

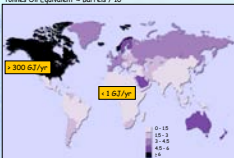
Energy: Fossil, Nuclear, Alternative

Units of Energy and Power

1 joule (J) = 1 amp per sec flowing through 1 ohm
1 watt (W) = 1 joule per second (J/s)
1 kilowatt-hour (kwh) = 1000 watts exerted for 1 hr
≈ running a blow-dryer for 1 hr
1 British thermal unit (Btu) = energy required to
heat 1 lb H₂O 1°F
1 std barrel (bbl) of oil = 42 gal = 5.8 M Btu
1 tonne of std coal = 27.8 M Btu = 4.8 bbl oil

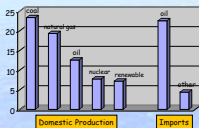
World per Capita Energy Use

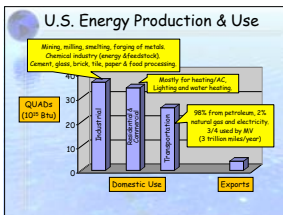
Tonnes Oil Equivalent = Barrels / 10



U.S. Energy Production & Use

QUADs
(10¹⁵ Btu)





U.S. Energy Production & Use

Let's do some math (see handout)

My laptop computer uses about 45 watts of power and my Dodge Durango gets about 12 mpg. If I trade in the Durango for a Toyota Prius that gets 50 mpg, how long could I run my laptop on the energy I saved for one year? I drive about 15,000 miles per year and 1 gallon of gasoline contains about 115,000 Btu. [1 kw = 3413 Btu]

Step 1: Calculate how much energy is needed to run my laptop continuously for a year.

45 watt \times (24 h/dy) \times (365 dy/yr) \times (1 kw/1000 watt) =
394.2 kw/yr

U.S. Energy Production & Use

Let's do some math (see handout)

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Step 2: Calculate how much gasoline would be saved if I traded in my Durango.

Durango: 15,000 mi/yr - 12 mpg = _____ gal/yr
 Prius: 15,000 mi/yr = 50 mpg = _____ gal/yr
 Savings: Durango - Prius = 950 gal/yr

U.S. Energy Production & Use

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Step 3: Computers don't run on gasoline so we need convert the energy savings to kwh/yr.

Convert to Btu/yr: gal/yr \times 115,000 Btu/gal = _____ Btu/yr

Convert to kwh/yr: Btu/yr \div 3413 Btu/kwh = _____ kwh/yr

U.S. Energy Production & Use

Let's do some math (see handout)

My laptop computer uses about 45 watts of power and my Dodge Durango gets about 12 mpg. If I trade in the Durango for a Toyota Prius that gets 50 mpg, how long could I run my laptop on the energy I saved for one year? I drive about 15,000 miles per year and 1 gallon of gasoline contains about 115,000 Btu. (1 kwh = 3413 Btu)

Step 4: Calculate how long the computer will run on the energy savings you've calculated.

Energy savings (kwh) = energy used by computer (kwh/yr) =
= 81 _____ year

Fossil Fuels

As we've already seen, most of the energy used in North America is supplied by fossil fuels: coal, oil and natural gas.

- » Fossil fuels are organic chemicals composed of the partially decayed remnants of organisms and in general were formed millions of years ago, during the Carboniferous period (286 M - 360 M ybp).
- » Fossil fuels are NONRENEWABLE resources, i.e. once they are used up, that's it. Fossil fuels continue to be formed today but at rates that are much too slow to replace what we are using.

Fossil Fuels - Formation

During the Carboniferous period, the climate was warm and mild and most plants grew year round. Vast swamps were filled with large leafy plants.

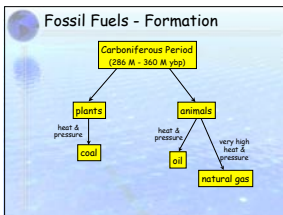
- » Plants in most environments decay rapidly after death due to the actions of aerobic bacteria and fungi
- » As ancient swamp plants died they fell into the swamps and were covered with water which slowed decomposition because of lack of oxygen
 - » Wood-rotting fungi can't function in absence of O_2
 - » Anaerobic bacteria don't decompose wood rapidly

