Thursday, October 4th….

Announcements….
• Homework 4 due today
• Paper 1 due next Thursday
• No class next Tuesday…. It is officially a Monday!
News items….

September 28, 2007

**Nevada Senator Calls for National Renewable Energy Zones**

New legislation urges U.S. to invest in new transmission lines to bring renewable energy to the grid.
Washington, DC [RenewableEnergyAccess.com]

U.S. Senator Harry Reid of Nevada is calling on President Bush to provide additional financing options for the building of new power lines and interconnections to enable the transmission of renewable energy from remote areas of the country to those with growing electricity demand.

The Clean Renewable Energy and Economic Development Act, which Reid introduced last week, would direct the President of the United States to identify areas of the country, especially rural areas, where renewable energy resources could generate at least 1,000 MW of electricity.

"I recently came out in opposition to the proposed coal power plants," said Reid. "But I want to do more than just voice my opinion. I want to be part of the solution... This legislation puts to rest the false assumption that the only way to finance transmission lines is through building dirty coal power plants."

Shows interesting thinking on setting up renewable energy infrastructure… Often the best sites for large solar or wind energy projects are away from population centers …. (We saw in the Ethanol article last time, that developing infrastructure is a key part of implementing any alternative energy strategy.)
First Renewable FIT Introduced in U.S.

Prices for solar and biogas introduced in the Michigan Renewable Energy Sources Act would be the best in North America.

by Paul GiPe
Lansing, Michigan [RenewableEnergyAccess.com]

Patterned after Germany's highly successful Renewable Energy Sources Act, Veteran Michigan Assemblywoman Kathleen Law submitted a bill to the Michigan House of Representatives earlier this week that creates the first comprehensive renewable energy feed-in tariff (FIT) introduced into any U.S. legislature.

Like the German law which has powered the country to world leadership in wind, solar, and biomass energy—and created nearly one-quarter million new jobs in its booming renewable energy industry—proponents of the bill are hoping the tariff will revive Michigan's flagging economy.

"We are extremely excited that Michigan has joined the ranks of so many progressive states in making the commitment to reduce our carbon footprint," said Subhendu Guha, President of United Solar Ovonic, which is headquartered in Michigan and is a leading manufacturer of thin film solar cells. "Policies like this will create new jobs in Michigan and will help maintain a cleaner environment."

The tariffs proposed in HB 5218 (2007) are equivalent to those in Germany and would be the highest in North America if the bill is made a law.

- Hydro less than 500 kW: $0.10 USD/kWh
- Biogas less than 150 kW: $0.145 USD/kWh
- Geothermal less than 5 MW: $0.19 USD/kWh
- Wind: $0.105 USD/kWh
- Wind energy from small wind turbines: $0.25 USD/kWh
- Rooftop solar less than 30 kW: $0.65 USD/kWh
- Solar façade cladding less than 30 kW: $0.71 USD/kWh

Renewable tariffs, like those in HB 5218 (2007), encourage homeowners, farmers, and businesses to sell their renewable energy for a profit by allowing them to "feed" their electricity into the grid. Many people call such tariffs "Advanced Renewable Tariffs," because the price paid per kilowatt-hour of electricity differs by technology.

For example, because solar is more expensive than wind on a cost per watt basis, the tariff for solar energy is much higher than that for wind energy so that homeowners can profitably install solar panels on their roofs across the state.
FIT’s (Feed In Tariffs) are prices the local electric company is mandated to pay small scale producers of electricity that feed into the grid.

- In Germany, electric companies are mandated to pay small scale generators of solar, wind or hydro power at 4 times the market rate. As a consequence Germany has become a world leader in solar power installations & solar technology.

- Michigan seems to be recognizing that alternative energy can be good for a State’s economy.

- In Massachusetts, currently, if your rooftop solar panels produce more electricity than you use in any given month (e.g. in the summer), then you contribute this excess to the electric company free of charge.

The solar industry is currently hoping to get this period changed to a year (so that extra power in the summer can contribute to winter months), but FIT’s are not yet on the table (as far as I know).
Let’s start today with a little calculating & try to see whether the claims (from last lecture) on the anti-SUV website are true?

Switching from an average new car to a 13 mpg SUV for a year would waste more energy than leaving a refrigerator door open for six years, a bathroom light burning for 30 years, or a color TV turned on for 28 years. (www.suvsuck)

Let’s try for the comparison with the bathroom light…
What ingredients do we need to assemble before we can make the comparison?
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Let’s try for the comparison with the bathroom light …
What ingredients do we need to assemble before we can make the comparison?

- fuel economy ratings for an “average new car”
- average annual mileage (city & highway)
- energy content in a gallon of gas
- average efficiency of an electric power plant

How much of infrastructure to include is a question in any energy comparison? Are there other things we could fairly include on either side?
First, note that SUV’s vary greatly in fuel economy..

