Anthropogenic Changes: Resources

Energy Resources

The most widely used energy resources are fossil fuels (oil, gas, coal), nuclear power (nuclear fission) and moving water. The first two are nonrenewable energy resources, while moving water, wind and Earth's internal heat are renewable energy resource.

- Fossil fuels: oil and coal are made of organisms that lived a long time ago. Burning fossil fuels has the same effects as burning plants.
- non-renewable resources: resources that take long to be replaced relative to the human life span
- download key world energy statistics published by the International Energy Agency
- petroleum is raw material for many chemical products, including solvents, fertilizers, pesticides and plastics
- 84% (37 out of 42 gallons in a typical barrel) of petroleum is processed as fuel, incl. gasoline, diesel and kerosene
- at the current rate of consumption, oil reserves will be depleted within a few decades

Table 1: Consumption of Energy in the U.S., 1997

Energy Resource	Fraction 1997	Fraction 2002
Petroleum	41%	41%
Natural Gas	24%	22%
Coal	22%	24%
Nuclear	7%	9%
Hydroelectric	5%	3%
others	1%	1%

- OIL AND NATURAL GAS
  - industrialized societies today rely primarily on oil and natural gas for their energy needs
  - Oil and gas are hydrocarbons, ring or chainlike molecules of C and H, and are organic chemicals
  - Hydrocarbons have varying viscosity and the volatility depends on the molecule size

- form primarily from dead algae and plankton
- require a long (geologic times) process to form, involving burial and increase in T and P
- oil window: oil and natural gas exist only under certain T and P conditions. At T¿160oC, any remaining oil breaks down to form gas and at T¿250o the remaining organic matter transforms into graphite. Under normal conditions, oil exists at depths only down to 6.5km.
- oil reserves: oil can be found in sedimentary deposits. Large oil fields can be found in the Canadian Arctic Ocean, Gulf of Mexico, North Sea, Kara Sea/Northern Russia and the Persian Gulf (largest oil fields)
- Huge natural gas reserves can be found in Siberia (1/3 of the world's reserves)
- Two oil reserves that are very important U.S. domestic resources are the Gulf of Mexico and off-shore Alaska. The latter currently provides up to 20% of U.S. domestic oil and there are plans to expand oil production into the Arctic National Wildlife Refuge (see more).
- With 7 Mio barrels per day (1 barrel = 42 Gallons), the U.S. is the largest consumer worldwide, using about 25% of the produced oil (and contributing 25% of the world's CO2 production)
- In the 1970ies, when the U.S. oil production passed its peak (Hubbert's Peak, the U.S. lost its position as largest producer
- U.S. oil reserves now account for only 4% of the world's reserves
- the U.S. must now import more than 50% of its used oil.
- The world consumption now exceeds the rate of discovery of oil (by factor 3)
- at the current rate of consumption, know oil resources will be depleted within a few decades
- predictions place Hubbert's Peak of world oil production around 2005
- natural gas is more abundant than oil
- Gas burns more cleanly than oil. Burning gas produces only CO2 (the least amount of C of all fossil fuels) and water, while burning oil produces more complex organic pollutants.
- Gas transportation requires expensive high-pressure pipelines and containers making gas less attractive as energy source than oil

- COAL
  - Coal forms from plant material (wood, stems, leaves) in swamps and adjacent forests

- Most coal was formed in the late Carboniferous and Permian Periods (320-245 Mio years ago) when the continents were locked together to form Pangaea
- Coal is the most polluting fossil fuel but reserves will last 3 times as long as the oil reserves (300 years).
- The U.S. burn 1 Billion tons of coal per year, mostly at electrical power plants that generate 23% of U.S. electricity.
- classification of coal:
  * Peat: 50% Carbon (C); not yet coal
  * Lignite: from peat (soft dark-brown coal) (70% carbon)
  * Bituminous Coal: from lignite at higher T (100-200oC) (85% C)
  * Anthracite Coal: from bituminous coal at even higher T (200-300oC); formed at 8-10 km depth (95% C); burns most efficiently and clean
  * Graphite: at even higher T and P
- anthracite coalis the rarest type of coal. In the US, it is found at two places in Pennsylvania and Arizona
- More than half of the world's coal can be found in the United States and Former Soviet Union.

