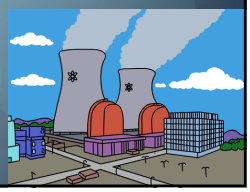
Chapter 16

Non-Renewable Energy Sources





Outline

- Energy Resources and Uses
- Coal
- Oil
- Natural Gas
- Nuclear Power
  - Nuclear Fission
  - Reactors Types
  - Waste Management
  - Nuclear Fusion

How Do We Measure Energy?

- Work - application of force over distance
  - (measured in joules)
- Energy - the capacity to do work
- Power - rate at which work is done
  - (measured in watts)
  - Newton - force needed to accelerate 1 kg 1 meter per second
  - Joule - amount of work done when a force of 1 newton is exerted over 1 meter
  - Watt –one joule per second

Measuring Energy

- Lighting a standard 100 watt light bulb for 10 hours uses 1000 watt-hours of power or 1 kilowatt-hour.
- The average American home uses 11,000 kilowatt-hours of electricity per year.

Typical Energy Usage

Table 19.2 Some Energy Uses

Uses	kWh/year*
Computer	100
Television	125
100 W light bulb	250
15 W fluorescent bulb	40
Dehumidifier	400
Dishwasher	600
Electric stove/oven	650
Clothes dryer	900
Refrigerator	1100

* Averages shown; actual rates vary greatly.

Global Commercial Energy Production

- Currently, fossil fuels supply 88% of the world's commercial energy needs.

Per Capita Consumption

- Richest countries have consumed nearly 80% of all commercial energy despite having only 20% of population.
- Experts predict that by 2035 emerging countries such as China and India will consume 60% of commercial energy.

Per Capita Energy Use

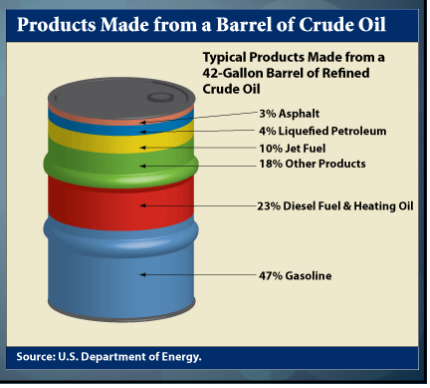
- Each person in a rich country consumes nearly as much oil in a day as the poorest people in the world consume in a year.
- Some countries such as Norway, Denmark, and Japan have a much higher standard of living than the U.S. but use half as much energy.
- This suggests that we could keep our standard of living while conserving energy.

How Energy Is Used

- Largest share of energy used in the U.S. is consumed by industry (31%). In some cases, it is not used for energy but is made into plastics, fertilizers, lubricants, etc.
- Residential and commercial customers use 41%, mostly for heating, cooling, and light .
- Transportation consumes about 28% of all.
- About half the energy in fuels is lost during conversion, shipping, and use, and huge amounts of pollution are released.

Petroleum is .....

- OIL
- What is made from oil?



Oil

- Petroleum is formed in a similar way to oil: Organic material buried in sediment and subjected to high pressure and temperature.
  - An "oil pool" is usually composed of individual droplets or a thin film permeating spaces in porous sandstone (like water in a sponge)
  - We recover about 30-40% of oil in a formation before it becomes uneconomical to continue.

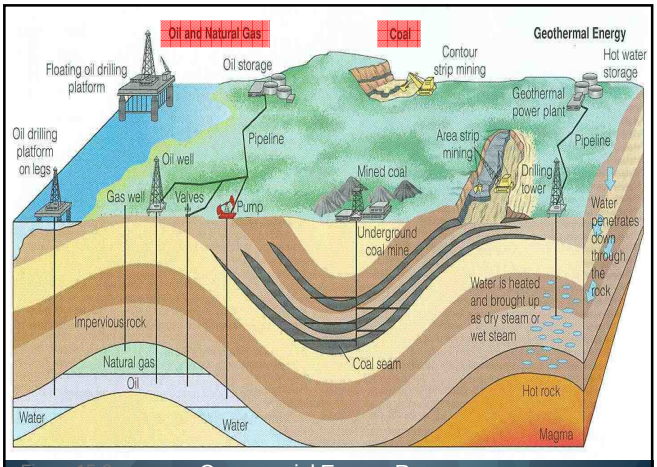


Figure 15-2 Commercial Energy Resources

Petroleum - Crude oil. a mixture of gaseous, liquid, and semisolid hydrocarbons. Needs to be refined into it's different products.

