Thursday, November 29th….

Announcements….

• Homework 9 due on Tuesday.
Google's Goal: Renewable Energy Cheaper than Coal

Creates renewable energy R&D group and supports breakthrough technologies

Mountain View, Calif. (November 27, 2007) – Google (NASDAQ: GOOG) today announced a new strategic initiative to develop electricity from renewable energy sources that will be cheaper than electricity produced from coal. The newly created initiative, known as RE<C, will focus initially on advanced solar thermal power, wind power technologies, enhanced geothermal systems and other potential breakthrough technologies. RE<C is hiring engineers and energy experts to lead its research and development work, which will begin with a significant effort on solar thermal technology, and will also investigate enhanced geothermal systems and other areas. In 2008, Google expects to spend tens of millions on research and development and related investments in renewable energy. As part of its capital planning process, the company also anticipates investing hundreds of millions of dollars in breakthrough renewable energy projects which generate positive returns.

"We have gained expertise in designing and building large-scale, energy-intensive facilities by building efficient data centers," said Larry Page, Google Co-founder and President of Products. "We want to apply the same creativity and innovation to the challenge of generating renewable electricity at globally significant scale, and produce it cheaper than from coal."

Page added, "There has been tremendous work already on renewable energy. Technologies have been developed that can mature into industries capable of providing electricity cheaper than coal. Solar thermal technology, for example, provides a very plausible path to providing renewable energy cheaper than coal. We are also very interested in further developing other technologies that have potential to be cost-competitive and green. We are aware of several promising technologies, and believe there are many more out there."

Page continued, "With talented technologists, great partners and significant investments, we hope to rapidly push forward. Our goal is to produce one gigawatt of renewable energy capacity that is cheaper than coal. We are optimistic this can be done in years, not decades." (One gigawatt can power a city the size of San Francisco.)

"If we meet this goal," said Page, "and large-scale renewable deployments are cheaper than coal, the world will have the option to meet a substantial portion of electricity needs from renewable sources and significantly reduce carbon emissions. We expect this would be a good business for us as well."

Coal is the primary power source for many around the world, supplying 40% of the world's electricity. The greenhouse gases it produces are one of our greatest environmental challenges. Making electricity produced from renewable energy cheaper than coal would be a key part of reducing global greenhouse-gas emissions.

"Cheap renewable energy is not only critical for the environment but also vital for economic development in many places where there is limited affordable energy of any kind," added Sergey Brin, Google Co-founder and President of Technology.

Oil Drops Sharply on Inventory Report

By THE ASSOCIATED PRESS
Published: November 28, 2007

Filed at 3:45 p.m. ET

NEW YORK (AP) -- Oil's rise to $100 a barrel, which seemed a done deal as recently as two days ago, was dealt a severe blow Wednesday when the government reported an increase in supplies at the Nymex delivery terminal in Cushing, Okla., which is closely watched by traders as a benchmark of oil inventory tightness.

Anemic growth in demand and a jump in refinery activity also weighed on prices, which have dropped sharply in recent days on concerns about the economy and expectations supplies will grow.

"The report ... added to the bearish sentiment in the market," said Eric Wittenauer, an energy analyst at A.G. Edwards & Sons Inc. in St. Louis. "It comes at a period in time when OPEC is boosting production ... and considering another increase in production."

Light, sweet crude for January delivery plunged $3.80 to settle at $90.62 a barrel on the New York Mercantile Exchange following Tuesday's drop of $3.28 a barrel.
EU sees CO2 capture, storage in trade scheme - draft

by Reuters News on 28 November 2007, 16:45 PM  0 comments  , 19 views
Categories: Reuters News

UPDATE 2- BRUSSELS, Nov 28 (Reuters) - Companies should get credit under the European Union's emissions trading scheme for capturing and storing carbon dioxide (CO2) instead of releasing it into the atmosphere, the European Commission will propose.

The draft legislation, part of a wider package of climate change rules, aims to integrate trapping and holding CO2 into the EU's trading scheme, giving firms another way to meet limits set on their output of the main gas blamed for global warming.

"CO2 captured and stored will be credited as not emitted under the emissions trading scheme," the draft document, obtained by Reuters on Wednesday, said.

The EU emissions trading scheme is the 27-nation bloc's key tool to fight climate change. It sets limits on the amount of CO2 that factories can emit.