Table 2: The Global Distribution of Coal Reserves

Country	Fraction
United States	28%
Former Soviet Union	26%
China	11%
Western Europe	10%
Australia	10%
Eastern Europe	6%
other	9%

Summary on Fossil Fuels and Consumption

- global energy demand doubled in last 30 years
- hydrocarbons now account for ¿ 50% world's energy production
- fossil fuels account for nearly 80%
- fossil fuels are non-renewable
- U.S. oil production peaked in 1970ies

- U.S. has to import 50% of its oil
- peak in global oil production by 2005
- oil consumption now exeeds rate of discovery by factor 3
- oil reserves exhausted within 50 years
- gas reserves probably within 100 years
- coal reserves probably within 300 years
- burning fossil fuels pollutes the environment
- burning fossil fuels accelerates the greenhouse effects
- burning coal causes acid rain

Air Pollution due to the Burning of Fossil Fuels

Table 3: Primary Pollutants from Burning Fossil Fuels

Pollutant	Fraction
Carbon Monoxide	49.1%
Sulfur Oxides	16.4%
Nitrogen Oxides	14.8%
Volatile Organics	13.6%
Particulates	6.0%

NB: the greenhouse gas CO2 is not considered a pollutant and is therefore not included in this table! CO2 in the atmosphere has increased from 290 ppm in 1850 to 370 ppm in 2000.

Table 4: Sources of the Primary Pollutants

Process	Fraction
Transportation	46.2%
Stationary Source Fuel Combustion	27.3%
Industrial Processes	15.0%
Miscellaneous	9.0%
Solid Waste Disposal	2.5%

The pollution per car was even greater before catalytic converters were introduced in the 1970ies (see more).

Nuclear Power

- Nuclear power is considered an immense energy source because a tiny amount of matter transforms into a great amount of thermal energy
- nuclear power is considered as an alternative energy source to fossil fuels because it does not produce green house gases
- at current estimates nuclear fuel reserves will last about three times as long as oil reserves (about 300 years)
- Uranium is the only naturally occuring element that undergoes fission and is the last of the 92 naturally occuring elements. Uranium occurs naturally in granitic plutons
- Most of the naturally occuring Uranium is the relatively stable isotope 238U (half life: 4.5 Billion years), while the unstable 235U used in nuclear reactors accounts for only 0.7%
- Uranium enrichment for fuel rods requires energy
- by-products of uranium production, use and reprossing produces Cesium (Cs) and Strontium (Sr) that can be absorbed by human tissue and do damage. Another by-product is Plutonium (Pu), which is weapons material and the most toxic element on earth. Pu also has a long-half life (24,000 years), i.e. stays around for a long time.
- a nuclear bomb requires only a few km of weapons-grade material. The world currently stockpiles more than 1000 tons.
- the three main disadvantages in nuclear power
  - long half life of nuclear waste requires politically and geologically safe storage
  - accidents contaminate the environment for a long time (e.g. after the 1986 explosion in Chernobyl, the area around the reactor is still uninhabitable)
  - civil security is at risk by terrorist attacks

The Special Role of Traffic

- transportation takes up 1/3 of the world's energy consumption
- transportation is responsible for almost half of the pollution produced
- finding alternatives current transportation is therefore essential!
- public transportation effective alternative in densely populated areas

- cars need to be made more fuel efficient (technology exists since the 1980s!)
- finding alternatives is crucial. Hybrid-automobiles and biodiesel are only temporary alternatives as hybrid cars still use fossil fuels and biodiesels contribute to greenhouse effect