Source: http://www.fueleconomy.gov
Fuel economy info for all new cars…
Fuel economies

- Average mid-size car: 21/27 mpg (city/hwy)
- Full size SUV: 13/16 mpg (city/hwy)

Average annual mileage: EPA uses 15,000 miles/year
45% highway, 55% city - which translates into 6750 highway miles and 8250 city miles.

\[
(gallons / year)_{\text{car}} = \left(\frac{6750 \text{ miles}}{27 \text{ miles / gallon}}\right) + \left(\frac{8250 \text{ miles}}{21 \text{ miles / gallon}}\right) = (250 + 393) \text{gallons} = 643 \text{gallons}
\]

\[
(gallons / year)_{\text{SUV}} = \left(\frac{6750 \text{ miles}}{16 \text{ miles / gallon}}\right) + \left(\frac{8250 \text{ miles}}{13 \text{ miles / gallon}}\right) = (422 + 635) \text{gallons} = 1057 \text{gallons}
\]

The SUV uses 414 extra gallons of gas per year (64% more). How does this translate into units of energy, BTU’s or Joules?
First, let’s also calculate how many extra pounds of CO$_2$ are produced by driving the mega-SUV and burning 414 more gallons of gas?

Burning 1 gallon of gas produces roughly 20 pounds of CO$_2$ - a surprisingly large amount, given that a gallon of gas weighs only about 6.3 pounds. How does this happen?

As we know, gasoline is made of various hydrocarbon molecules. When it burns, each carbon atom combines with two oxygen atoms from the atmosphere to form CO$_2$. A carbon atom has a weight of 12 (in atomic mass units), while an oxygen atom has a weight of 16.

A CO$_2$ molecule then has a weight of $12 + 16 + 16 = 44$, of which only a fraction $12/44 = 0.27$ comes from the carbon atom. Most of the weight of the CO$_2$ comes from the oxygen, which didn’t start out in the liquid gasoline.

Gasoline is 87% carbon by weight and 13% hydrogen.

$$\text{(weight)}_{\text{CO}_2} = (6.3 \text{ pounds}) \times (0.87) \times (44/12) = 20 \text{ pounds}$$
How much CO$_2$ do the car and SUV emit through their tailpipes?

\[(\text{CO}_2)_{\text{car}} = (643 \text{ gallons/year}) \times (20 \text{ pounds/gallon}) = 12,860 \text{ pounds/year}\]

\[(\text{CO}_2)_{\text{SUV}} = (1057 \text{ gallons/year}) \times (20 \text{ pounds/gallon}) = 21,140 \text{ pounds/year}\]

The SUV emits an additional 8280 pounds of CO$_2$ per year!

Back to energy usage….  
The average energy content of a gallon of gasoline is 131 MJ = 1.31 x $10^8$ Joules

\[(\text{Energy})_{\text{car}} = (643 \text{ gallons/year}) \times (131 \text{ MJ/gallon}) = 84,200 \text{ MJ/year}\]
\[= 8.42 \times 10^{10} \text{ Joules/year}\]

\[(\text{Energy})_{\text{SUV}} = (1057 \text{ gallons/year}) \times (131 \text{ MJ/gallon}) = 138,000 \text{ MJ/year}\]
\[= 13.8 \times 10^{10} \text{ Joules/year}\]

The SUV uses 5.4 x $10^{10}$ Joules more energy per year.  
How does this translate into light bulbs?
Let’s assume the bathroom light was a 100W light bulb. How much energy does this use in one year?

\[
(\text{Energy})_{\text{light bulb}} = (100 \text{ J/s}) \times (365 \text{ days/year}) \times (24 \text{ hours/day}) \times (3600 \text{ s/hour}) \\
= 3.1 \times 10^9 \text{ Joules/year}
\]

If we divide our extra energy for the SUV by this amount, we get how many years of leaving a light on it is equivalent to ....

\[
(5.4 \times 10^{10} \text{ Joules})/(3.1 \times 10^9 \text{ Joules/year}) = 17 \text{ years}
\]

The anti-SUV site claimed 30 years. Perhaps they assumed a more fuel efficient “average” car, or a more elaborate bathroom light…. 
But to be fair to the SUV, the electric power generating plants are not 100% efficient in turning fossil fuel energy into electric energy. What happens when we take this into account?

A typical coal fired power plant has an **efficiency of about 30%** - meaning that about 30% of the energy content of the coal is transformed into electrical energy, while the remaining 70% is waste heat.

\[
(Fossil\ fuel)_{light\ bulb} = (Energy)_{light\ bulb}/(0.3) = (3.1 \times 10^9 \text{ Joules/year})/(0.3)
= 1.0 \times 10^{10} \text{ Joules/year}
\]

Taking this into account, brings switching to a mega-SUV down to 5.4 years of a 100W bathroom light.
Before leaving this topic, let’s ask another question… How does switching off lights compare to not using your car, in terms of energy (or CO$_2$) savings?