Companies that come in beneath their target can sell the permits, while those that overshoot their limits must buy additional credits.
By Timothy Gardner

**UPDATE 2- NEW YORK, Nov 28 (Reuters) - U.S. emissions of the gases blamed for global warming fell 1.5 percent in 2006 on mild weather and increased use of natural gas to generate power, the statistics arm of the Department of Energy estimated on Wednesday.**

President George W. Bush said in a release that the results keep the country "well ahead" of his greenhouse gas intensity goal -- or how much of the gases are emitted per unit of economic activity.

But U.S. emissions were much higher than they were in 1990, a key mark in international efforts to fight climate change, because it is the year below which rich countries that signed the Kyoto Protocol have to cut their emissions by 2008 to 2012.

U.S. greenhouse gas emissions last year fell to 7,075.8 million tonnes of carbon dioxide equivalent, the Energy Information Administration, the DOE's analytical arm estimated. It was the first annual fall in U.S. emissions since 2001, when tourism travel slowed after the airplane attacks in New York and Washington, and the third since 1990.

The annual report was released ahead of a meeting of delegates from 190 countries in Bali, Indonesia, next month to decide how to bind outsiders led by the United States and China into a U.N.-led fight against climate change.

**U.S. EMISSIONS MUCH HIGHER THAN KEY 1990 YEAR**

However, U.S. greenhouse gas emissions are much higher than in 1990, the year from which rich countries under Kyoto have to cut emissions at least 5 percent by 2008 to 2012.

U.S. greenhouse emissions in 2006 were 15.1 percent higher than 1990, the report said.

And as energy demand and the U.S. population increase, the country's CO2 emissions from energy should rise at an average annual rate of 1.1 percent from 2004 to 2030, the report said.
A nuclear power reactor produces steam to turn a turbine electrical generator, much like a coal or natural gas fired power plant.

Talk briefly about 4 key ingredients of nuclear reactors
- **Fuel rods**
- **Control rods**
- **Moderator**
- **Coolant**
One of the key functions of a nuclear reactor is to control the fission chain reaction.

This involves controlling how many neutrons go on to induce new fission reactions.

- Too many neutrons leads to a runaway chain reaction - **supercritical**.
- Too few neutrons and the chain reaction fizzles out - **subcritical**.
- Just the right number keeps a steady chain reaction going - **critical**.

This is the desired state for a nuclear reactor

This is the desired state for a nuclear bomb
In a nuclear explosive, the issue is having enough neutrons get absorbed by U-235 nuclei before they leave the clump of material.

The bigger the piece of material, the smaller the fraction of neutrons that escape. This leads to the concept of a **critical mass**.

Assuming the material is in the shape of a sphere, there will be a smallest sphere that allows for a supercritical chain reaction.

The mass of this smallest critical sphere is the critical mass.

For pure U-235, the critical sphere has diameter 17 cm and mass 52 kg. For 20% U-235 (80% U-238) the critical mass is 400 kg.
The critical mass/radius can be decreased by surrounding the material with a substance that reflects neutrons back into the fissile material.
A nuclear weapon must be kept subcritical until it is detonated. There are a number of schemes for doing this.

“Little Boy” - the nuclear bomb dropped on Hiroshima on August, 6 1945 employed the **gun method** of detonation.

A hollowed uranium donut is fired onto a uranium spike. The bomb contained a total of 64 kg of Uranium.

A total of 0.6 g of matter was converted into energy, yielding an explosive equivalent of 13-16 kilotons of TNT.

70,000 people died as a direct result of the blast.
In a reactor running at **criticality**, exactly one of the neutrons resulting from each fission reaction will go on to initiate another fission reaction.

**Control rods**, made of materials that strongly absorb neutrons, such as boron or silver, are inserted into, or withdrawn from the reactor, to reduce or increase the number of neutrons available to the chain reaction.

Throughout the lifecycle of a fuel assembly the control rods must be re-adjusted to maintain criticality.

One common safety feature of nuclear reactors, is for the control rods to automatically drop fully into the core in the event of a system failure, effectively shutting off the reactor.
But the picture is slightly more complicated…..

The ability of neutrons to initiate fission reactions depends on the speed (kinetic energy) of the neutrons.