Metallic Resources

- Metallic resources come in native form and as ore.
- Native metals are easy to mine because they occur in pure form (e.g. gold nuggets, copper lumps). Examples for native metals: gold, copper, silver
- In ores the metals occur in metallic compounds such as oxides. The extraction of the metals require elaborate techniques that use high temperature smelting (e.g. iron ore) or toxic chemicals (e.g. need mercury for some gold compounds) to extract the metal from the compound.
- Many metals are not found in native form, e.g. iron.
  - some metals are not found in native form, e.g. iron
  - a rock qualifies as an ore, if:
    * the metal content is high
    * and the process to extract this metal is cost-effective
  - dependent on the market value we distinguish between base and precious metals: base metals: e.g. copper, iron, lead, zinc, tin
  - precious metals: e.g. gold, silver, platinum
  - of the 63 metals in use today, only 9 were known before 1700 (Gold, Silver, Copper, Mercury, Lead, Tin, Antimon, Iron, Arsenic), typically the metals found in native form
- WHERE DO METALLIC RESOURCES FORM?
  - magmatic deposits: bottom of a magma chamber
  - hydrothermal deposits: circulation of hot-water solutions
    * disseminated deposit: deposit throughout an intrusion
    * vein deposit: deposit in a preexisting crack
    * copper porphyry deposit: copper in a two-stage melted igneous rock
    * black smoker: precipitated nearly pure metal sulfides around black smokers
  - secondary-enrichment deposits: transport and re-deposition of ore minerals, typically at higher concentrations
  - sedimentary deposits: for example

    * banded-iron formation (BIF) in deep ocean, when environment suddenly became oxygen-rich
    * manganese nodules (manganese-oxide, typically about 10 cm diameter) on the ocean floor. Rich in manganese and copper (20% Mn + Fe, Cu, Ni). Technology to mine vast deposits underway (e.g. copper supply would last 720 years).
  - residual mineral deposits:tropical environments, iron and aluminum-rich soil residuum in the soil as consequence of severe leaching (E.g. bauxite is a aluminum-bearing residual from extreme leaching of granite).
  - placer deposits: native metals eroded from original deposit and settled as flakes in rivers (recovery similar to what happens during panning).

- EXPLORATION AND PRODUCTION

  in the past, prospectors looked for "shows" of ore (exposures of ore minerals at the surface). They looked out for quartz veins or stained rock (green or red by oxidizing metal-containing minerals).

  Today's geologists look at tectonic settings and measure the magnetic and gravity fields to find ore bodies (they are typically denser and more magnetic than ordinary rock).

  - open-pit mines: explosions separate blocks from bedrock; waste rock is separated from ore and brought to a "tailings pile". The ore is crushed, ore minerals extracted and smelted or treated with acidic solutions to separate the metal. The metal is then melted and poured into molds to make ingots (brick-shaped blocks).
  - underground mines: drive vertical shafts and horizontal adits into the ore-bearing rock. The deepest mine currently reaches 3.5 km where the temperature exceeds 55oC.

Non-Metallic Mineral Resources

E.g. building stone, gravel, sand, gypsum, phosphate (for fertilizer), salt.

- dimension stone: intact slabs and blocks of rock (e.g. granite or marble) cut out in a quarry (a quarry provides stone, a mine provides ore).

- crushed stone: for concrete, cement and asphalt. cement forms by precipitation of minerals out of slurry of water, lime (CaO) (66%), silica (SiO2) (25%), alumimun oxide (Al2O3) and iron oxide (Fe2O3). CaO comes from the calcite in limestone that is roasted in a furnace at high temperature. The other elements come from shale and sandstone. Concrete is a mixture of cement with sand and gravel. Bricks are made from dried and bakes clay (this process is a metamorphic process that recrystallize the clay and make it relatively impermeable). Glass comes from the melting of quartz and quartz sand. Drywall is made from a slurry of water and gypsum (CaSO4.H2O); asbestos is made from serpentine; plastics from oil; fertilizers such as phophate (PO43-) and potash (K2CO3) come from evaporites.

