Course CME 310
Solar Power For Africa

www.south-africa-tours-and-travel.com

ENERGY RESOURCES, ENERGY PRODUCTION AND ENERGY DISTRIBUTION

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ENERGY CONSUMPTION: TO GET THE IDEA

energy consumption of a nation is proportional to its Gross National Product (GNP) (the higher the GNP of a nation, the higher its consumption)

in a technological society, the average individual uses 230,000 calories per day

minimun energy needed by an individual is 2000 calories per day

average consumption

calories per day	purpose
10,000	preparing food
66,000	home and commerce
91,000	industry and agriculture
63,000	transportation

Source: EARTH SCIENCE AUSTRAILIA http://earthsci.org/education/education.html

WHERE DO WE GET THIS HUGE AMOUNT OF ENERGY FROM?

ENERGY AND ENERGY UNITS

what is energy? **ENERGY IS THE ABILITY TO DO WORK**
energy causes things to happen → e.g. the sun delivers light and heat, a moving car is powered by gasoline, a pencil falling of the table due to gravity

what is electricity? electricity is a general term to describe all phenomena related to stationary and moving electric charges !!!

what is power? **power is the rate of generating, using or transferring energy**

what is electric power? **electric power is the transfer of energy by the movement of electric charges** (in very simple terms)

energy units

1 Joule (J) = force of one Newton acting through one meter

1 calorie (cal) = 4.184 J (the Calories in food ratings are actually kilocalories.)

(electric) power unit

1 Watt (W) = a Joule of energy per second

WHERE WE GET ELECTRICITY FROM?

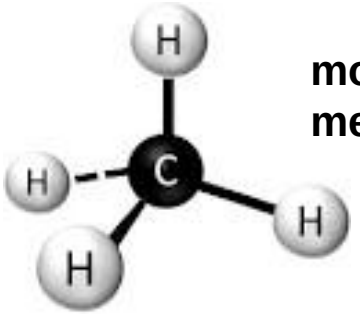
transforming the energy stored in our energy resources to generate electric power

- hydroelectric power
- nuclear power
- wind power
- solar power
- tidal power
- fossil fuel
- wave power
- biofuels
- geothermal power

FOSSIL FUELS

COAL

OIL (CRUDE OIL)



mostly methane

GAS (NATURAL GAS)

coal, **oil** and **gas** are called "fossil fuels" because they have been formed from the organic remains of prehistoric plants and animals

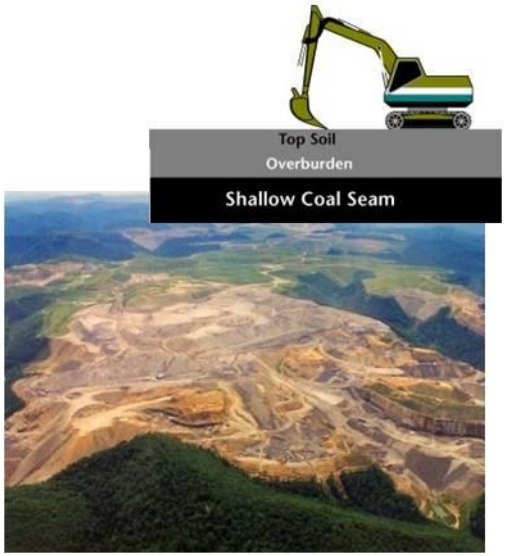
ENERGY IS STORED IN FORM OF CHEMICAL ENERGY

to release the stored energy you have to  it

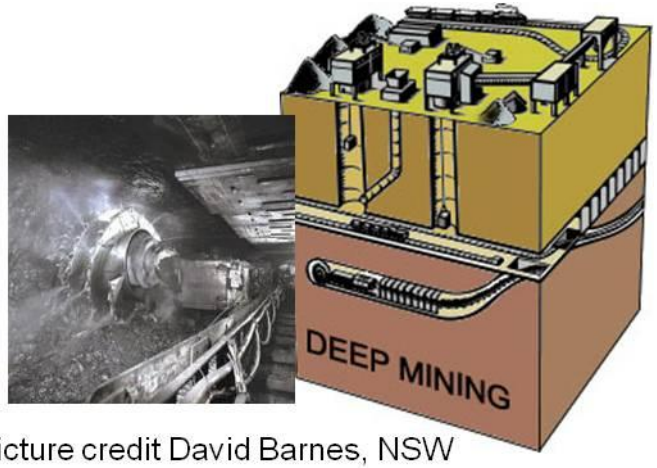
FOSSIL FUELS: COAL

use of coal: producing heat for production of e.g. electricity and steel. Separated ingredients of coal (methanol and ethylene) are used in making plastics, tar, synthetic fibers, fertilizers, and medicines

surface mining



underground mining



picture credit David Barnes, NSW Department of Mineral Resources

transportation

Source: Stock photography (copyrighted)

