol production double by 2012 to 7.8 billion gallons

**Bioethanol: Current Feedstocks**
- **Current Feedstocks:**
  - **Starches (Corn)**
  - **Sugars (Sugar Cane)**
  - **Coal (source)**: Crops which have to be grown.
  - **Crop oils required in agricultural processes of planting, growing, and harvesting.
  - Can be directly fermented and processed into Ethanol.
What is the Future of Bioethanol?

- **Corn ethanol** is considered to be a "transition" biofuel.
- "To have ethanol make a dent in gas consumption and global warming, we'll need a wide-scale switch from corn to cellulosic ethanol."

**Bioethanol: Future Feedstocks**

- New Feedstocks: Advanced Bioethanol Technology (R&D Phase)
  - Cellulose
  - Hemicellulose
  - Lignin

- Three main components of plant biomass are made of these substances:
  - Sources: Waste products from industrial processes
  - Agricultural residues (stover, stalks, bioethanol, etc.)

- Forestry residues (waste from lumber mills and forests)
  - Wood chips, sawdust, dead trees, tree branches

**R&D Bioethanol Feedstocks**

- *Gather vegetation*
- *Leaves and wood from cutting logs at sawmill*

**Challenges with New Feedstocks**

- Compared to Starch and Sugar:
  - Harder to break the cellulose and hemicellulose polymers into component sugars (monomers)
  - Cellulose has crystalline structure → insoluble, resistant to attack
  - Hemicellulose has some component sugars which are difficult to ferment
  - Lignin is composed of monomeric monomers, not sugar monomers

**Process for Making Bioethanol**

1. Convert biomass into usable fermentation feedstock (some form of sugar)
   - Polysaccharides → Glucose, Fructose, Galactose, etc

   **Hydrolysis** ("water splitting") of polysaccharides (polymer) into sugars (monomers)
   - **Acid Hydrolysis** (acid acts as a catalyst)
   - **Enzymatic Hydrolysis** (Cellulase enzyme catalyst)

**Polysaccharides**

- **Starch and cellulose**
  - Linear chain polymers composed of glucose monomer units
  - The bond between glucose units in the chain is different

- **Hemicellulose**
  - Linear polymers composed of several different 5- and 6-carbon monomers (xylose, galactose, etc.)
Cellulosic Ethanol

Mr. Stevens Director, Commissioner for Environment, European Commission, visits logen facility, fuels up with cellulose ethanol - September 22, 2005

Problems with Ethanol as a Fuel??

1. Higher concentrations of ethanol (5% to 15%) could degrade engines and fuel lines (corrodes metal, makes plastic brittle)
   - Today, flex-fuel vehicles' fuel delivery systems are typically stainless steel or Teflon-coated components to prevent the E85 from corroding them
   - Automotive only warrant the use of E10 in non-flex fuel vehicles
   - However, recent studies by the American Coalition for Ethanol have shown that E20, E90, and E100 do not cause damage when run in non-flex fuel vehicles

2. Slight drop in fuel economy (~10%) for E85 compared to pure gasoline
   - Ethanol has a lower energy content than gasoline
   - Therefore, more oil has to be burned

http://www.eheartc.org/energytaskforce/energytasks/0919article.html

Projection of Contribution of Bioethanol to U.S. Energy Consumption

- By 2025:
  - Oil Replaced: 8 million barrels/day
  - CO₂ Displaced: 500 MMT/year
  - Transportation Needs Met: 30%

(MMT = million metric tons)

Sam Cleas, Stokyo to Popsicle Science "STEP TO END AMERICA'S FOSSIL FUEL ADDICTION" July 2006

Biodiesel

- Fatty Acid Methyl Ester
  - Produced from transesterification reaction of Triacylglycerols from Fat or Vegetable Oils and Methanol
  - Reaction is catalyzed by base (KOH, NaOH, etc.)

