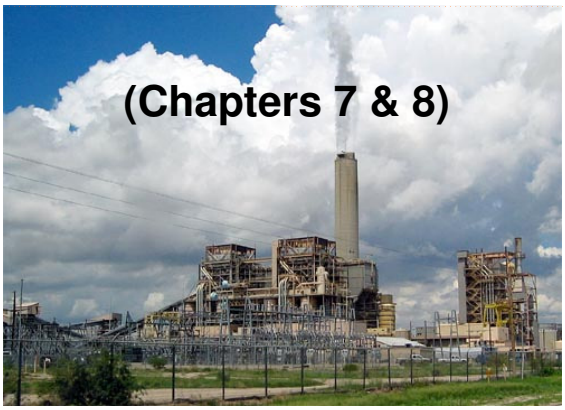
Lecture Topic # 5

Energy Sources
Part 1: Fossil fuels



A coal-fired power plant: Photo by Steev Hise (CC). Image available at http://www.allamericanpatriots.com/news_topics/greenhouse_gases?page=3

1

Fuels Used to Generate *Electricity*

* **Coal and oil -** contain hydrocarbons; emit greenhouse gases like CO_2 when burned

Combustion: $C_xH_y + O_2 \longrightarrow CO_2 + H_2O + \text{Heat}$

Hydrocarbons in coal, oil **Greenhouse gas**

* **Natural gas,** CH_4 (*methane*) – also releases CO_2

Combustion: $CH_4 + O_2 \longrightarrow CO_2 + H_2O + \text{Heat}$

Nuclear fuel, such as ***uranium*** and ***plutonium***

- *Radioactive decay produces* heat

* Coal, oil (petroleum) and natural gas are collectively called **fossil fuels**. They are nonrenewable energy sources.

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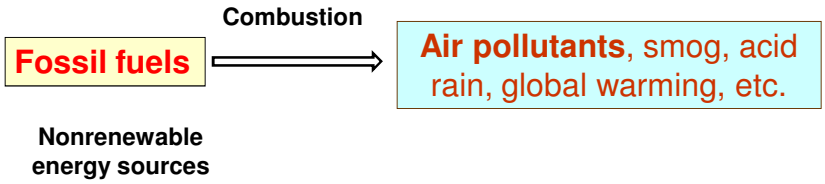
Energy Use and Pollution

From Chapters 3-5:



Solution:

- Switch to **renewable energy** (e.g. solar, wind) and **alternative fuel** (e.g. H_2) – *will be discussed in the next chapter*

Goal: To reduce air pollution

3

Nonrenewable Energy

Definition: ***Nonrenewable energy sources*** are those that cannot be replaced after we have used them up

Example: ***Fossil fuels*** (coal, oil and natural gas)

- Created hundreds of millions of years ago when ancient plants and animals died and were buried in swamps, lakes and seabed

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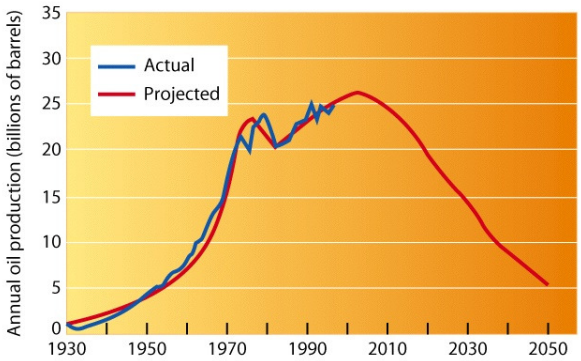
Supply of Fossil Fuels

- Supplies of fossil fuels are limited.
- There is probably enough crude oil (petroleum) and gas to last us until the mid-century - See graph
- Coal reserves may last for several centuries



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Background: Generation of Electricity