How much energy is saved by switching off a 100W light bulb for an hour (assuming the electricity comes from a 30% efficient coal fired power plant)? What does this amount to in terms of gallons of gas?

\[
(\text{Energy})_{\text{saved}} = (100 \text{ J/s}) \times (3600\text{ s}) \times (1/0.3) = 1.2 \text{ MJ} \\
= (1.2 \text{ MJ}) (1 \text{ Gallon}/131 \text{ MJ}) = 0.01 \text{ Gallons}
\]

By turning off a light bulb that would otherwise have stayed on for an hour, you save the energy equivalent of 1/100 of a gallon of gasoline. While the light bulb savings may add up and are certainly worthwhile, we see that car trips deserve even more care and scrutiny…. 
Today we’ll be talking about coal…

In 2004, total world energy consumption was 447 Quads ($10^{15}$ BTU) coming from…

- Oil 167.7 Quads = 37%
- Natural gas 103.8 Quads = 23%
- Coal 114.5 Quads = 25%
- Nuclear 27.5 Quads = 6%
- Renewables 37.7 Quads = 9%

Coal is a rock, and quantities of coal are measured in terms of weight - tons of coal.

World coal consumption in 2004 was 6098.8 million tons of coal.

How do we convert from tons of coal to the energy content of coal measured in BTU’s?
One way is to use the energy calculators at...

Let’s just use this figure and do the calculation ourselves....

http://www.eia.doe.gov/kids/energyfacts/science/energy_calculator.html#coalcalc
Using this figure for the energy content of a ton of coal, we get…

\[ E = (20,754,000 \text{ BTU/ton}) \times (6,098,800,000 \text{ tons}) \]
\[ = 127 \times 10^{15} \text{ BTU} \]
\[ = 127 \text{ Quads} \]

which does not match the world figure of 114.5 Quads for 2004.

My suspicion is the following… Different types of coal have different compositions and hence different heats of combustion (energy content). Most likely, the figure we are using is for an average ton of coal in the U.S. An average ton of coal in the world might have a different (lower) value.
We can compare the energy contents of different fossil fuels if we put them all in the same units.

For (average) gasoline the figure is…

Gasoline 45.8 MJ/kg
LNG 55 MJ/kg

For coal

\[
2.08 \times 10^7 \text{ BTU/ton} = (2.08 \times 10^7 \text{ BTU/ton}) \times (1 \text{ ton}/2000 \text{ lb}) \times (2.2 \text{ lb/kg}) \times (1054 \text{ J/BTU})
\]

\[
= 2.4 \times 10^7 \text{ J/kg}
\]

\[
= 24 \text{ MJ/kg}
\]

We see that the energy content of coal per unit weight is considerably less than gasoline or LNG. It costs considerably more to transport a given energy contents worth of coal than it does for oil.
U.S. Coal consumption: 1,125,000,000 tons (2005), approximately 18% of world total.

- 92% of U.S. coal consumption used for generating electric power
- 50% of electricity in the U.S. comes from coal fired power plants
- Imports and exports currently make up only a small part of the U.S. coal picture...

More than 3 tons per person!

When you think about coal, think about electricity…

U.S. Electric Power Industry Net Generation, 2005

- Coal: 49.7%
- Natural Gas: 18.7%
- Nuclear: 19.3%
- Hydroelectric: 16.5%
- Other: 0.1%
- Petroleum: 3.0%
- Other Renewables: 2.3%

Total = 4.065 Billion KWh

Electric Utility Plants = 63.0%

Independent Power Producers & Combined Heat and Power Plants = 37.0%
Possible attendance boosting mechanisms…
Material covered in lectures is an important part of the course.

Pros & cons for most methods

• Taking attendance - works, but cumbersome

• Not putting course materials online - works by making people come to class to find out about homeworks, but takes away important resource.

• Shorter assignments due during class each time - cumbersome

• Brief in-class assignments - asking you for your thoughts/comments on the issue under discussion, or a short computation on what we’re going over - cumbersome, but can add to course content. Breaks up long lectures.

Comments?

I’m leaning towards this one…
Instructions for Midterm paper

Physics 190E – Energy & Society
Midterm Paper 1
Due Thursday October, 11

Assignment description:

• Your paper topic and the basic questions you will be addressing were handed in as homework 4. Try to state these questions near the beginning of the paper.

• In general, I am interested in the information you include, rather than in eloquence.

• Your paper should be roughly 3-4 pages long, in 12 point type, with margins no larger than 1” at top and bottom, 1.25” at left and right (the standard defaults for Microsoft Word). The word count should be in the range 900-1200.

• You should put any text taken directly from a source in quotation marks and give the citation as a footnote.

• Your paper should not be one quote after another. Take the time to synthesize what you’ve read and put it in your own words.

• You may include graphics and tables, but these don’t substitute for total word count.

• Your paper should be turned in both electronically (through SPARK) and as a hard copy in class.