Global Mineral Needs and Reserves

- Mineral resources are non-renewable resources (i.e. the lifetime is limited). Combined with energy resources, the U.S. mine, quarry and pump 18 billion tons/year. For comparison, the Mississippi transports 190 million tons of sediments into the Gulf of Mexico.
- How Much Do We Need? In "Physical Geology", Carlson et al., refer to the Mineral Information Intitute to estimate per capita/year needs in the U.S.:
  - 18,000 kg total are mined, not including energy resources
  - 4,400 kg stone
  - 3,500 kg sand and gravel
  - 325 kg limestone for cement
  - 160 kg clays
  - 165 kg salt
  - 760 kg other nonmetals
  - 545 kg iron
  - 19 kg aluminum
  - 9 kg copper
  - 5 kg lead
  - 5 kg zinc
  - 3 kg manganese
  - 11 kg other metals
  - for comparison, some numbers for energy resources6: 3050 kg petroleum
  - 2650 kg coal
  - 1900 kg natural gas

The Dependence on Importing Minerals

- 99% of gemstones are imported (e.g. from Israel, Belgium and India)

- Strategic metals: metals that are alloyed with iron to make special-purpose steels needed in the aerospace industry; many need to be imported6: e.g. manganese (100%), cobalt (95%), chromium (73%) and platinum (92%).
- many other raw materials are 100% imported

Table 5: Metals used in the U.S. and Where They Come From

metal	Metal's Origin
arsenic trioxide	China, Chile, Mexico
bauxite and alumina	Australia, Jamaica, Brazil
bismuth	Belgium, Mexico, China
strontium	Mexico, Germany
thallium	Mexico, Belgium, Germany
thorium	UK, France

Table 6: Lifetime (in years) of Currently Known Ore Resources

metal	World Resources	U.S. Resources
Iron	120	40
Aluminum	330	2
Copper	65	40
Lead	20	40
Zinc	30	25
Gold	30	20
Platinum	45	1
Nickel	75	¡1
Cobalt	50	¡1
Manganese	70	0
Chromium	75	0

THE BOTTOM LINE: mineral resources are non-renewable and many global resources will last a few more decades. The U.S. has to import large fractions of the metals used.

Recycling

Estimates in the 1960ies and 1970ies predicted a shortfall of available minerals. But mineral consumption has slowed in the meantime and current estimates predict that resources will last about 100 years. The rate of mineral consumption has slowed especially in industrialized nations due to a shift of economics from construction and manufacturing to service and technology. The demand for raw minerals has decreased because of recycling and substitution by low-cost ceramics, composites and plastics.

Table 7: Fraction of Recycled Metals

Metal	Fraction
Au (Gold)	45%
Pt (Platinum)	45%
Al (Aluminum)	45%
Pb (Lead)	73%
Cu (Copper)	60%
Fe (Iron), Steel	56%

Issues that determine whether a mineral is to be recycled or not: costs, environmental impact, availability.

Mining and the Environment

- open-pit mining leaves landscape scars
- mining leaves waste rock in tailings piles (artificial hills)
- acid mine runoff (sulfides released in ore-mining)
- smelting in ore-processing creates acidic air and rain

Plastic[2]

- plastics are durable, lightweight, and can be made into virtually anything
- plastics are not biodigradeable
- only 3.5% of plastics are recycled in any way
- in the U.S., 63 pounds of plastic packaging goes into landfills per person per year
- broken, degraded plastic pieces outweigh surface zooplankton in the Central North Pacific by 6 to 1

  SOME PLASTIC MILESTONES

  - 1869: John Wesley Hyatt invents celluloid, the first plastic product given a trade name
  - 1909: Bakelite introduced as the "first thermoset plastic" (once set it is set for life)

- 1939:Nylon stockings debut at the World's Fair
- 1946: Earl S. Tupper produced a 7-ounce polyethylene tumbler, the first Tupperware product
- 1955: the Corvette is the first car to use plastic for body panels
- 1957: the Hula Hoop creates a surge in demand for polyehtylene
- 1983: microwave ovens open up a new market for plastic packaging
- 2000: in the U.S., pre-production plastics reaches 100 billion pounds of virgin resin pellets per year

Recommended Reading

- "Coal" by Barbara Freese, 2004, Penguin Books, ISBN: 01-42000981:a good book on coal, its history and how it changed mankind

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