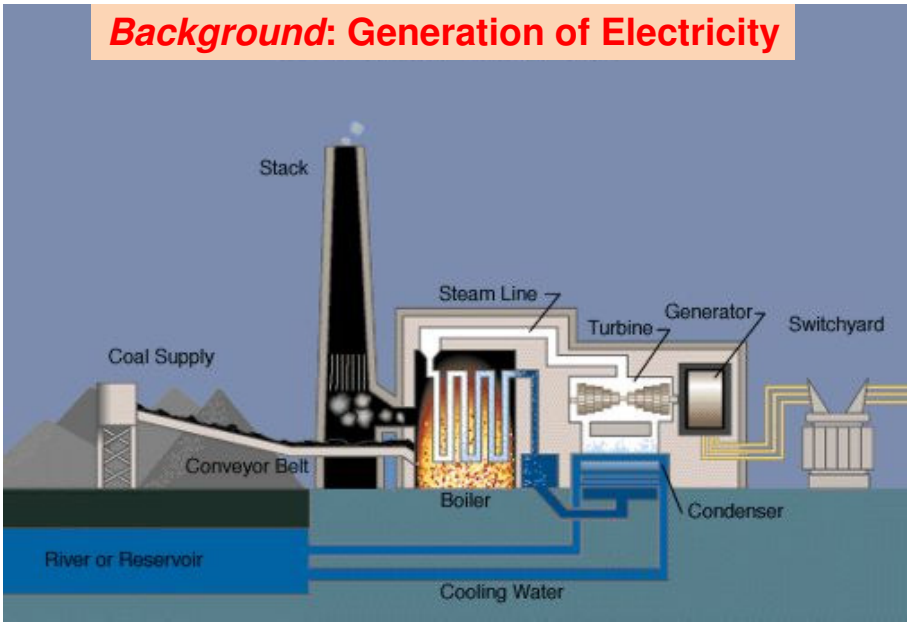

Image available at http://s8216267.wordpress.com/2008/05/12/sim-city-day-5/

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Generation of Electricity – Cont.

Most power plants are big boilers that burn a fuel to make heat. In most **boilers**, wood, coal (hence the term ***coal-fired power plant***), oil or natural gas is burned to make heat. That heat energy is used to boil water to make steam. The steam is fed under high pressure to a turbine. The **steam turbine** has many blades that look like the blades of a fan. When the steam hits the blades they spin a shaft that is attached to the bottom of the blades. The **shaft** is connected to a **generator** that changes the mechanical spinning energy into electricity.

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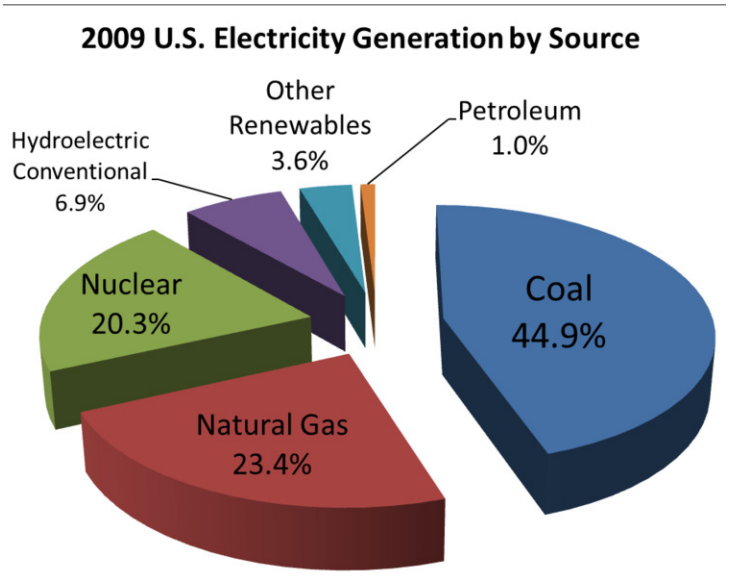

Sources of electricity in the USA 2009. Data from http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html. Image available at http://en.wikipedia.org/wiki/File:2008_US_electricity_generation_by_source_v2.png

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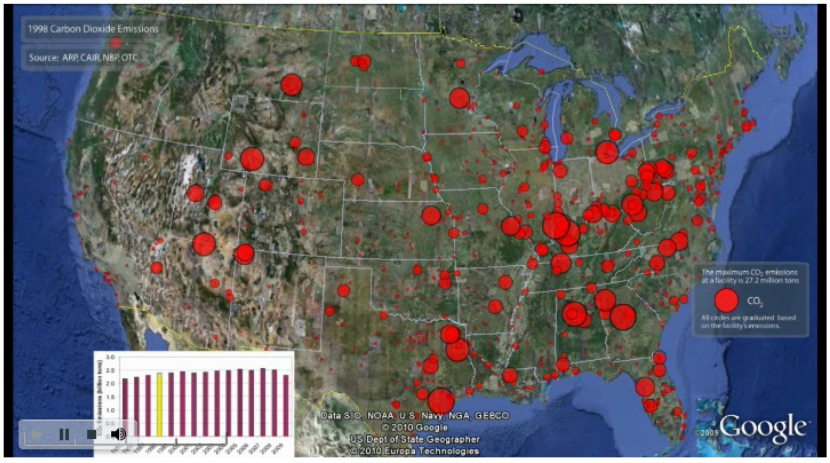
National CO_2 Emissions from Fossil Fuel-Burning Power Plants as Measured by Acid Rain Program Continuous Emissions Monitoring Systems (CEMS) ; http://www.epa.gov/captrade/maps/co2.html