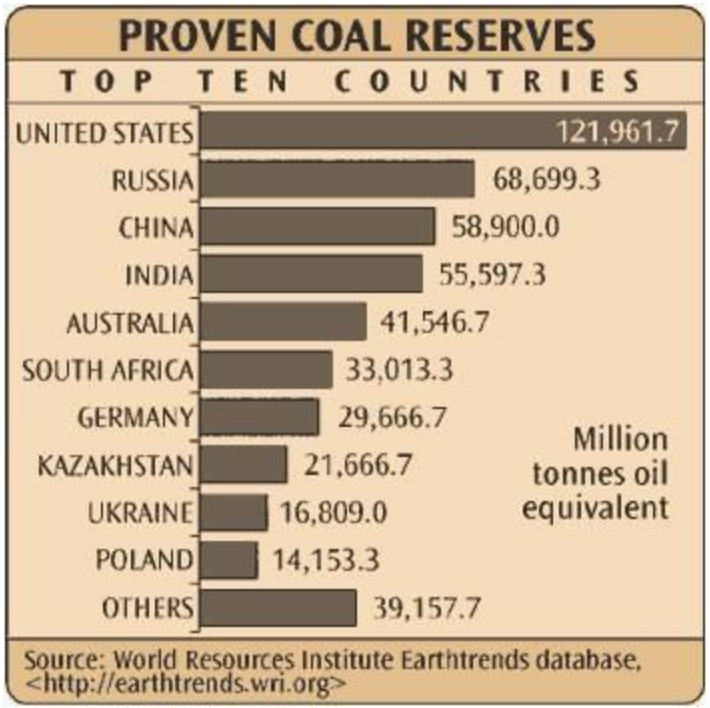
shipping coal can cost more than the cost of mining it

processing of coal

after coal comes out of the ground, in a preparation plant other rocks and dirt, ash, sulfur, and unwanted materials are removed

Source: National Energy Education Development Project

FOSSIL FUELS: COAL



Coal in electricity generation

South Africa 93%	**Poland 92%**	**PR China 79%**
Australia 77%	**Kazakhstan 70%**	**India 69%**
Israel 63%	**Czech Rep 60%**	**Morocco 55%**
Greece 52%	**USA 49%**	**Germany 46%**

Source: IEA 2010

FOSSIL FUELS: OIL ("petroleum")

<u>products</u>: range from fuels, to tar and asphalt for roads, to plastic goods
only a small amount is used for electric power generation