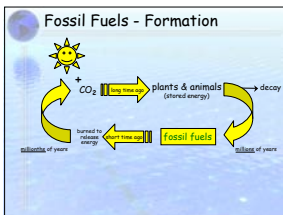
Fossil Fuels - Formation

- » Over time, more and more dead plants piled up.
- » Sea levels also changed periodically & layers of sediment accumulated, covering the dead plants
- » As huge amounts of time passed, the heat and pressure that accompanied burial converted any non-decomposed plant material into a carbon-rich rock called COAL.
- » OIL was formed similarly when large numbers of microscopic aquatic organisms died and settled in sediments
- » As they accumulated, their decomposition depleted oxygen in the sediments - this stopped further decomposition

Fossil Fuels - Formation

- » As time passed, the dead remains were covered and buried deeper in the sediments to form the mixture of HYDROCARBONS (i.e. compounds of C & H) we call oil
- » Natural gas which is mostly CH_4 (i.e. methane) formed in the same way as oil only at much higher temperatures and pressures





Fossil Fuels - Coal

Coal occurs in different grades largely as a result of varying amounts of heat and pressure that it was exposed to during its formation; older is better and buried deeper.

Type	C(%)
Peat	60
Lignite (brown coal)	70
Subbituminous	70-85
Bituminous (soft coal)	85-90
Anthracite (hard coal)	95

Fossil Fuels - Coal

Coal is usually found in underground seams i.e. layers that vary in thickness from about 1 cm - 100 m.

Because they are fairly easily located, geologists think that most if not all, coal deposits have probably been identified:

est. total world reserve = $\frac{100}{1}$ Tre*

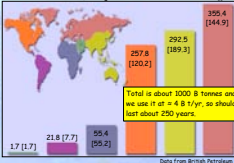
est. proven world reserve = $\frac{10}{2}$ Tre**

$\frac{2}{1}$ Tre***

* In Energy (Aubrecht), ** in your textbook, *** British Petroleum

World Proven Coal Reserves

Thousand Million Tonnes, ending 2002; anthracite & bituminous in []



U.S. Coal Reserves

Coal Areas of the Contiguous United States



Fossil Fuels - Coal Mining

Two general kinds of coal mining used - underground and surface.

Underground Mining

- » More than 100 ft from the surface
- » 40% of US production
- » Digs a hole in the ground and follow the coal
- » More deaths and injuries (100,000 deaths last century) - respiratory diseases e.g. black lung disease

Surface Mining

- » Within 100 ft of the surface
- » 60% of US production
- » Strip-mining dig a trench, take out coal, put soil and rocks from new trench in old trench
- » Safer for miners

Fossil Fuels - Coal Mining

Strip Mining in Wyoming



Fossil Fuels - Coal Mining

Strip Mining in Wyoming



Fossil Fuels - Impact of Coal Mining

1977 Surface Mining Control and Reclamation Act (SMCRA): Abandoned surface coal mines must be restored to original condition and no mining allowed in sensitive areas (e.g. national parks).



► **Acid Mine Drainage:** Rainwater seeps thru exposed iron sulfides and forms sulfuric acid which is carried into waterways.

► 1977-1997: \$15B spent, 2/3 of it in PA, KY, WV & WY

Fossil Fuels - Cleaner Coal?

The major pollutant in coal is SULFUR but heavy metals (e.g. mercury) are also input to the atmosphere when coal is burned.

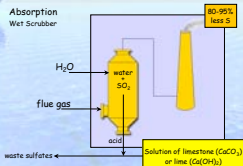
Type with shown Sulfur content	Sulfur Content (%)		
	Low (0-1)	Medium (1.1-3.0)	High (3+)
Lignite	90.7	9.3	-
Subbituminous	99.4	0.4	-
Bituminous	29.8	26.8	43.4
Anthracite	97.1	2.9	-

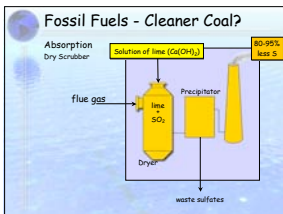
We can reduce sulfur emissions by three different techniques.

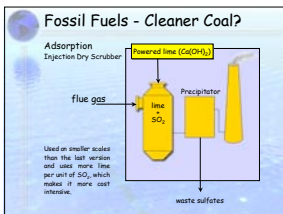
(1) alternative fuels (2) absorption (3) adsorption

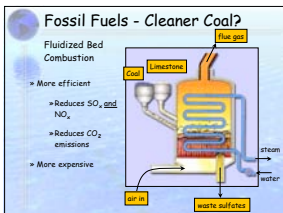
Fossil Fuels - Cleaner Coal?

Absorption
Wet Scrubber



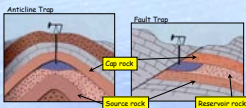






Fossil Fuels - Oil

Oil and natural gas are often found together though they don't have to be. They are usually found indirectly by the detection of structural traps.