Slow neutrons are absorbed more easily…..

\[ ^{235}U + n \rightarrow ^{236}U \]

Nuclear reactors include materials called **moderators** to slow down neutrons. Water is one frequently used moderator.

In a **water moderated reactor**, if the chain reaction goes above criticality, the water heats up. The hotter water functions less well as a moderator, which means that there will be fewer slow neutrons.

This negative feedback mechanism tends to force the reactor back towards criticality.
What a nuclear reactor produces is heat, just like a coal, or natural gas fired power plant. The heat is then converted to electrical energy.

In a water moderated reactor, the water also acts as the coolant for the reactor core. It carries the heat from the reactor to the electrical generator.

In a boiling water reactor (BWR), the water is vaporized into steam which turns turbines to produce electricity.
The uranium fuel of most conventional nuclear reactors is in the form of **fuel rods**, each containing pellets of enriched uranium, and grouped together in bundles.

A typical BWR reactor would have about 100 such fuel rod assemblies.

Fuel rods have a useful lifetime of about 3 years, after which they are replaced.

Used fuel rods contain the products of all the fission reactions that have taken place within. Many of these fission products are highly radioactive and need to be kept isolated for extremely long periods of time.

This is the basic high level nuclear waste issue associated with nuclear energy.
A radioactive material decays by emission of energetic alpha, beta and gamma rays.

The rate at which a given type of unstable nucleus decays is characterized by its half-life - $t_{1/2}$.

$$N(t) = N_0 \left( \frac{1}{2} \right)^{t/t_{1/2}}$$

Number remaining at time t.

Original number at time t=0.

In order to know how long radioactive waste stays dangerous, we need to know the half-lives of its components.

After 1 half-life, 1/2 of the nuclei will have decayed.
\[ N(t) = N_0 \left( \frac{1}{2} \right)^{t/t_{1/2}} \]

Number remaining at time \( t \).

Original number at time \( t=0 \).

Number of half-lives elapsed | Fraction remaining | As power of 2
--- | --- | ---
0 | 1/1 | \( 1/2^0 \)
1 | 1/2 | \( 1/2^1 \)
2 | 1/4 | \( 1/2^2 \)
3 | 1/8 | \( 1/2^3 \)
4 | 1/16 | \( 1/2^4 \)
5 | 1/32 | \( 1/2^5 \)
6 | 1/64 | \( 1/2^6 \)
7 | 1/128 | \( 1/2^7 \)
... | ... | ... 
\( N \) | \( 1/2^N \) | \( 1/2^N \)
• Spent fuel rods contain a vast array of radioactive nuclei. Overall, a spent fuel rod is one million times more radioactive than when it was installed in the reactor.

• For example, a 1000 MW reactor will produce about 500 lbs of Pu-239 each year.

• Pu-239 has a half-life of about 25,000 years. It decays into U-235 (among other things) which has a half-life of about 700,000 years.

• Radioactive waste remains hazardous for 10-20 half-lives. Therefore, spent fuel rods must be isolated from the environment for millions of years.
• Through the present time, spent fuel rods have remained on site at nuclear power plants, primarily in “temporary” storage pools.

• As of 2002, there were 47,000 metric tons of spent fuel rods stored at reactor sites.

• The Federal government and the nuclear industry have long sought a permanent storage site for high level nuclear waste.

• Since 1987, efforts led by the DOE have focused solely on Yucca Mountain, NV as a possible permanent high level radioactive waste repository.

• Yucca mountain was formed by volcanic activity 12 million years ago. It is located in a former nuclear test area.
• The Yucca Mountain repository is designed to hold 135,000 metric tons of waste. (recall that spent fuel rods are now around 50,000 metric tons in addition to waste from government nuclear weapons labs).

• Yucca Mountain was originally scheduled to open in 1998. Current best estimates are for 2020.

• There has been a great deal of debate over the geological suitability of the site for long term waste storage.

• There is great opposition to Yucca Mountain within Nevada. Upwards of 70% of Nevadan’s are said to oppose the project. According to Senator Majority Leader Harry Reid (from Nevada), “The proposed Yucca Mountain nuclear waste dump is never going to open.”

Good paper topics…
• Looking into both sides of the Yucca Mountain debate.
• What are other nations doing with high level radioactive waste?
We are now in position to understand the basics of the most serious accidents that have happened at nuclear reactors ……

The **Chernobyl disaster** of April 26, 1986 in Ukraine was initiated by a very complicated series of events, but essentially resulted from the improper removal of the control rods during a test of coolant safety systems.