off-shore drilling

land drilling

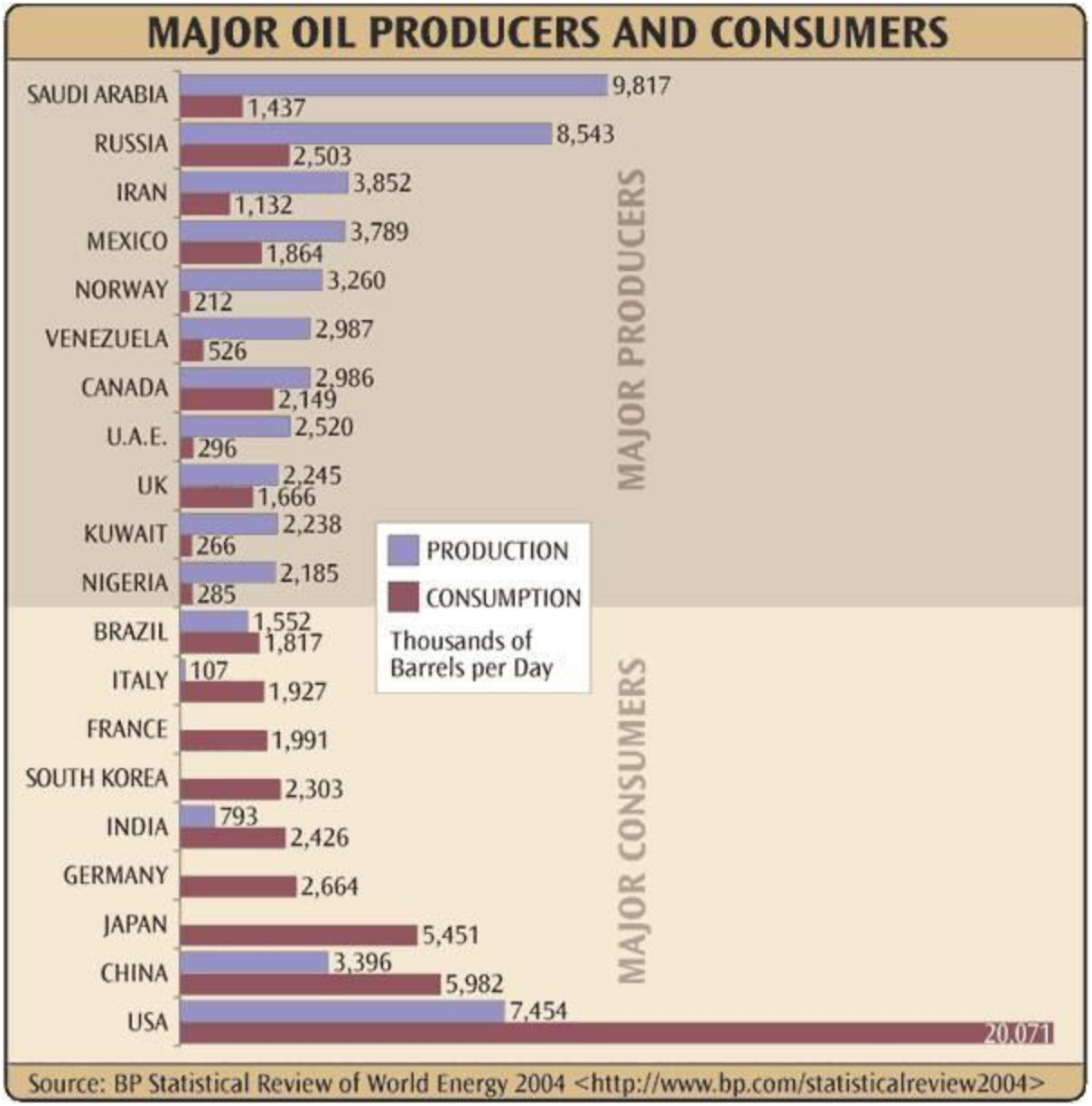
http://crudeoilspotprices.com

crude oil has to be processed to be used !!!

- **it is heated and the vapors are sorted with a distillation column**
- **depending on the temperature in the distillation process different products are extracted**