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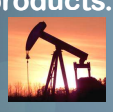
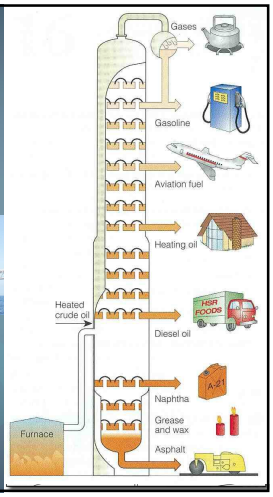


Refining is done by boiling the crude oil in a Distillation Column.

Click Me!

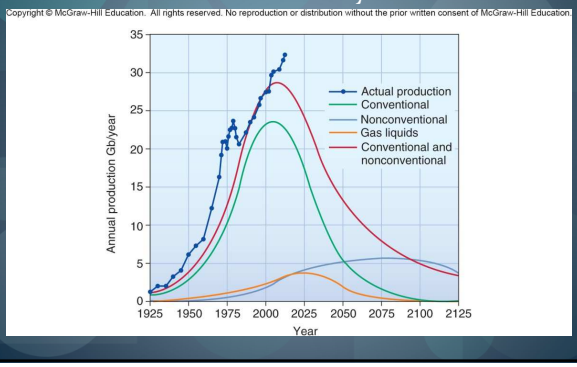


Have We Passed Peak Oil?

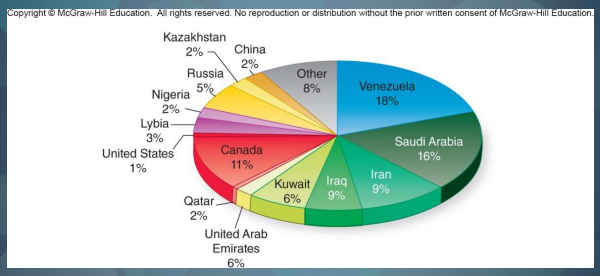
- Reserves
  - Total amount of oil in the world is estimated at 4 trillion barrels. (Half is thought to be ultimately recoverable.)
  - The "Greater Middle East" contains 91% of proven, economically-recoverable oil.
  - China expects to double its energy demands in 15 years; if that occurs they will bypass the US in energy use.

Peak Oil

Many geologists predict that oil production will peak in the next few years.



Locations of Proven Oil Reserves



Like Other Fossil Fuels, Oil Has Negative Impacts

- Disrupts wildlife and plants
- Burning oil produces carbon dioxide and nitrogen oxides.
- Every year 1.5 billion tons of oil are shipped in ocean tankers or through pipelines.
  - In 1978, the Amoco Cadiz ran aground contaminating 350 km of French coastline.

Tar Sands and Oil Shales

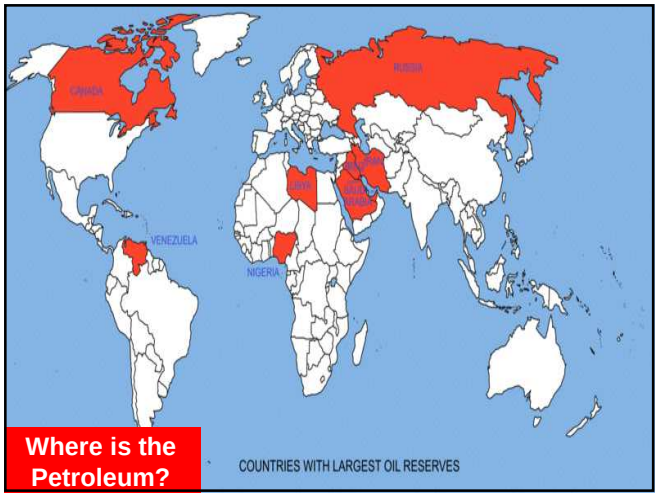
- Tar sands and oil shales contain 10X as much as conventional reserves.
- Tar sands are composed of sand and shale particles coated with bitumen, a viscous mixture of long chain hydrocarbons. They have to be mixed with steam to extract the bitumen, which is then refined.
- Process creates toxic sludge, releases greenhouse gases, contaminates water, and destroys boreal forest in Canada where most of reserves are.