(Clicking on the **Play** button in the bottom left corner of the map sets the map in motion.)

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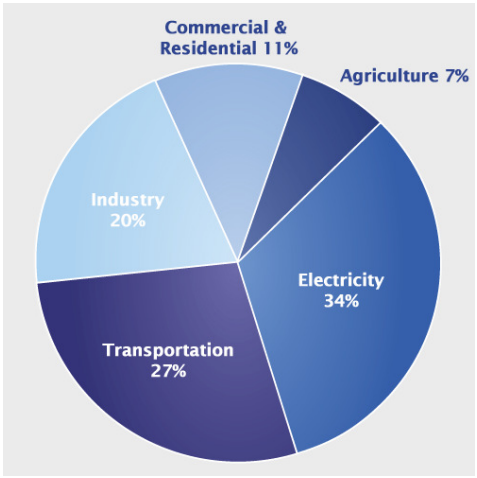
Total U.S. Greenhouse Gas Emissions by Economic Sector in 2010



Electricity > Transportation > Industry

Total Emissions in 2010 = 6,822 Million Metric Tons of CO_2 equivalent

* Land Use, Land-Use Change, and Forestry in the U.S. is a net sink and offsets approximately 15% of these greenhouse gas emissions

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Image available at http://www.epa.gov/climatechange/ghgemissions/sources.html

Emissions by Country

In 2008, the top carbon dioxide (CO_2) emitters were China, the United States, the European Union, India, the Russian Federation, Japan, and Canada. These data include CO_2 emissions from fossil fuel combustion, as well as cement manufacturing and gas flaring. Together, these sources represent a large proportion of total global CO_2 emissions.

Emissions and sinks related to changes in land use are not included in these estimates. However, changes in land use can be important – global estimates indicate that deforestation can account for 5 billion metric tons of CO_2 emissions, or about 16% of emissions from fossil fuel sources. Tropical deforestation in Africa, Asia, and South America are thought to be the largest contributors to emissions from land-use change globally. [3] In areas such as the United States and Europe, changes in land use associated with human activities have the net effect of absorbing CO_2, partially offsetting the emissions from deforestation in other regions.

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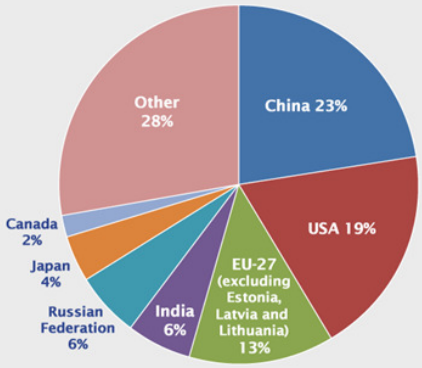
References

1. IPCC (2007). *Climate Change 2007: Mitigation of Climate Change* . EXIT Disclaimer Contribution of Working Group III to

2008 Global CO_2 Emissions from Fossil Fuel Combustion and some Industrial Processes (million metric tons of CO_2)



Source: National CO_2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2008.

