

Lecture 9: Wednesday, February 20, 2008

HW#2 is due in class TODAY.

Remember also that our first hour exam is next Wednesday in class. We will spend Monday's lecture on exam review.

The class web site

<http://www.physics.rutgers.edu/~karin/140>

includes required reading (articles and weblinks) and useful course information (including the homeworks)

Homeworks #1 and #2 will be handed back in class on Monday.

Ocean energy

I will show two videos.

Geothermal energy

Heat from VERY deep in the earth
Crust has a thickness of 30 to 90 km
Top of the mantle is about 1000 C

Source: radioactive decay

- Heating systems: directly use hot water from springs and reservoirs near surface
- Electricity generation: requires very high-temperature heat or steam
- Geothermal heat pumps: use stable ground or water temperatures near the surface to control building temperatures

Ring of Fire





Geothermal energy in Iceland

Icelanders are world leaders in the use of geothermal energy for domestic and industrial purposes. About 87% of the population enjoy central heating by geothermal energy at a price that is generally less than half of the comparable cost of oil or electric heating, thus contributing to making Iceland one of the cleanest environments in Europe. Geothermal steam has been used directly for a number of industrial processing applications in Iceland for decades now, and has also been developed for electricity generation on a small but growing scale. In 2003 the total installed geothermal electric power was 200 MW and the production around 1,420 GWh.

Table 18.1 GEOTHERMAL POWER PLANTS

Site	Installed Capacity (MWe)	
	1990	2003
United States	2775	2200
Philippines	890	1931
Mexico	700	953
Italy	545	790
Indonesia	145	807
Japan	215	561
New Zealand	283	421
Iceland	45	200
El Salvador	95	162
Costa Rica	0	161
Kenya	45	127

Source: International Geothermal Association.

MIT-led panel backs 'heat mining' as key U.S. energy source

January 22, 2007

A comprehensive new MIT-led study of the potential for geothermal energy within the United States has found that mining the huge amounts of heat that reside as stored thermal energy in the Earth's hard rock crust could supply a substantial portion of the electricity the United States will need in the future, probably at competitive prices and with minimal environmental impact.

An 18-member panel led by MIT prepared the 400-plus page study, titled ["The Future of Geothermal Energy" \(PDF, 14.1 MB\)](#). Sponsored by the U.S. Department of Energy, it is the first study in some 30 years to take a new look at geothermal, an energy resource that has been largely ignored.

The goal of the study was to assess the feasibility, potential environmental impacts and economic viability of using enhanced geothermal system (EGS) technology to greatly increase the fraction of the U.S. geothermal resource that could be recovered commercially.

Although geothermal energy is produced commercially today and the United States is the world's biggest producer, existing U.S. plants have focused on the high-grade geothermal systems primarily located in isolated regions of the west. This new study takes a more ambitious look at this resource and evaluates its potential for much larger-scale deployment.

NUCLEAR ENERGY: WORLD.

443 reactors in 31 countries generate 6.5% of total world energy demand

Many new plants planned around the world:
India (19), China (63), US (20?)