Canadian Tar Sands

© Larry MacDougal/Canadian Press via AP Images

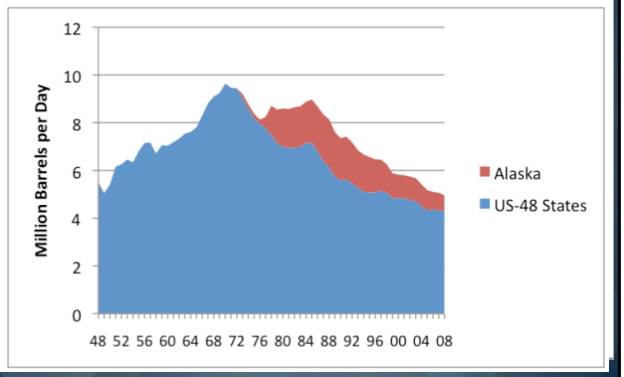
Oil Shales

- Oil shale is sedimentary rock rich in kerogen. Kerogen can be heated and extracted.
- Large reservoirs of oil shales occur in western U.S.
- Might yield several trillion gallons of oil.
- Mining is expensive, uses vast quantities of water (which is a scarce resource in the west), contributes to air and water pollution, and produces huge quantities of waste.



Where is the Petroleum?

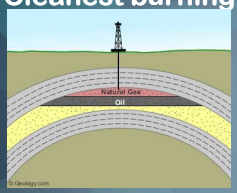
US oil production peaked in 1970

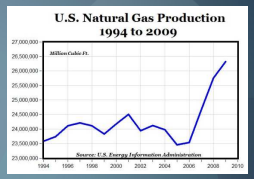


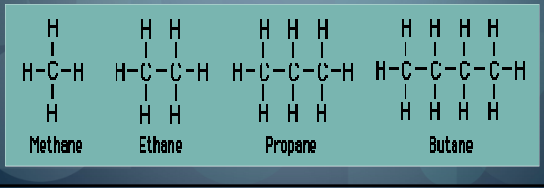
16.2: Natural Gas

Found above crude oil

Cleanest burning nonrenewable energy.







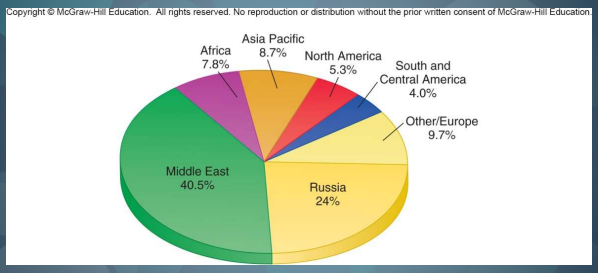
Natural Gas

- World's third largest commercial fuel
  - 24% of global energy consumption
  - Composed primarily of methane
  - Produces half as much CO_2 as equivalent amount of coal
  - Most rapidly growing energy source

Natural Gas

- Two thirds of reserves are in Middle East and former Soviet Union.
- At current rates of use, we have a 60-year supply worldwide.
- U.S. has 3% of world reserves, or about a 10-year supply, but it is estimated that there is twice as much that could ultimately be tapped. LNG-Gas is liquefied to ship it by ocean. A ship explosion would be equivalent to a medium-sized atomic bomb.
- Methane can be extracted from coal seams.

Proven Natural Gas Reserves By Region



Unconventional Gas Sources

- Methane hydrate - Small individual molecules of natural gas trapped in a crystalline matrix of frozen water. Found in arctic and beneath ocean.
  - Thought to hold 10,000 gigatons of carbon, or twice as much as combined amount of all traditional fossil fuels
    - Difficult to extract, store, and ship
- Methane could be extracted from garbage, manure.

Hydraulic Fracturing "Fracking"

A highly productive new Natural Gas technology

Positives:

- Produces large amounts of natural gas.

Negatives:

- millions of gallons of wastewater.
- Methane migrating into drinking water.
- Air Pollution from trucks.