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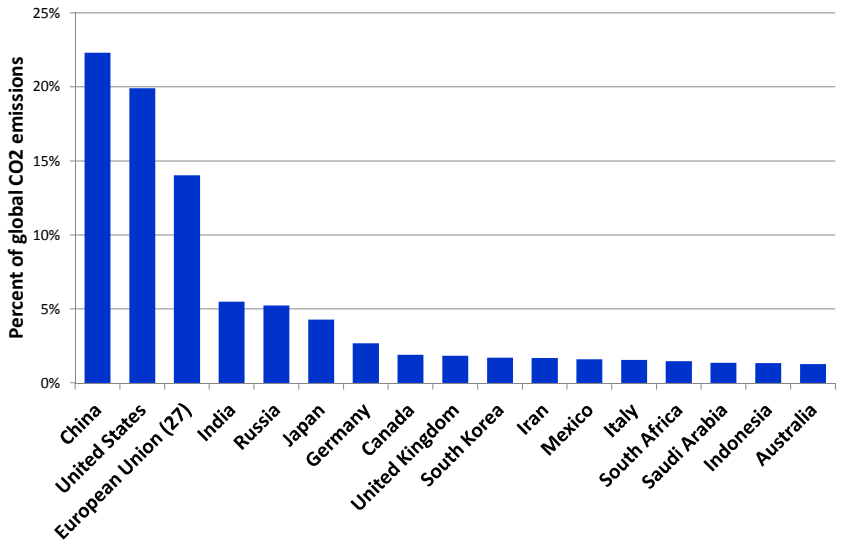
Total emissions of CO_2 by country in 2007



Source of data:
http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions#cite_note-7

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Fossil fuels: Coal

- Most abundant and cheapest of the fossil fuels
- 75 % of the world's coal reserves comes from:
  - U.S.
  - Russia
  - China
  - India
  - Australia
- Dirtiest; produces the most CO_2 per joule of (electrical) energy produced

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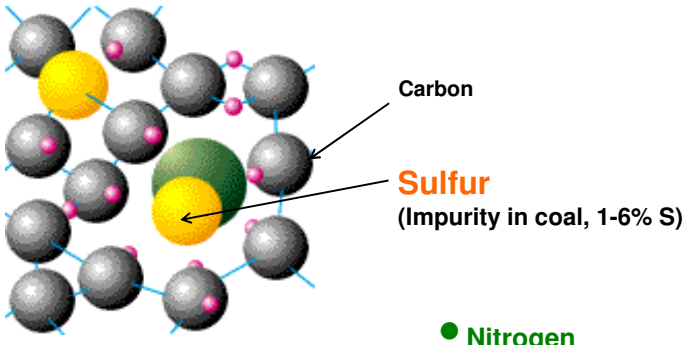
What else is in coal?



The structure of coal

Thus, burning of coal also releases ***sulfur dioxide*** (SO_2), some **nitrogen oxides** (NO_x) and naturally occurring elements like Hg, U and Pb as by-products.

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Fossil fuels: Petroleum (Crude Oil)

- **Petroleum** is a mixture of hydrocarbons

  Source: fossil remains of microscopic marine animals

Petroleum (crude oil) flowing into temporary tanks. Image available at http://www.northstarenergyinc.com/index.php/homepage/news/26

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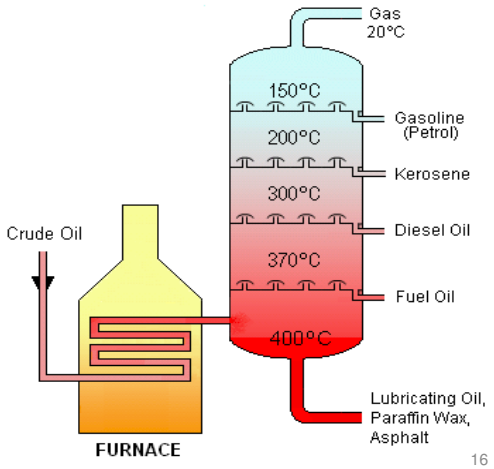
Products of petroleum refining

- Oil refineries utilize the process of ***fractional distillation*** – to separate petroleum into its constituent hydrocarbons.

  (Image available at http://www.qedoc.org)

Notes:



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Petroleum – Cont.

- Gasoline is a major fraction of petroleum refining

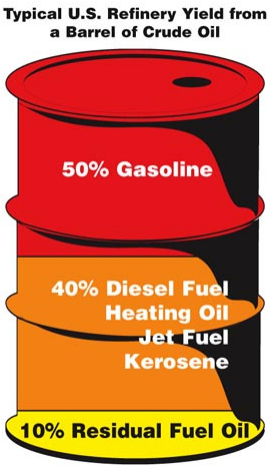

Image available at http://www.ocean.udel.edu/oilspill/crudeoil.html

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Petroleum – Cont.

