Announcements

• Homework #6 reduce word count to 300-400 on essays!
• Hand out sample final and review sheet
• Extra reading assignment for tomorrow
• Email this week of grades so far

Alternative Energy
i.e. not fossil fuels

Alternative Energy Sources

The energies we will discuss are:
• Nuclear
• Wind
• Solar
• Biodiesel
• Hydrogen fuel cells

Other sources of energy:
• Geothermal
• Hydro power
• Tidal

Why Alternative Energies?

• Greenhouse gasses - global warming
  – US emits about 20% of the world’s anthropogenic greenhouse gasses.
• Acid rain
• Human health
• Energy independence
• Need for long-term energy supplies.

Nuclear Power

How is Nuclear Power Generated?

One way to capture this energy is to:
1) heat water
2) which makes steam
3) which can turn a turbine.
### Pros and Cons

#### Pros
- Produces no greenhouse gases
- Available 24 hrs/day
- Cheap to produce (is it?)
- Little fuel consumed, relatively large amounts of uranium exist (~45 years worth at $50/pound. Current price = $30/pound. Also, plutonium can be used.)
- US has large uranium deposits

#### Cons
- Produces extremely hazardous radioactive waste that can last 10,000+ years (maybe 100,000+). Where do you store it?
- Safety - meltdowns, reactor leaks

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### Wind Power

#### How is Wind Power Generated?
- Wind blows past a turbine (like a propeller)
- Turbine is turned --> energy
- Power produced is proportional to (wind velocity)^3

**Example:**
- Average wind speed = 5 m/s
  - Case 1: 4, 6 m/s
    - Average power = \(\frac{1}{2} \times 4^3 + \frac{1}{2} \times 6^3 = 140\)
  - Case 2: 1, 9 m/s
    - Average power = \(\frac{1}{2} \times 1^3 + \frac{1}{2} \times 9^3 = 365\)

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### Where is the wind? Part 2

**Annual 50m Wind Speed**

**July 1993 - June 1994**

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### Pros and Cons

#### Pros
- Produces no greenhouse gases
- Competitive in price to fossil fuel energy in very good locations
- Unlimited energy source (no fuel)
- Decentralized production

#### Cons
- Not available 24 hours a day, irregular (in most places)
- Generally more expensive than fossil fuels
- Limited by location, where the wind is
- Kills birds? Not many compared to buildings (think windows :)

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### Where is the wind?

**www.nrel.gov**
Solar Power

Solar power is harnessed through two principal means:

1. Solar thermal collectors, which can produce hot water and warm air for homes and industrial applications.
2. Solar photovoltaic cells, shown here, which generate pollution-free electricity directly from sunlight.

Pros and Cons

- **Pros**
  - produces no greenhouse gasses
  - Unlimited energy source (no fuel)
  - Solar systems last 40+ years
  - peak production time is often the peak use time (A/C)
  - decentralized production

- **Cons**
  - expensive equipment makes solar energy the most expensive alternative energy
  - somewhat limited by location

Biodiesel
What is Biodiesel?

• Methyl or ethyl esters
• Formed by **transesterification**:
  \[ \text{alcohol} + \text{oil} \rightarrow \text{less alcohol} + \text{biodiesel} + \text{fertilizer} + \text{glycerin} \]
• European oil source: canola oil
• US oil source: restaurant grease, soybean oil
  → US biodiesel smells like French fries... because... esters are aromatic! (think bananas, apples, dirty socks...)

**The Biodiesel Cycle**

Is this C cycle closed or is there a 'leak' of C to the atmosphere?

**Pros and Cons**

• **Pros**
  - Reduced NET \( \text{CO}_2 \) emissions
    • none if 'leak' plugged
  - Better for human health
    • reduced carbon monoxide, particulate, and PAH emissions.
  - Less smog potential
    • reduced unburned hydrocarbon emissions
  - Reduced acid rain potential
    • no sulfate emissions
  - Energy independence

• **Cons**
  - slightly higher ozone production potential
    • slightly increased \( \text{NO}_x \) emissions (potentially reducible through tech. since no sulfates)
  - more expensive than diesel/gasoline
    • ~$4/gallon to produce

**AVERAGE BIO DIESEL EMISSIONS COMPARED TO CONVENTIONAL DIESEL, ACCORDING TO EPA**

<table>
<thead>
<tr>
<th>Emission Type</th>
<th>B100</th>
<th>B20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Unburned Hydrocarbons</td>
<td>-07%</td>
<td>-29%</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>-48%</td>
<td>-12%</td>
</tr>
<tr>
<td>Particulate Matter</td>
<td>-47%</td>
<td>-12%</td>
</tr>
<tr>
<td>Nox</td>
<td>+10%</td>
<td>&lt;2%</td>
</tr>
<tr>
<td>Non-Regulated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfates</td>
<td>-100%</td>
<td>&lt;20%</td>
</tr>
<tr>
<td>PAH (Polycyclic Aromatic Hydrocarbons)**</td>
<td>-80%</td>
<td>-31%</td>
</tr>
<tr>
<td>vPAH (petroel-PAHs)**</td>
<td>-95%</td>
<td>-50%</td>
</tr>
<tr>
<td>Ozone potential of speciated HC</td>
<td>-50%</td>
<td>-10%</td>
</tr>
</tbody>
</table>

* Estimated from B100 result
** Average reduction across all compounds measured
*** 2-nitrofluorene results were within test method variability

www.biodiesel.org

**Hydrogen Fuel Cells**

\[ 2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{energy} \]

Sounds GREAT! Nothing bad in that equation!

Is there a catch? (you know there always is)
The Catch

- Where do you get H₂?
  - not naturally occurring in large quantities
- H₂ is generated in large quantities via electrolysis
  - 2H₂O + energy → H₂ + 2O₂
- Where do we get THIS energy?
  - Rephrased: How does the US generate electricity?
  - Answer: This is your car on coal or nuclear. Any questions?

Pros and Cons

- Pros
  - No greenhouse gas emissions, if cells are charged by non-greenhouse gas emitting energy source.
  - Could be economical within ~10-20 years.
  - Energy independence (independent of oil)
- Con
  - Given current US energy production, fuel cells will likely be charged with coal and nuclear power.

Who are the emitters of GHG?

Who are the future emitters of GHG?

Projections indicate that fossil fuels will continue to dominate energy production.
This figure shows US past and future estimates.