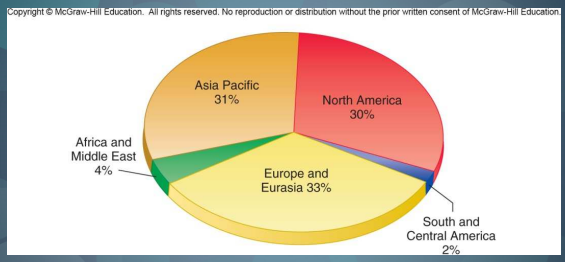
Coal

- Fossilized plant material preserved by burial in sediments and compacted and condensed by geological forces into carbon-rich fuel.
  - Most laid down during Carboniferous period (286 million to 360 million years ago).
  - Because coal took so long to form, it is a nonrenewable resource.

Coal Resources Are Vast

- World coal deposits are ten times greater than conventional oil and gas resources combined.
  - "Proven reserves" - have been mapped, measured, and shown to be economically recoverable.
  - That could increase to thousands of years if estimates of unknown reserves are included.

Location of World's Coal Deposits



Coal Mining Is Dirty and Dangerous

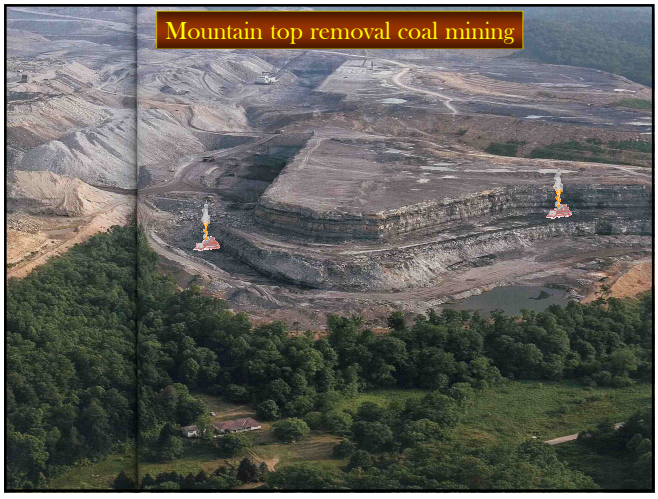
- Mining
  - Between 1870 and 1950, more than 30,000 American coal miners died of accidents and injuries in Pennsylvania alone.
    - Thousands have died of respiratory diseases.
      - Black Lung Disease - inflammation and fibrosis caused by accumulation of coal dust in the lungs or airways
  - China currently has the most dangerous mines, with 91,172 killed in mining accidents in 2008.

Coal Mining Is Destructive

- Strip mining is cheaper and safer than underground mining.
  - Often makes land unfit for other use
  - Acid drainage damages streams.
  - Mountaintop removal, practiced in Appalachia, causes streams, farms, and even whole towns to be buried under hundreds of meters of toxic rubble.

Mountain Top Removal

© George Steinmetz/Corbis



Burning Coal Releases Pollutants

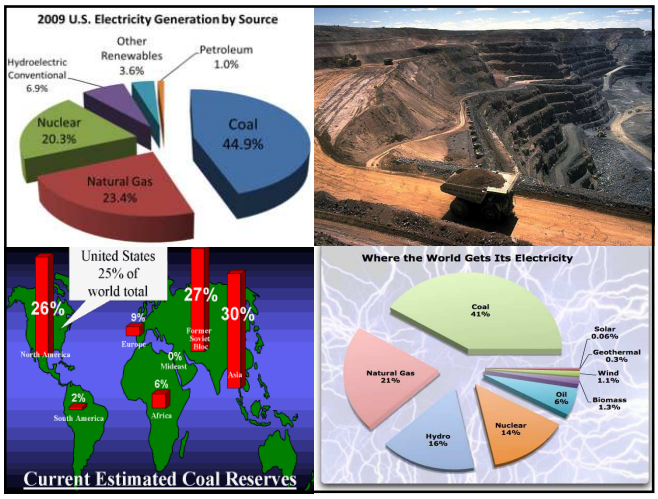
- Coal burning releases radioactive and toxic metals into the atmosphere.
  - Coal combustion is responsible for 25% of all atmospheric mercury pollution in the U.S.
- Ash from coal combustion is stored in open storage ponds, which are at risk of catastrophic failures causing millions of dollars in damages and polluting local water supplies.
- Coal burning releases sulfur and nitrogen oxides, particulates, and carbon dioxide which contribute to acid rain, air pollution, and global warming.