Advantages of Biodiesel as an Alternative Fuel

1. Clean burning
   - Significantly less emissions when burned than petroleum diesel (CO₂, unburned hydrocarbons, particulate emissions)
2. Produced from sustainable, renewable resources
   - Vegetable oil from soybeans
   - Yellow grease from animal fats, etc.
3. Contains no petroleum, but can be blended with petroleum diesel
4. Can be used in diesel engines with little or no modification
5. Biodiesel is non-toxic
6. Essentially free of sulfur and aromatics
7. Excellent lubrication qualities

Common Fuel Blends:
- 10% (3%) biodiesel
- 5% (20%) biodiesel, 95% petroleum diesel

U.S.: Biodiesel Retail Fueling Sites

[Data as of 12/06] From National Biodiesel Board
Cellulosic Ethanol

Mr. Stevens Dierks, Commissioner for Environment, European Commission, visits logen facility, fuels up with cellulosic ethanol - September 22, 2005

Problems with Ethanol as a Fuel??

1. High concentrations of ethanol (10%, 15%) could clog hose pumps and fuel lines (corrodes metal, makes plastic brittler).
   - Today, Flex-Fuel vehicles' fuel delivery system is typically fuel-proofed with stainless steel or Teflon-coated components to ensure the E85 does not corrode them.
   - Autogas stations only warrant the use of E10 in non-Flex Fuel vehicles.
   - However, recent studies by the American Coalition for Ethanol have shown that E20, E30, and E38 do not cause damage when run in non-Flex Fuel vehicles.

2. Slight drop in fuel economy (~10%) for E85 compared to pure gasoline.
   - Ethanol has a lower energy content than gasoline.
   - Therefore, more of it has to be burned.

http://www.ars.usda.gov/Science/PlantEconomics/Circlets/01184Article.html

Projection of Contribution of Bioethanol to U.S. Energy Consumption

- By 2025:
  - Oil Replaced: 8 million barrels/day
  - CO₂ Displaced: 500 MMT/year
  - Transportation Needs Met: 30%

(1 MMT = million metric tons)

From Clea, Story by Popular Science: "STEP TO END AMERICA'S FOSSIL FUEL ADDICTION" July 2006

Biodiesel

- Fatty Acid Methyl Ester
  - Produced from Transesterification reaction of Triglycerides from Fat or Vegetable Oil and Methanol
  - Reaction is catalyzed by base (KOH, NaOH, etc.)

Advantages of Biodiesel as an Alternative Fuel

1. Clean burning
   - Significantly less emissions when burned than Petroleum Diesel (CO₂, unburned hydrocarbons, particulate emissions)
2. Produced from abundant, renewable resources
   - Vegetable oil from soybeans
   - Yellow grease from animal fats, etc.
3. Contains no petroleum, but can be blended with petroleum diesel
4. Can be used in diesel engines with little or no modification
5. Biodegradable, non-toxic
6. Resistant to freeze, stable at extremes
7. Excellent lubricity qualities

Common Fuel Blends:
- B100 (pure biodiesel)
- B10 (10% Biodiesel, 90% Petroleum Diesel)
U.S. Biodiesel Sales Volume

- 2005 -- 75 million gallons
- 2004 -- 25 million gallons
- 2003 -- 20 million gallons
- 2002 -- 15 million gallons
- 2001 -- 5 million gallons
- 2000 -- 2 million gallons
- 1999 -- 500,000 gallons

Estimates from National Biodiesel Board

Biofuels in the World

- Biofuels can be made practically worldwide.
- In several countries, they comprise a significant portion of their transportation needs

Brazil

- World's leader in production of sugar and sugarcane-based ethanol
- Produced 4.4 billion gallons of bioethanol in 2005
- Requires a 20% blend of ethanol in all gasoline sold in the country (E20)
- Recent introduction of flex-fuel vehicles has increased domestic consumption of bioethanol and spurred increased investment in ethanol production
- The use of bagasse (residue left after extraction from sugar cane) to generate power in sugarcane ethanol mills
  - Lower energy usage in ethanol production
  - Major cost savings


European Union

- EU has established a Biofuels mandate for Fuel Consumption
  - From voluntary target of 2% in 2005 to 5.75% in 2010
  - In 2005 biofuel use was below the 2% target, but is growing significantly

- Main biofuel in the EU: Biodiesel (80% of EU biofuel usage)


Finland

- Bioenergy accounts for
  - 20% of primary energy consumption
  - 10% of electricity demand
- These are the highest levels for any industrialized country
- Goal: increase bioenergy usage by 35% over next decade

Nepal
- Currently have 127,000 biogas plants built by Biogas Sector Partnership (with Dutch and German support)
- Biogas plants use bacteria to generate methane gas from cattle dung in underground digesters. The gas is burnt in kitchen stoves instead of wood or kerosene.
- Biogas burns cleaner and decreases smoke pollution risk in homes.
- 400,000 tonnes of firewood and 800,000 litres of kerosene are no longer needed each year, avoiding 600,000 tonnes of greenhouse gases.
- BSP plans to build 200,000 m³ in the next 5 years.