- Right: A distillation column at the Richmond Refinery
- Photo of a petroleum refinery (below)

Images available at
http://www1.eere.energy.gov/industry/petroleum_refining/printable_versions/profile.html
and http://www.eia.doe.gov/kids/energyfacts/sources/non-renewable/refinery.html

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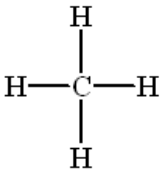
Fossil Fuels: Natural Gas

Natural gas consists of short-chain alkanes

- **Methane** (CH_4) is the principal component of natural gas.



- Methane is transported through pipelines to consumers
  - Used for cooking, heating homes & buildings
- Combustion of methane:

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2H_2O + \textbf{heat}$$

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Where We Find Natural Gas

The U.S. has a lot of natural gas, enough to last for at least another 60 years.

Canada, also has a lot of gas, and some gas pipelines that begin in Canada run into the U.S.

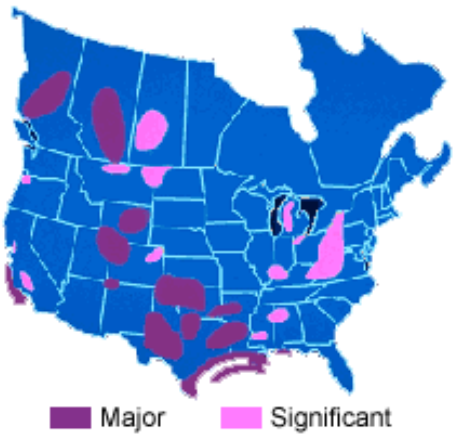

Image available at http://www.fossil.energy.gov/education/energylessons/gas/

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How Does Natural Gas Get To Our Homes and Businesses?

- A **liquefied natural gas** (**LNG**) tanker on its way to the Distrigas terminal in Everett, headed into Boston Harbor under the flight path of Logan International Airport. (David L. Ryan/ Globe Staff)

Image available at
http://www.boston.com/news/local/massachusetts/articles/2006/09/10/despite_millions_spent_boston_is_vulnerable/

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How Does Natural Gas Get To Our Homes and Businesses?

19 interstate natural gas **pipeline systems** operate within the Northeast Region

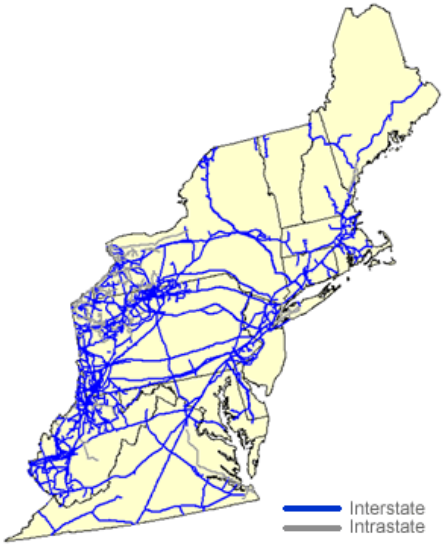

Image available at
http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/northeast.html

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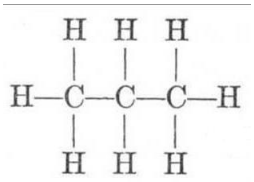
Natural Gas – Cont.

- **Propane**, C_3H_8, is obtained from natural gas or from petroleum refining.



- Propane and/or **butane** are sold individually or as a liquid mixture called ***liquefied petroleum gas*** (**LPG**) in small tanks.

Propane tanks. Image available at http://wolfstone.halloweenhost.com/HalloweenTech/pnupro_PropaneAirTank.html

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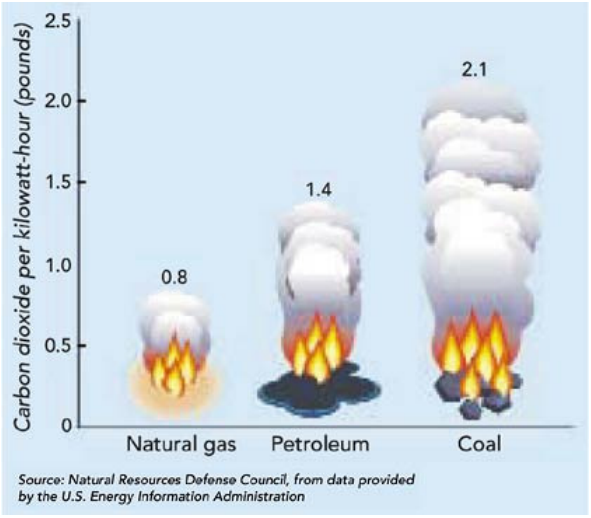
Amount of CO_2 that is emitted into the atmosphere per unit of electrical energy produced is plotted for three fossil fuels. Burning coal emits more CO_2 per unit energy than any other fuel. *Illustration by Ian Worpole*