Clean Coal Technology Could Be Useful

- Carbon dioxide could be sequestered by pumping it into deep geologic formations, which could also enhance oil recovery.
- New technology (such as integrated gasification combined cycle) captures CO_2 as well as removing sulfur and mercury. This would cut down on emissions.
- Flex-Fuel Boilers – coal can be mixed with biomass fuels to produce energy with less carbon dioxide emissions.

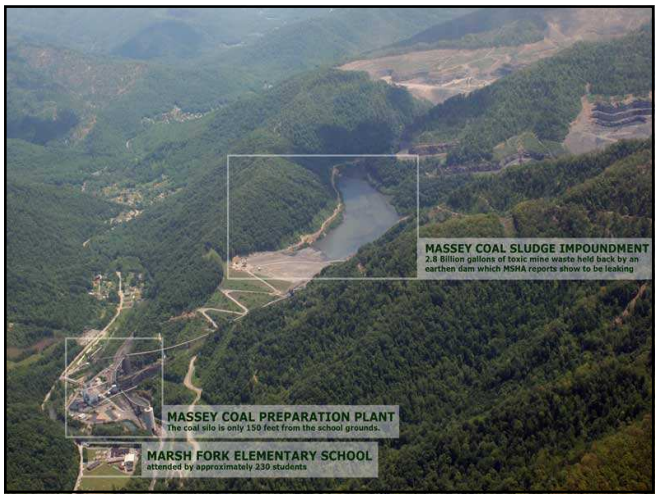
16.3: Coal

brown coal, low heat / high moisture – lignite
soft coal, high sulfur content – bituminous
hard coal, high heat content – anthracite


2009 U.S. Electricity Generation by Source
Other Renewables 3.6%
Petroleum 1.0%
Hydroelectric Conventional 6.9%
Nuclear 20.3%
Coal 44.9%
Natural Gas 23.4%
United States 25% of world total
26%
27%
30%
8%
0%
6%
2%
Former Soviet Bloc
Europe
Mideast
Asia
Africa
North America
South America
Current Estimated Coal Reserves
Where the World Gets Its Electricity
Coal 41%
Solar 0.06%
Geothermal 0.3%
Wind 1.1%
Biomass 1.3%
Oil 6%
Nuclear 14%
Hydro 16%
Natural Gas 21%


Valley fill from MTR mining

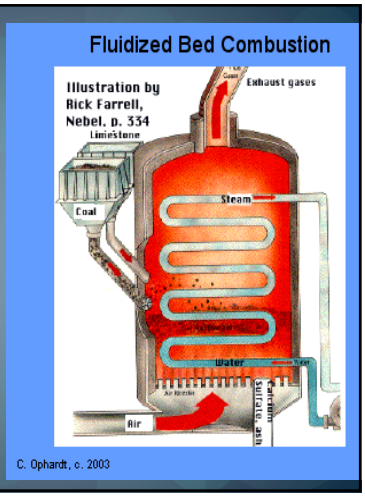

Tennessee Valley Authority coal sludge pond spill, 12/22/08



Coal is the dirtiest fuel source (because of Air Pollutants Sulfur and Carbon Dioxide. . Here's a way to burn it cleaner.

Fluidized-bed combustion:
Add Limestone (Calcium Carbonate) to cut Sulfur, Nitrogen Oxides emissions.

See Figure 16-11, page 442.



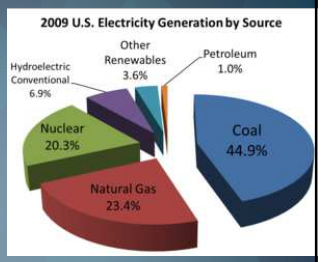
Alternatives to Coal, Oil, and Natural Gas

- Using trash (Municipal Solid Waste) as an energy source and as a new source of synthetic fuels.

- Synthetic Fuels such as liquid gas and fertilizers can also be made from natural gas using new technologies.
- The problem with new technologies is typically that they are very expensive.