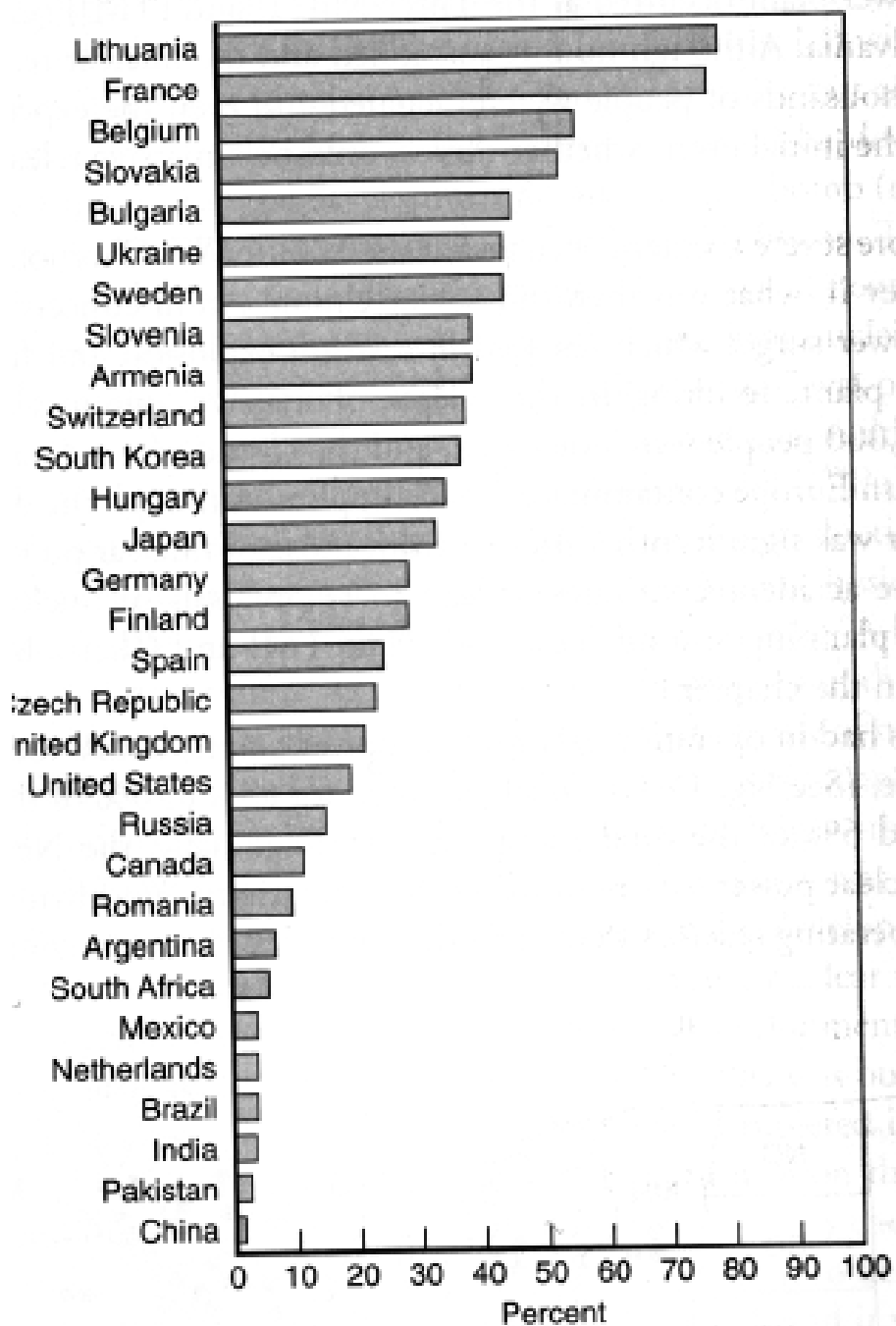
N. Lewis: "to produce 10 TW of power would require construction of 10,000 new 1 GW nuclear power plants over the next 50 years, that is one every other day."

Table 14.1 WORLD NUCLEAR POWER 2004

Country	In Operation		Under Construction
	Number of Units	Total Net MWe	Number of Units
Argentina	2	935	1
Armenia	1	376	
Belgium	7	5,527	
Brazil	2	1,900	1
Bulgaria	4	2,722	
Canada	22	15,200	
China	9	6,587	4
Czech Republic	4	3,548	2
Finland	4	2,756	
France	59	63,368	1
Germany	18	20,643	
Hungary	4	1,755	
India	14	2,550	8
Iran			2
Japan	53	45,220	4
Korea, North			2
Korea, South	18	14,900	6
Lithuania	2	2,370	
Mexico	2	1,310	
Netherlands	1	450	
Pakistan	2	425	1
Romania	1	630	
Russia	30	20,793	3
Slovakia	6	2,442	1
Slovenia	1	660	
South Africa	2	1,842	
Spain	9	7,588	
Sweden	11	9,451	
Switzerland	5	3,220	
Taiwan	6	5,144	
Ukraine	13	11,207	2
United Kingdom	27	12,052	
United States	104	98,975	
World Total	443	366,546	38

Source: International Atomic Energy Agency.