Fossil Fuels - Oil

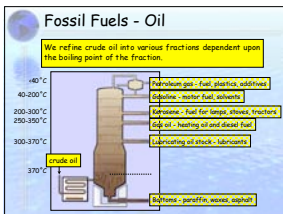
Primary and secondary (or enhanced) recovery used to obtain oil.

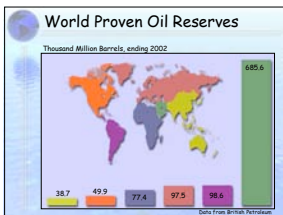
- » primary recovery - drill a hole in the ground and pump it out
 - » but for every 1 bbl pumped out, 3 are left in the ground (i.e. we recover about 25% of what's there)
- » secondary recovery - once a well is "dry" we can pump H_2O , CO_2 or air into the well to force out more oil - but process is expensive and may or may not be cost effective.

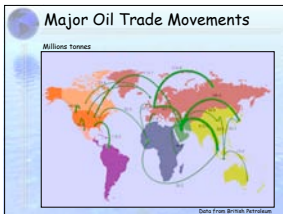
Fossil Fuels - Oil

The composition of oil varies greatly with geographic location because undoubtedly the populations of the microscopic aquatic organisms from which oil was formed varied

- » For example, Libya has "sweet" crude meaning it is extremely low in sulfur, while oil from elsewhere may contain more sulfur compounds.







Fossil Fuels - Oil

One of the main concerns about fossil fuel use is how long it will last - as we increase the population and standards of living around the world, more and more people will want to use fossil fuels.

- » Current global consumption of oil: 278 bbl annually with proven reserves of 10508 bbl - which means IF consumption stays the same oil runs out in about 40 years
- » Main importers of oil: the U.S., Japan & W Europe (excl. U.K. & Norway - they are exporters, see map on previous slide)
- » More than 1/2 of world demand for oil is by the developed nations and 1/2 of that is by the U.S. (2/3 of which is used by the transportation sector)

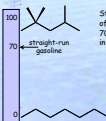
Fossil Fuels - Oil

Majority of the U.S. oil consumption (2/3) goes toward transportation in form of gasoline. Gasoline is composed mainly of hydrocarbons having anywhere from about 5 to 12 carbon atoms (fraction that boils between 40-200°C).

- » The different HCs in gasoline burn differently - some better than the others
- » As the quality of burning decreases - engine knocking increases
- » We rate the quality of a HC (i.e. its ability to burn in an engine) with an OCTANE number (ON)
- » In general, HCs with carbons connected in straight chains burn the worst while those with branched chains burn the best

Fossil Fuels - Oil

The straight-chain HC called heptane is arbitrarily assigned an Octane Number (ON) of 0 and the branched-chain HC called iso-octane is assigned an ON of 100



Straight-run gasoline (i.e. gasoline straight off the still) has an octane number of around 70 - compare this with the gasoline you put in your car which is ON 86

We can increase the octane number of the gasoline via several methods:

- cracking
- isomerization
- additives

Fossil Fuels - Oil

The straight-chain HC called heptane is arbitrarily assigned an Octane Number (ON) of 0 and the branched-chain HC called iso-octane is assigned an ON of 100

(a) Increase the ON via "Cracking"

Takes heavier compounds from higher boiling fractions and breaks or "cracks" them into smaller compounds in the gasoline fraction.

Usually uses a catalyst to speed up the process - developed by Mobil Oil and Union Carbide

Fossil Fuels - Oil

The straight-chain HC called heptane is arbitrarily assigned an Octane Number (ON) of 0 and the branched-chain HC called iso-octane is assigned an ON of 100

(b) Increase the ON via "Isomerization"

Also called "reforming" - takes straight-chain HCs and rearranges them to make highly branched and thus higher ON compounds.

Uses expensive precious metal catalysts - platinum (Pt), palladium (Pd), rhodium (Rh) and iridium (Ir)

Fossil Fuels - Oil

The straight-chain HC called heptane is arbitrarily assigned an Octane Number (ON) of 0 and the branched-chain HC called iso-octane is assigned an ON of 100

(c) Increase the ON via Additives

Gasoline is "reformulated" - the mixture of compounds present is changed.