Nuclear Energy

- Need to mine the fuel source: Uranium.
- Very Expensive to build.
- Very low emissions.



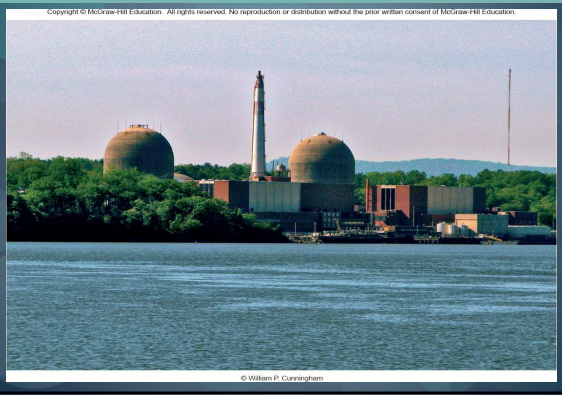
- Here is how a plant works.

Why did the Fukushima Plant Metldown?

Nuclear Power

- In 1953, President Dwight Eisenhower gave his famous "Atoms for Peace" speech.
  - Nuclear-powered electrical generators would provide power "too cheap to meter."
    - Between 1970 and 1974, American utilities ordered 140 new reactors for power plants.
    - But construction costs were high and there were safety fears.

Nuclear Power Plant

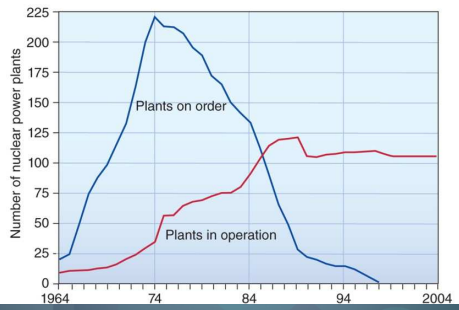


© William P. Cunningham

Nuclear Power

- After 1975, only 13 orders were placed for new nuclear reactors, and all of those were subsequently cancelled.
  - In all, 100 of 140 reactors on order in 1975 were cancelled.
    - Electricity from nuclear power plants was about half the price of coal in 1970, but twice as much in 1990.

Nuclear Power Plant History

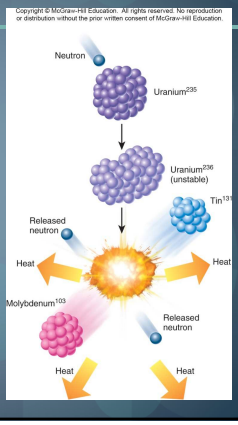


How Do Nuclear Reactors Work?

- Most commonly used fuel is U^{235}, a naturally occurring radioactive isotope of uranium.
  - Occurs naturally at 0.7% of uranium ore, but must be enriched to 3%
- Formed in cylindrical pellets (1.5 cm long) and stacked in hollow metal rods (4 m long)
  - About 100 rods are bundled together to make a fuel assembly.
    - Thousands of fuel assemblies, containing 100 tons of uranium, are bundled in reactor cores.

Nuclear Fission

- When struck by neutrons, radioactive uranium atoms undergo nuclear fission, releasing energy and more neutrons.
- Triggers nuclear chain reaction



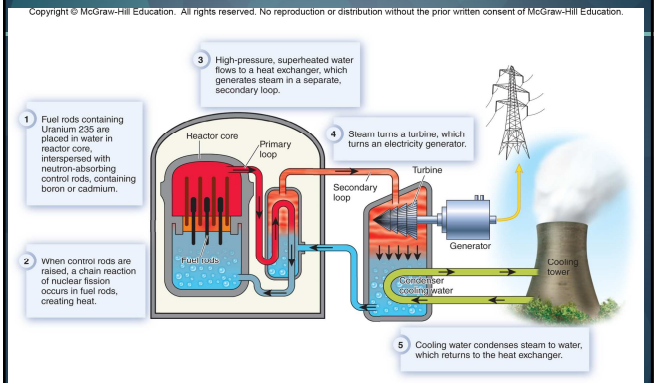
How Do Nuclear Reactors Work?