Nuclear Shares of National Electricity Generation, 2002



Pour les générations futures, nous développons les énergies de demain.
 Pour préparer l'avenir, nous mettons en service dès 2012 la nouvelle génération de centrale nucléaire, l'EPR. EDF, leader européen des énergies de demain. edf.com



January 24, 2008

OP-ED COLUMNIST

America Needs France's Atomic Anne

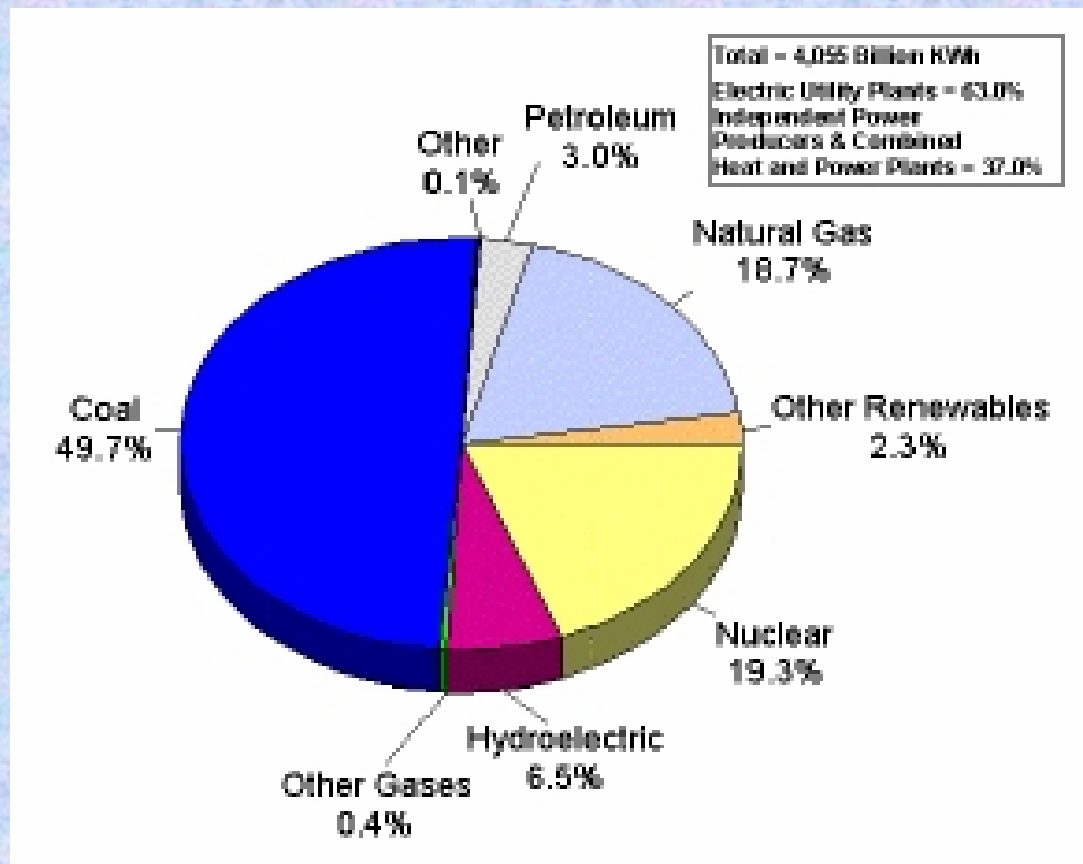
By ROGER COHEN

It's not often that I find myself recommending a French state-owned industry as the answer to major U.S. problems, but I guess there's an exception to every rule.

In this case the exception is the French nuclear energy company Areva, which provides about 80 percent of the country's electricity from 58 nuclear power plants, is building a new generation of reactor that will come on line at Flamanville in 2012, and is exporting its expertise to countries from China to the United Arab Emirates.

Contrast that with the United States, where just 20 percent of electricity comes from nuclear plants, no commercial reactor has come on line since 1996, no new reactor has been ordered for decades, and debate about nuclear power remains paralyzing despite its clean-air electricity generation in the age of global warming.

Areva is headed by Anne Lauvergeon, a brilliant product of France's top schools. She's earned the sobriquet "Atomic Anne," a stylish "Vive les Nukes" saleswoman. The United States needs her equivalent to cut through its nuclear power hang-ups.