The reactor overheated, fuel assemblies melted, the graphite moderator burned and **steam explosions** burst the reactor casing sending large amounts of radioactive material into the atmosphere.

Note that this was not a nuclear explosion.
The accident at Three Mile Island on March 28, 1979 was a “loss of coolant accident” (LOCA) caused by a number of overlapping technical failures in the coolant system.

It led to a meltdown of the reactor core, but unlike Chernobyl, the reactor vessel remained intact, as well as the surrounding cement containment building. There was no massive release of radioactive material into the environment.
By coincidence, the film “The China Syndrome” - about a (fictional) nearly averted nuclear catastrophe in a California power plant, starring Jane Fonda and Michael Douglas - opened in theaters 2 weeks before the Three Mile Island accident.

In the Simpson’s episode “the Trouble with Trillions”, Homer claims to have been responsible for “3 meltdowns and a China Syndrome”.

Physics 190E: Energy & Society
Fall 2007
Three Mile Island and Chernobyl had a substantial impact on the nuclear industry. The decline had already started in the years prior to TMI, with cancelled orders for nuclear plants becoming common. TMI and Chernobyl, however, had a powerful influence on attitudes towards nuclear power.

No new nuclear power plants have been approved in the U.S. since 1978, the year before the TMI accident.
Concerns over greenhouse gas emissions and rising fossil fuel costs are giving renewed impetus to nuclear power. The industry talks about a global “nuclear renaissance”.

A few indicators….

- China has completed 8 nuclear power plants in the last 5 years.
- India plans to build between 20 and 30 nuclear plants by 2020.
- The U.S. Energy Policy Act of 2005 contains a number of important subsidies for the nuclear industry meant to spur construction of new power plants.
Energy Policy Act of 2005.....
(from wikipedia)

- Nuclear-specific provisions:[2]
  - Extends the Price-Anderson Nuclear Industries Indemnity Act through 2025;
  - Authorizes cost-overrun support of up to $2 billion total for up to six new nuclear power plants;
  - Authorizes a production tax credit of up to $125 million total per year, estimated at 1.6 USc/kWh during the first eight years of operation for the first 6,000 MW of capacity[3]; consistent with renewables;
  - Authorizes $1.25 billion for the Department of Energy to build a nuclear reactor to generate both electricity and hydrogen;

The recent applicants for permits to the NRC are getting in line for these subsidies.

Price-Anderson indemnifies nuclear power plants for any damages exceeding $10 billion. Following an accident, the first $300 million are paid by a plant’s own insurance, the first $10 billion are paid collectively by all nuclear power plants, any remainder is paid by the federal government.
This has been a brief tour of nuclear power issues..

Today’s in class exercise….

What is your attitude towards nuclear power?

What questions do you feel you need more information on to form a solid opinion?

Good paper topics…
Homework #9
Physics 190E - Energy and Society
Due Tuesday, December 4th

The material for this homework is covered in lectures 21 & 22. Remember to show your work!

1. An average U-235 fission reaction produces 200 MeV of energy.
   a) If one fission reaction is happening each second, how many Watts of power are being released?
   b) Assuming that a nuclear power plant has a thermodynamic efficiency of 33%, how many fissions are taking place per second in a 1000 MW power plant?
   c) What is the mass in kilograms of one U-235 nucleus?
   d) How many kilograms of U-235 are being used up each day by the power plant?

2. The heat of combustion of the explosive TNT is 15 MJ/kg.
   a) How much energy is released by burning 1 kiloton = 1000 tons of TNT?
   b) How many U-235 fissions would produce this same amount of energy?
   c) How many kilograms of U-235 would have to be fissioned to produce this amount of energy?
   (Note: the bomb dropped on Hiroshima on August 6, 1945 released the energy equivalent of 20,000 tons of TNT)

3. How much energy is produced by the lithium reaction with neutrons below?
   \[ n + \frac{7}{3}Li \rightarrow \frac{4}{3}He + \frac{3}{2}H \]
The binding energies per nucleon are 4.877272 MeV for lithium-6, 2.825811 MeV for hydrogen-3 (tritium) and 7.072832 MeV for helium-4.

   List 10 interesting things you learned from the article. One sentence for each is sufficient.