Notes:

Image available at http://www.naturalhistorymagazine.com/0506/0506_feature.html

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Global Coal Production (1981-2007)

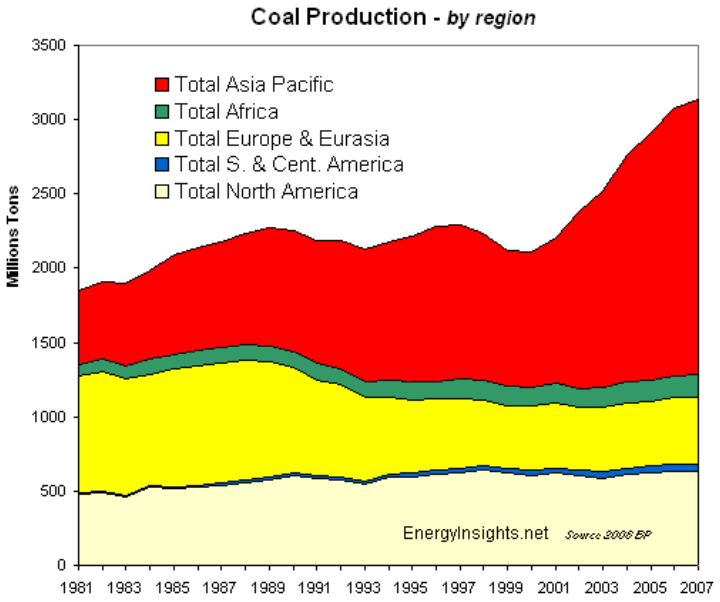

Image available at http://www.energyinsights.net/cgi-script/csArticles/articles/000042/004262.htm

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Total Global Coal Consumption (1965-2007)

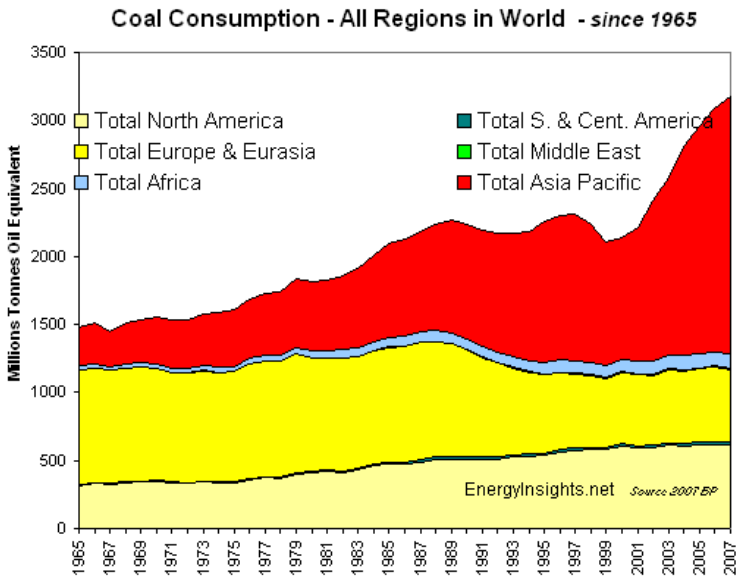

Image available at http://www.energyinsights.net/cgi-script/csArticles/articles/000042/004262.htm

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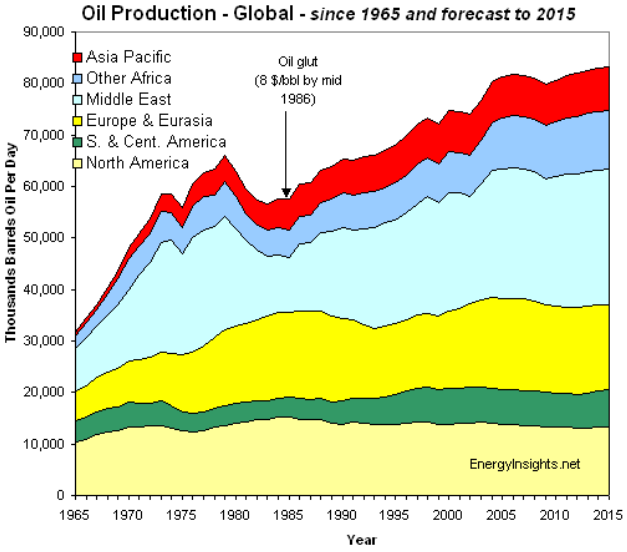
Historical and Projected Oil Production (1930-2050)