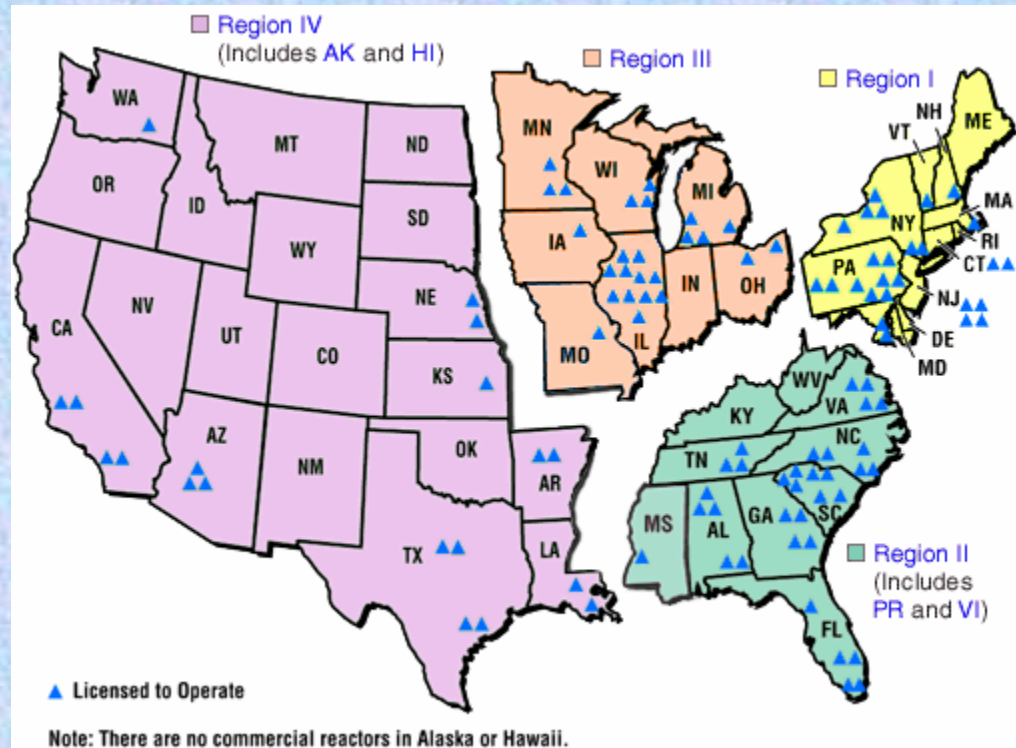


U.S. electricity generation 2005

from www.eia.doe.gov

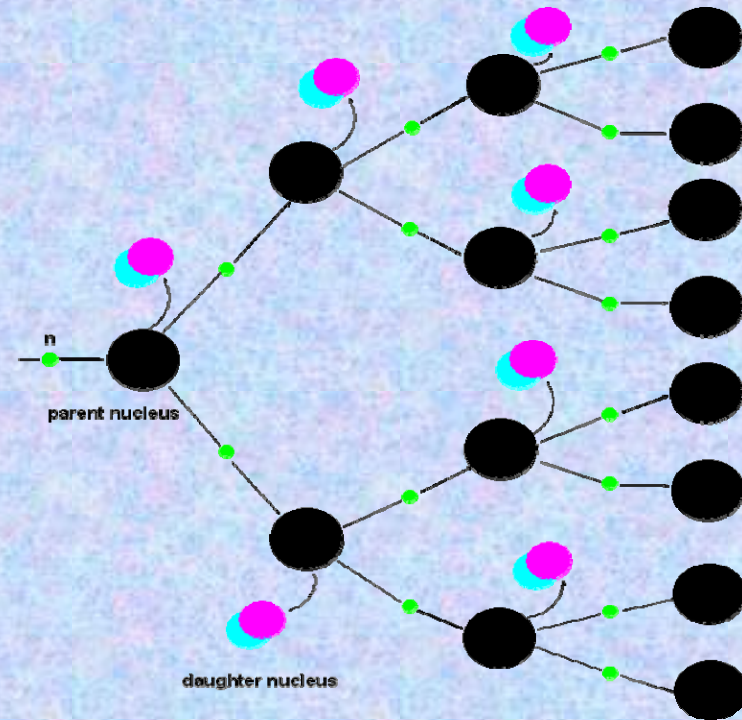
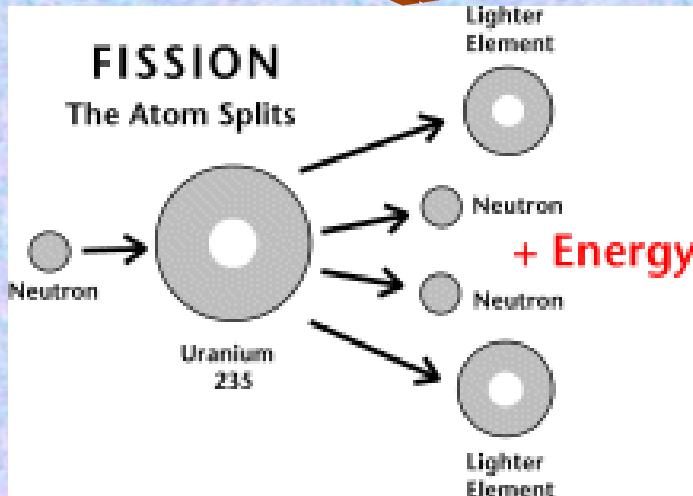
Nuclear: 781,986 thousand megawatthours produced from a capacity of 100,000 MW