for electrical power production

FOSSIL FUELS: OIL



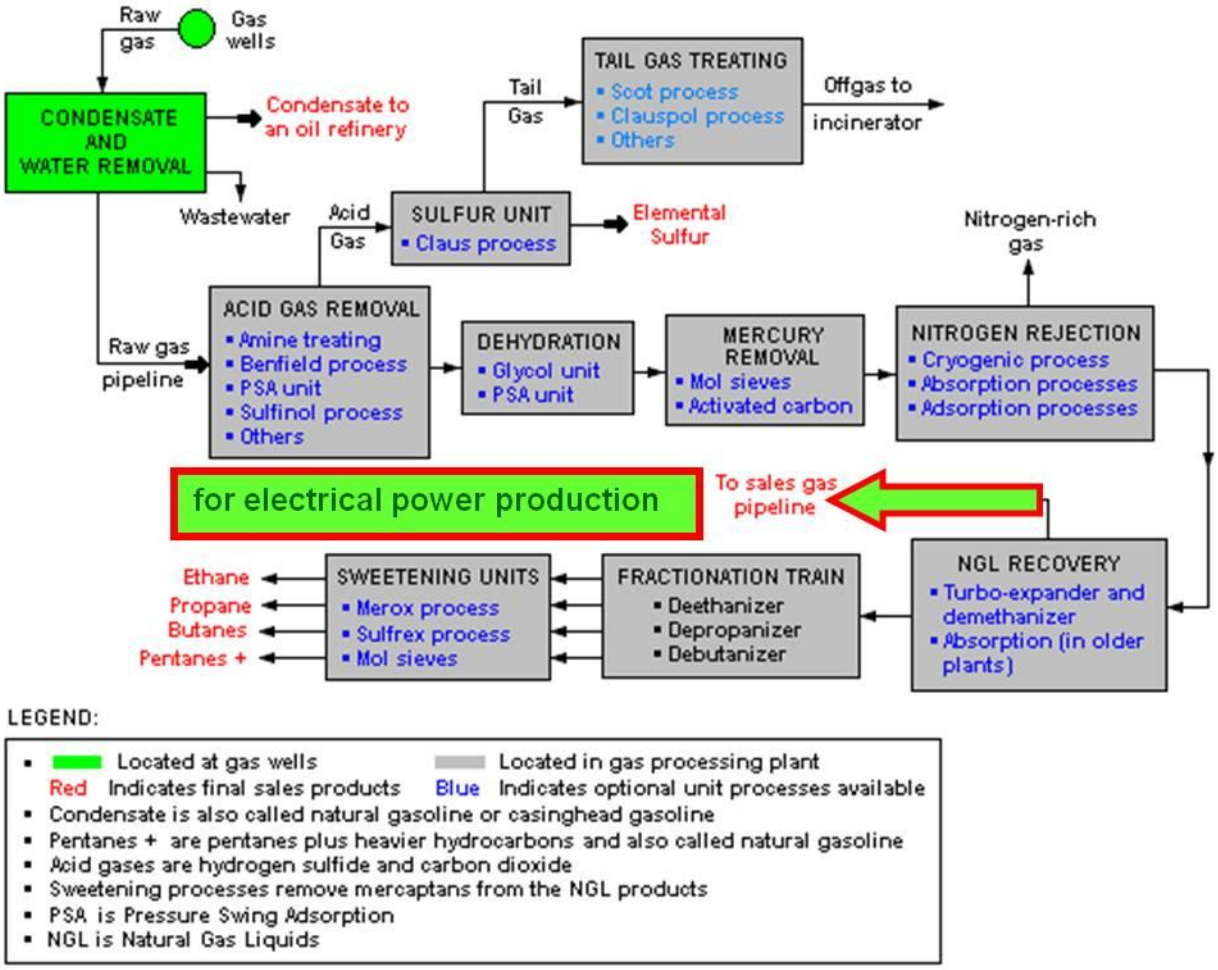
FOSSIL FUELS: GAS

use of coal: burned in power stations to produce heat and electricity, also used by people to heat their homes

natural gas has to be cleaned before it can be used **!!!**

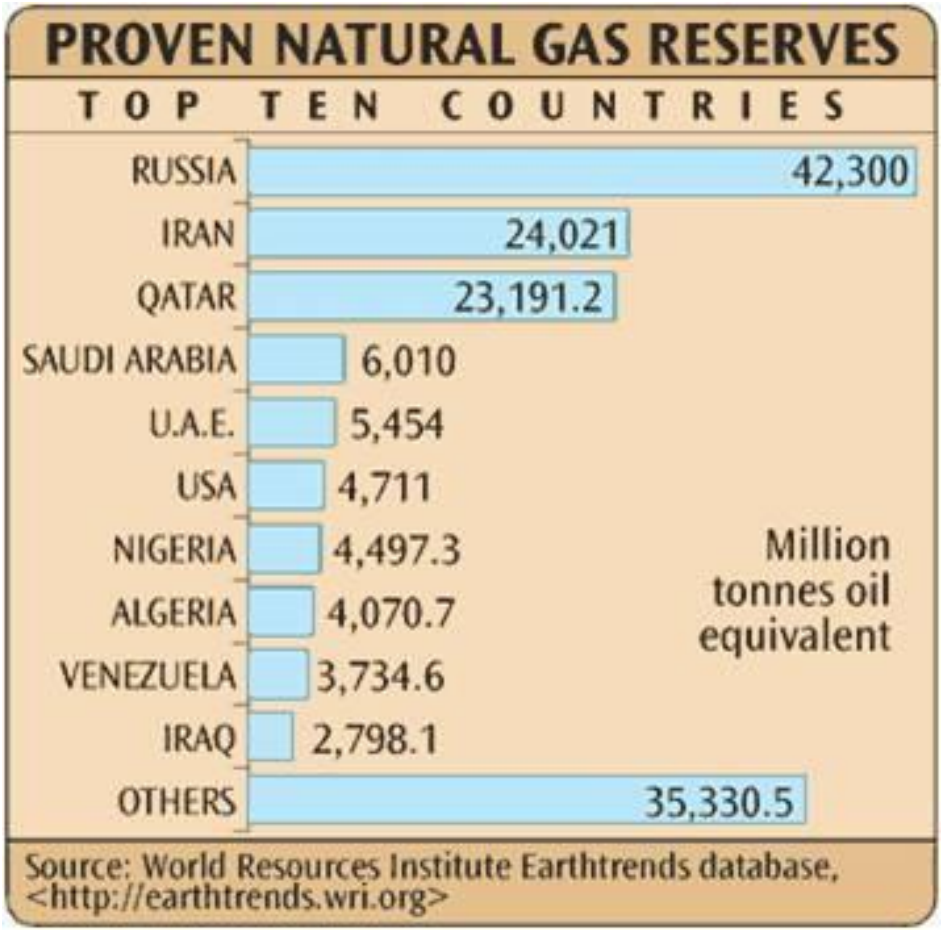
a natural gas processing plant

Source: Duke Energy Gas Transmission Canada



FOSSIL FUELS: GAS

natural gas provides around 20% of the world's consumption of energy



FOSSIL FUELS: ELECTRIC POWER GENERATION

principles of a <u>steam power plant</u>

- **oil and gas can be burnt directly**
- **coal is crushed to a fine dust and burnt**