- Reaction is moderated in a power plant by neutron-absorbing cooling solution
  - In addition, control rods composed of neutron-absorbing material are inserted into spaces between fuel assemblies to control reaction rate.
    - Water or other coolant is circulated between the fuel rods to remove excess heat.
    - Greatest danger is a cooling system failure resulting in a meltdown and release of radiation

There Are Various Kinds of Reactors

- Seventy percent of nuclear power plants are pressurized water reactors (PWR).
  - Water is circulated through core to absorb heat from fuel rods and then pumped to steam generator where it heats a secondary loop. Steam from secondary loop drives high-speed turbine producing electricity.
  - Both the reactor vessel and steam generator are housed in a special containment building preventing radiation from escaping, and providing extra security in case of accidents.
  - Under normal operating conditions, a PWR releases very little radioactivity. The most famous accident in the U.S. happened at Three Mile Island near Harrisburg, PA. The reactor suffered a partial meltdown of the core.

PWR



Kinds of Reactors (cont.)

- A simpler, but more dangerous design, is a boiling water reactor.
  - Water from core boils to make steam, directly driving turbine generators
    - Highly radioactive water and steam leave containment structure and chances of accident are high.

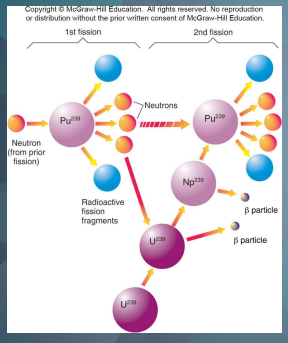
Kinds of Reactors (cont.)

- Graphite moderator reactors - operate with a solid moderator instead of a liquid
  - These are common in Britain, France, and former Soviet countries.
- Graphite moderator reactors have been involved in the biggest nuclear power disasters.
  - Chernobyl in Ukraine
  - Windscale in England

Alternative Reactor Design

- High-Temperature, Gas-Cooled Reactors
  - Uranium encased in tiny ceramic-coated pellets and helium used as coolant.
  - If reactor core is kept small, it cannot generate enough heat to melt ceramic coating even if cooling is lost.
  - There are not many of these plants in operation.

Breeder Reactors



- Breeder reactors create fissionable plutonium and thorium isotopes from stable forms of uranium.
- Use plutonium reclaimed from spent fuel from conventional fission reactors as starting material.

Breeder Reactor Drawbacks

- Reactor core must be at very high density, thus water cannot be used as coolant.
  - Liquid sodium is used instead. Liquid sodium is corrosive, burns with intense heat, and explodes on contact with water. A breeder reactor will self-destruct in a few seconds if coolant fails.
- Breeder reactors produce weapons grade plutonium as waste.

We Lack Storage for Radioactive Wastes

- Production of 1,000 tons of uranium fuel typically generates 100,000 tons of tailings and 3.5 million liters of liquid waste.
- There are now approximately 200 million tons of radioactive waste in piles around mines and processing plants in the U.S.
- About 100,000 tons of low-level waste (clothing, tools) and about 15,000 tons of high-level (spent-fuel) waste in the U.S.
- Spent fuel assemblies have been stored in deep water-filled pools at the power plants. (Designed to be temporary.)

We Lack Storage for Radioactive Wastes

- U.S. Department of Energy announced plans to build a high-level waste repository near Yucca Mountain, Nevada, in 1987.
  - Radioactive waste would be buried deep underground
  - Funding for the project was cut off in 2009 after 20 years and over $100 billion.
- Russia has offered to store nuclear waste from other countries at Mayak in Ural Mountains. An explosion there in 1957 made the area the most radioactive place on earth, so Russians feel it can't get much worse.

Decommissioning Old Nuclear Plants

- Most plants have only a 30-year operating life.
- Reactors must be disassembled and the parts removed by remote controlled robots.
- The debris must be stored as nuclear waste for thousands of years.
- Decommissioning all the U.S. reactors currently in use could cost between $200 billion and $1 trillion.

Changing Fortunes of Nuclear Power

- Public opinion has fluctuated over the years.
  - When Chernobyl exploded in 1985, less than one-third of Americans favored nuclear power.
    - Now, 59% of all Americans support nuclear-energy.
- Currently, 103 nuclear reactors produce about 20% of all electricity consumed in the U.S.