NUCLEAR POWER:



104 plants
96,980 MW
Oyster Creek 619 MWe
Three Mile Island 802 MWe

How does nuclear power work?



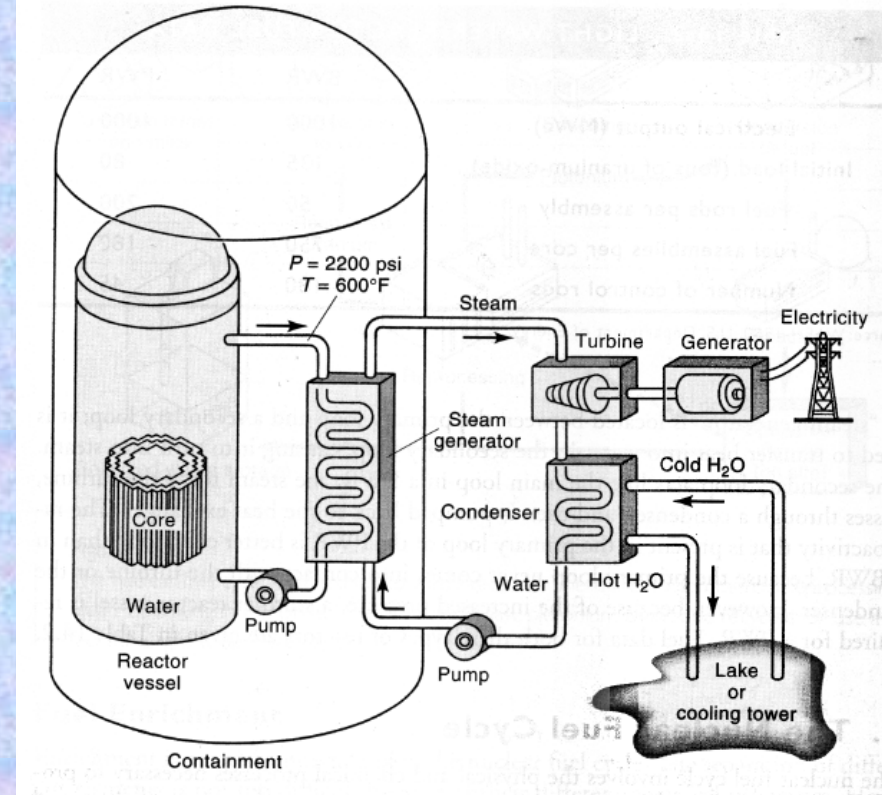
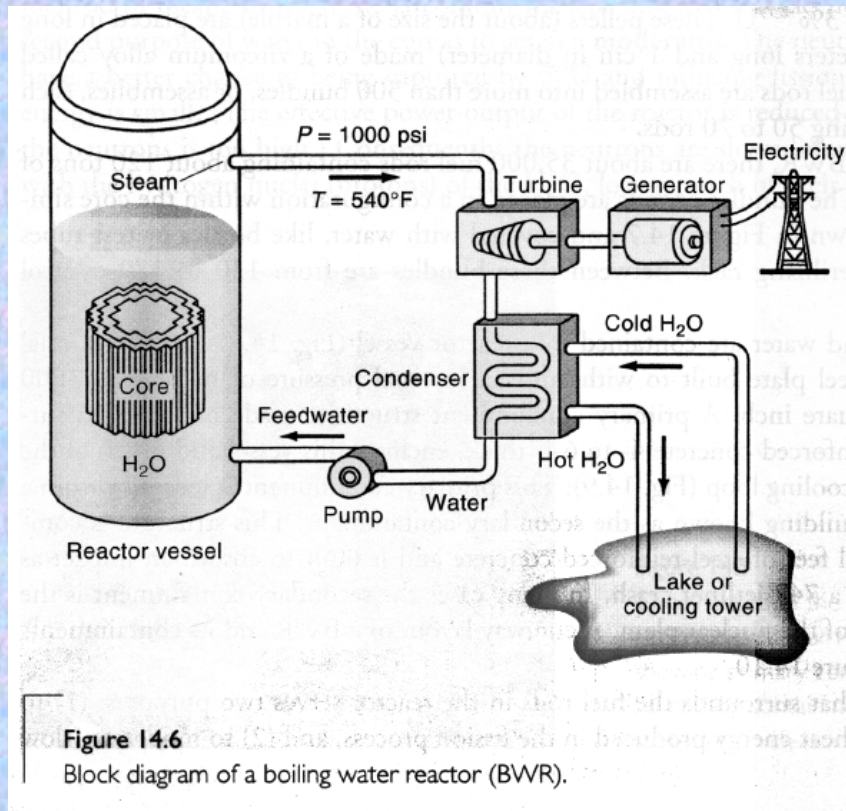
- Chain reaction
- Enrichment of ratio of U-235 to U-238 (3%)
(this takes about 10% of energy produced)