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Global Gas Production (1970 to present -projected 2015)

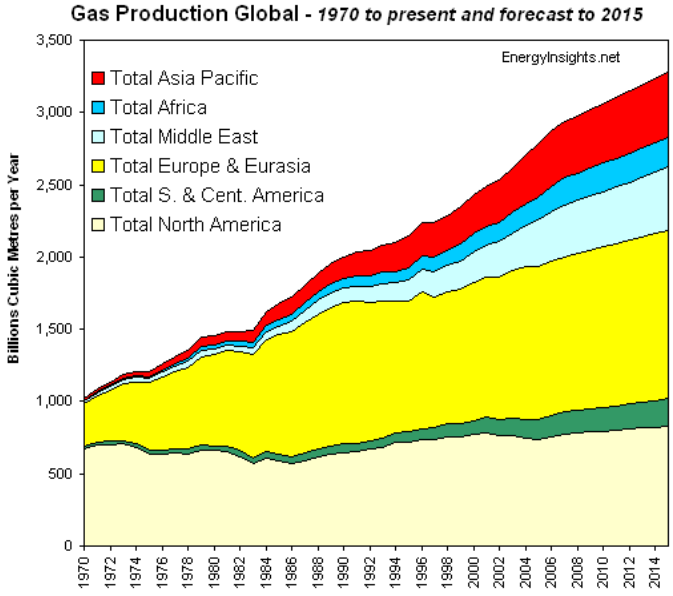

Image available at http://www.energyinsights.net/cgi-script/csArticles/articles/000000/000061.htm

Global Gas Consumption (1965 projected to 2015)

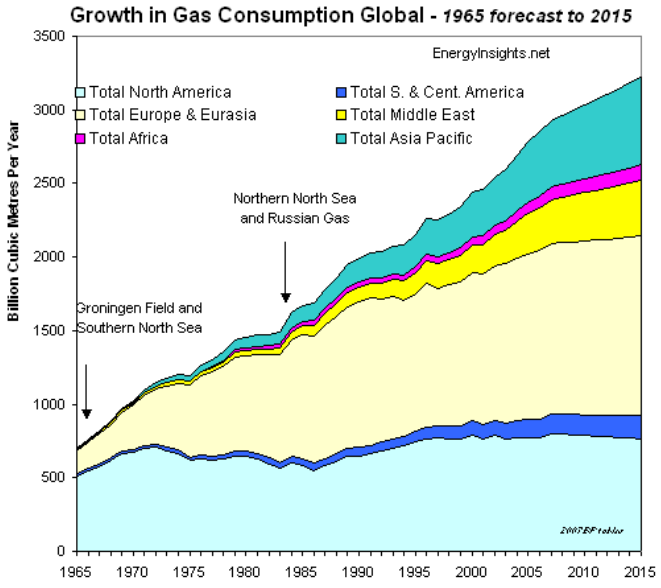

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Image available at http://www.energyinsights.net/cgi-script/csArticles/articles/000000/000017.htm

Efforts to reduce pollution from fossil fuels

SO_2 and NO_x

- Acid Rain Program
  - Scrubbers, electrostatic precipitator
  - Clean coal technology
- 3-way catalytic converters

Other pollutants

- Reformulated gasoline
  - Use of ***additives*** to boost the octane rating of gasoline --- increase burning efficiency

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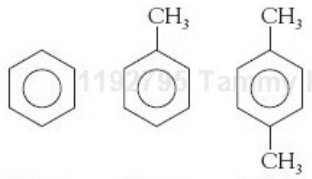
TABLE 7-1 Octane Numbers of Common Gasoline Additives

Compound	Octane Number
Benzene	106
Toluene	118
p-Xylene (1,4-dimethylbenzene)	116
Methanol	116
Ethanol	112
MTBE	116

BTX, or other organic substances such as MTBE (discussed later), which themselves have high octane numbers. A list of the common additives is shown in Table 7-1. Collectively, the **benzene** + *toluene* + *xylene* component in gasoline is called **BTX.**



benzene toluene *p*-xylene

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Efforts to reduce pollution …

CO_2 emissions?