China
- China Biodiesel Capacity Forecast 2005-2010

Zimbabwe
- Has major potential to produce ethanol from molasses.
- Study in 2000 says that capacity to produce ethanol from all sugars available could account for 43% of their annual gasoline consumption.

Images References

Source References

Questions?
2005 Energy Act: My Personal Opinion

- I think that the US Energy Bill is very important for the country. After not having an energy policy for over 10 years it was important for the government to push through this legislation. I think it does a lot in terms of providing funding towards new technology that will make energy production more efficient and ecologically friendly. Furthermore, I think it addresses a key concern which is energy dependence on foreign sources of energy. Two key areas are hydrogen fuel cells and nuclear technology. I think that these two sources of energy are the future of our country.


- Restarting the nuclear power industry will vastly improve air pollution (reducing sulfur, mercury and NOx) and will also cut down on greenhouse gas emissions. This is particularly important because we already possess the nuclear technology and are comfortable with it which makes it a safer alternative.
- In regards to hydrogen, we possess the technology to produce hydrogen fuel cells, but I feel as if the infrastructure to support hydrogen energy is still at least 25 years away. I feel that the funding towards hydrogen supply and infrastructure is a step in the right direction.

2005 Energy Act: My personal Opinion cont. (cont.)

- There is one issue that I have with the energy bill, this is the vast amount of money that is seemingly being given away to the oil industry. Hurricane Katrina showed that our petroleum/gasoline supply is fragile; however, it also showed that the skyrocketing price of gasoline and oil as a result of supply shortages provides oil companies and executives with billions of dollars of profits. I think that it is unnecessary for Congress and the Bush administration to continuously pump money into the oil and gas industry when those companies are profiting so much off of the American people as it is. The energy bill has no policy regarding high gasoline prices, but still provides billions in subsidies to the oil and gas industry.

Environmental Impact: What Should We Do?

- Obviously, the more regulations put out by the US and international corporations to limit gas emissions and radiation would be extremely helpful. We have not yet run out of fossil fuels, and until we do we will continue to use them at high rates. Our environment will be sacrificed so we can have cheap energy. Eventually, we will have to move into renewable resources like biomass, hydro, wind, and solar energy sources so that our environment can still be habitable.

Environmental Impact: What Should We Do? (cont.)

- I think we must move into a higher use of renewable resources with in the next one hundred years. We can continue to limit emissions and pollution but eventually those limits will cause fossil fuels to be more expensive. If we can start programs now to expand and make more reasonable the renewable power sources, it would be extremely beneficial for our future.

Hydropower: My Conclusions

Hydroelectric power and the dams that are used for large-scale operations have both positive and negative environmental impacts. Despite its potential to reduce the harmful emissions from fossil fuels burning for energy generation, there will not be an increase in new dams because of the negative environmental impacts on fish and the high cost of building new dams.

Hydropower: Conclusions, continued

- Because of the incentives from the Energy Bill, there will be an increase in efficiency in existing hydropower plants.
- Worldwide, I predict that there will continue to be a steady increase in the consumption of hydropower because it is a renewable resource and countries are looking for economical alternatives to being reliant on other countries for fossil fuel imports. The only limitation on future growth is the high cost of building new plant if there is a need to build a new dam.

Nuclear Energy: What do I think?

- Nuclear is the largest emissions-free resource available.
- Over the next few years, nuclear energy will make a huge comeback in the U.S.
- It makes sense to take advantage of it, because it is much more safe and efficient than when we stopped construction in the '70s.

Figure 3. Summary of some of the personal opinions/conclusions provided by students