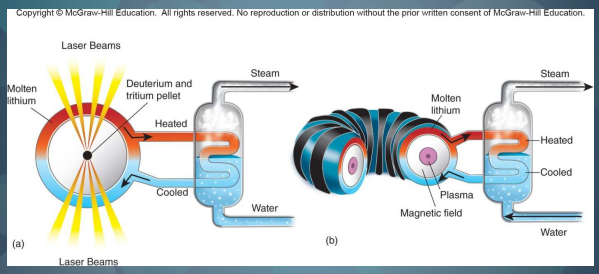
Changing Fortunes

- With oil and gas prices soaring, advocates are once again promoting nuclear reactors.
- Some prominent environmental conservationists now promote nuclear as a clean power source that doesn't emit greenhouse gases.
  - Over the past 50 years, the U.S. government has provided $150 billion in nuclear subsidies, but less than $5 billion to renewable energy research.
  - Where might we be now if the ratio had been reversed?

Nuclear Fusion

- Nuclear Fusion - Energy released when two smaller atomic nuclei fuse into one large nucleus. Energy in sun, hydrogen bombs.
  - Temperatures must be raised to 100 million °C and pressure must reach several billion atmospheres.
    - Magnetic Confinement
    - Inertial Confinement
  - Despite 50 years and $25 billion, fusion reactors have never produced more energy than they consume.

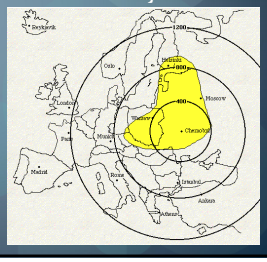
Nuclear Fusion



March, 1979, Three Mile Island Reactor #2 suffers 50% meltdown. Safety systems worked.

Chernobyl – Complete Nuclear Meltdown

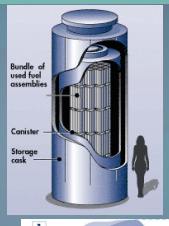
- On Friday, April 25, 1986, as a result of human error during experiments being performed by the staff at Chernobyl, the cooling system failed resulting in the melting of fuel and the release of radioactivity.



Current Worldwide Nuclear Trends

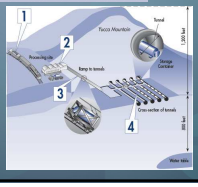
- Japanese reactors must shut down for maintenance every 13 months, and in the wake of the Fukushima nuclear crisis in March 2011 those that have gone offline have not been restarted. All but two of the country's 54 reactors are idle, and by May the rest are expected to be shut down, cutting off 30% of Japan's electricity-generating capacity.
- July 1, 2012 First Japanese Nuclear Power Plant Restarted
- On 30 May 2011, Germany, Europe's economic powerhouse, decided to phase out atomic power between 2015 and 2022.
- Switzerland looks set to follow. It is examining a proposal to phase out the country's nuclear plants by 2034. Now Italy will not revive its nuclear industry.
- USA's 104 reactors produced 20% of total electrical output

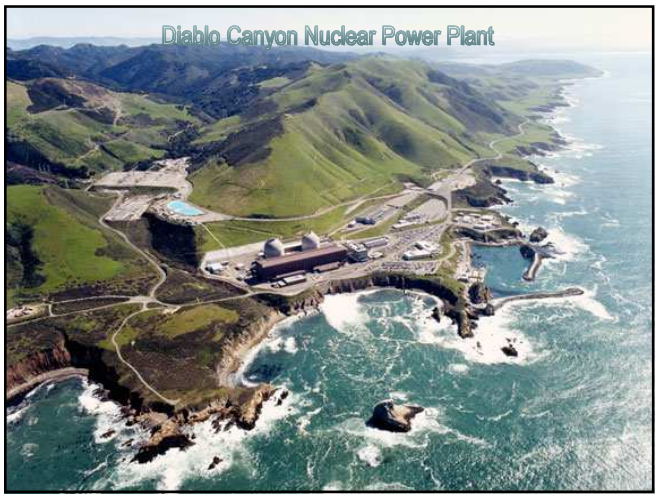
What to do with the waste?



Most is stored on site in a Dry Cask

Yucca Mountain Underground Storage? Not Anymore…





CONVENTIONAL ENERGY

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