- CO_2 will be produced as long as we continue burning fossil fuels

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CO_2 sequestration

- Process of depositing recovered CO_2 (from burning of fossil fuels) in an underground or ocean location
  - Goal is to prevent its release into the air

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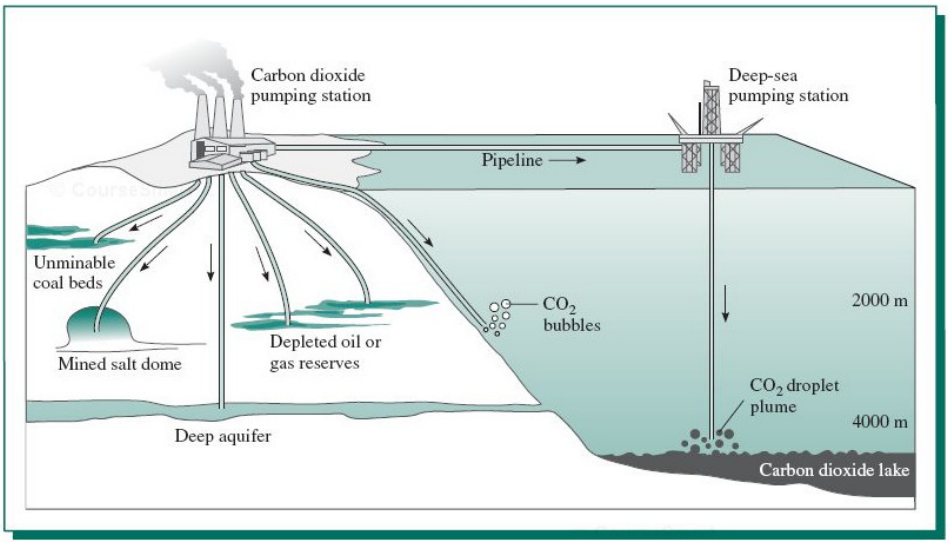
FIGURE 7- 9 Potential sequestration sites for carbon dioxide.
[Source: Redrawn from Scientific American (Feb. 2000): 72 79.]



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Carbon dioxide destined for ocean storage could be transported by a pipeline that extends to the depth required (Figure 7- 9).

(1) Shallow injection (200-400 m depth) in the ocean

- Works if the seafloor there is slanted sufficiently to allow the dense, CO_2-rich water to be transported by gravity to greater depths.
- Most of the gas would return to the surface and enter the atmosphere within a few decades if the CO_2- rich water was simply diluted by mixing with surrounding water, rather than sinking.

(2) Deep sea injection (3000-5000 m depth)

- Produces a pool of liquified CO_2 (due to high pressure and low temp.) which is denser than ocean water
- Could take centuries to dissolve in surrounding water
- Earthquakes could destabilize the pool, releasing massive amounts of CO_2

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CO_2 sequestration (Figure 7- 9) – Cont..

(3) Deep underground storage

(a) Pumping into **saline reservoirs,** large formations of porous rocks saturated with salty water (brine)

- Lie well below freshwater supply
- Caprock overlying the formation must be secure to prevent upward migration of CO_2

(b) Pumping into **depleted oil and gas reservoirs**

- These underground caverns are known to be stable
- Good for storing CO_2

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Removing CO_2 from the atmosphere

- Process of extracting CO_2 that is already dispersed into the atmosphere

(1) ***Iron fertilization*** proposal

- Involves adding iron to Fe-deficient oceans
- Fe induces plankton bloom
  - CO_2 is used by plankton during photosynthesis
- ***Potential problem***: When planktons die, their decomposition will use up dissolved O_2 and release methane and nitrous oxide (i.e. greenhouse gases)

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Removing CO_2 … Cont.

(2) ***Growing plants***

- Would absorb and temporarily sequester CO_2 during the growing process
- ***Potential problem***: Clearing of ground to plant trees also release CO_2 into the air > amount of CO_2 absorbed during growth

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Reducing CO_2 emissions by improving energy efficiency

(1) Use of low wattage fluorescent light bulbs

- Replacement for incandescent light bulbs
- Payback period is a few years

(2) Use of automobiles that burn gasoline more efficiently (higher mpg)

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