Nuclear power plant design

Basic design: light water reactors

(boiling water reactors and pressurized water reactors)

Reaction is controlled by neutron absorption of water and control rods



Heavy water reactors (hydrogen in water is replaced by deuterium)
Unenriched uranium can be used.

Breeder reactors: fast neutrons from fission convert U-238 to Pu-239
More of the energy of the natural uranium is extracted

Difference between power plant and bomb: 90%+ pure U-235 or Pu-239
A power plant will NEVER blow up like a bomb!
Production of pure Pu-239: the problem with reprocessing and breeder reactors

Input and output

- Mining of uranium, distribution of reserves (Australia: about 30%)
- Spent fuel: reprocessing (chemical), high-level waste, low-level waste

Only 35 countries worldwide possess reported uranium reserves³ (11 low-income, 13 middle-income, and 11 high-income). The developing countries possess 54% of these reserves, with major reserves located in Niger (0.19 million metric tons), Brazil (0.16 million metric tons), Kazakhstan (0.43 million metric tons), Russia (0.16 million metric tons), and South Africa (0.24 million metric tons). Only industrialized countries possess large reserves: Australia (0.59 million metric tons), Canada (0.54 million metric tons), and the United States (0.32 million metric tons).

Safety and security issues

- Accidents? Three Mile Island 1979, Chernobyl 1986 (interest in passive vs active safety systems)
- Misuse of radioactive material

Fusion

Energy production in the Sun comes from a sequence of nuclear reactions, with the net result



No radioactive byproducts!

Fusion on earth?

“Fusion power is twenty years away, and it has been for the last fifty years”

Fusion: the future?

France Will Get Fusion Reactor to Seek a Future Energy Source



The model of the site of the International Thermonuclear Experimental Reactor (ITER) that is to be built at Cadarache in southern France.
(NY Times, June 2005)

Federal budget train wreck for FY 2008: “the spending bill also eliminated the United States’ planned contribution of \$160 million to ITER, a test fusion reactor that is intended to lead to commercial energy production by emulating the process that powers the Sun.” (from NYTimes, December 22, 2007)