Used to use Tetraethyllead - phased out starting 1974 (can possibly use manganese as alternative)

Use benzene (ON 106) and toluene (ON 124)

Use methanol (ON 107), ethanol (ON 108), MTBE (ON 116)

Fossil Fuels - Oil

Alternative Sources of Oil

Tar sands - sedimentary rocks or sand deposits impregnated with tar, asphalt or bitumen... oil is too thick to be pumped out

- Mined like coal, oil washed out of sand with hot water and then refined like oil... process takes enormous amounts of energy
- Estimated to contain 2-3 times the world's oil reserve
- Major deposits in Venezuela and Alberta, Canada - Canadian deposits (75% of total) estimated to be 2000 B bbl Currently producing 500,000 bbl/dy

Fossil Fuels - Oil

Alternative Sources of Oil

Oil shales - fine-grained sedimentary rocks that contain an oil-like substance (kerogen)

- Mined like coal, then crushed and heated to 500°C, yields about 14 gallons of oil per ton of shale
- Estimated to contain 3 times the world's oil reserve
- Major deposits in Australia, Estonia, Brazil, Sweden, China and the U.S. - U.S. deposits (67% of total) estimated to be 2000 B bbl (90% of which is in Colorado, Utah and Wyoming)
- Currently NOT cost competitive

Fossil Fuels - Natural Gas

Natural Gas Deposits

What is natural gas?

- Crude Natural Gas is composed mostly of METHANE (CH_4) gas with smaller amounts of ethane, propane and butane as well as some water, Helium and Argon
- Water and inert gases (He, Ar, etc) are removed first and then the propane and butane are removed and is then compressed to a liquid and sold as LNG (i.e. liquefied natural gas)

Fossil Fuels - Natural Gas

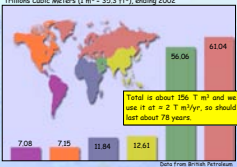
Natural Gas Deposits

Where is natural gas found?

- » Recall that we said oil and natural gas are often found together - this does not have to be the case
- » Russia (6% of world's oil reserve) has 33% of the world's natural gas reserve and Iran has about 15% of the world's natural gas reserve (see maps)
- » Large amounts of natural gas are released from coal beds - estimated that the states of Colorado, Wyoming and Montana could have 10% of the world's total methane - Powder River Basin in Wyoming has about 1 T m^3

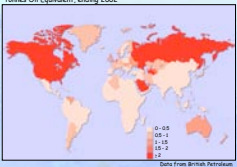
World Proven Natural Gas Reserves

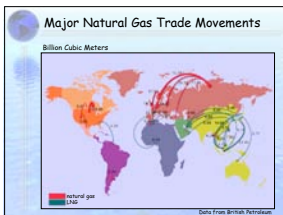
Trillions Cubic Meters ($1 \text{ m}^3 = 35.3 \text{ ft}^3$), ending 2002



World per Capita Natural Gas Use

Tonnes Oil Equivalent, ending 2002





Fossil Fuels - Natural Gas

Natural Gas Deposits

- » Advantages of natural gas as compared to oil or coal are:
 - » Burns relatively cleanly - produces almost no soot and no SO₂ emissions
 - » Produces less CO₂ per unit of energy
- » Disadvantage
 - » Generally farther from areas that could use it, so it needs to be transported longer distances and costs about 4x as much as oil to transport

Fossil Fuels - Pollution

1989 Alaskan Oil Spill - 260,000 bbl

- » 1000s km² of water covered
- » 1000s of animals died
- » Cost to Exxon could total \$10 Billion
- » Oil Pollution Act of 1990 = set liability for damages & required double hulls by 2015

Fossil Fuels - Pollution

Arctic National Wildlife Refuge (ANWR)

- Established 1960
- Expanded to 18 M acres in 1980
- 1987 - 3% chance of finding oil
- Pressure to explore has swung back and forth - Bush administration is currently leaning toward exploration



Fossil Fuels - Pollution

Arctic National Wildlife Refuge (ANWR)

- Supporters argue that there is little evidence of environmental disruption
- Opponents say oil exploration will cause permanent damage
- Supporters claim that caribou populations have increased thus countering claims of damage
- Opponents cite a USFWS study that found there are fewer wolves and bears - the top predators are most affected by habitat disruption and therefore caribou have increased in numbers because of a lack of predators
- Opponents and supporters agree that it is not financially practical to restore developed areas in the Arctic to their natural states - permanent changes to the environment

Fossil Fuels - Pollution

1991 Persian Gulf Oil Spill - 6,000,000 bbl

- Many oil wells set on fire
- Lakes of oil spilled into the desert around the burning wells
- Estimated to take 100+ years for the environment to recover
- It appears though that the Persian Gulf has acclimated over the years to having oil present and is recovering faster than initially thought