source: world coal association

steam turbine

firing coal or gas or nuclear power

steam turbine generator

Burn Fuel → **Heat water to make steam** → **Steam turns turbines** → **Turbines turn generators** → **Electrical power**

chemical ⇒ heat ⇒ mechanical ⇒ electrical energy !!!

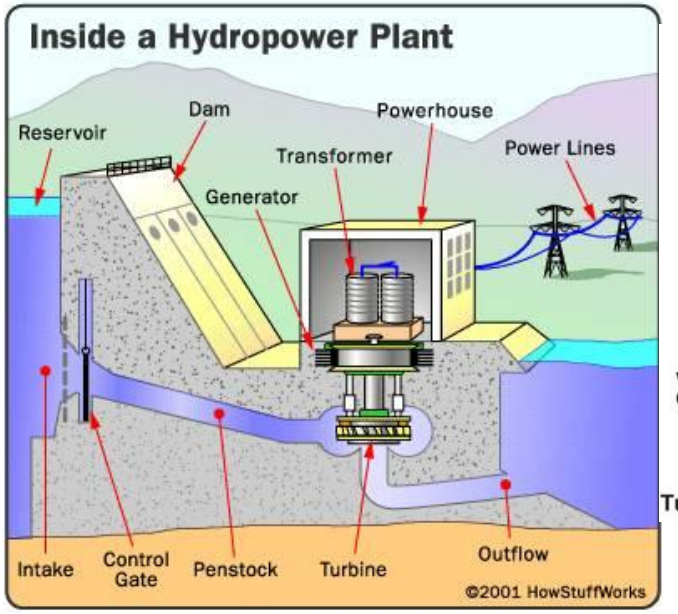
FOSSIL FUELS – PRO AND CONS

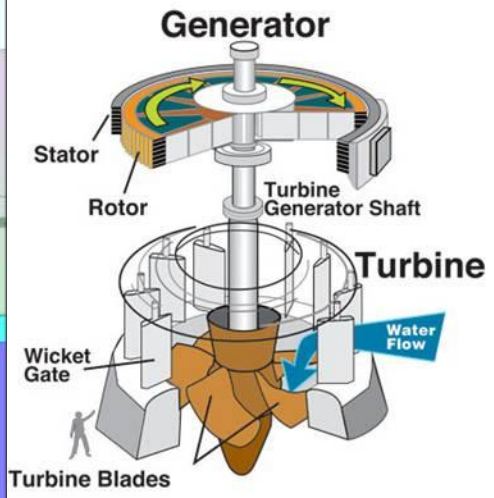
ADVANTAGES	DISADVANTAGES
fossil fuels are relatively cheap	fossil fuels will become more and more expensive to extract and will be scarce
advanced technologies have been developed to allow efficient extraction	extracting fuel will become more dangerous as the mines get deeper or the oil-rigs go further out to sea
the technology already exists for their use e.g. petrol-driven engines	pollution from these fuels is said to be responsible for global warming, acid rain, and oil spillage
the means of controlling pollution from these fuels exists	it is very expensive to control the pollution and the price of fuel would have to rise
the income from the sale of the fuels can help a country's economy	NOT RENEWABLE ENERGY
at present, no other energy source can fully replace fossil fuels	

HYDROELECTRIC POWER

principle: a dam is built to trap water, usually in a valley where there is an existing lake,
the gravitational energy of the water is used to turn the turbine directly

Courtesy of City of Tallahassee, Florida, Copyright 2001





gravitational ⇒ mechanical ⇒ electrical energy

gravitational energy is stored in the water in the dam

high pressure of water at turbine → large amount of mechanical energy
↓
large amount electrical energy

note: in mountainous countries such as Switzerland and New Zealand, hydroelectric power provides more than half of the country's energy needs

HYDROELECTRIC POWER – PRO AND CONS

ADVANTAGES	DISADVANTAGES
Cheap energy even if high construction costs are taken into account	flooding of large area can change the microclimate
RENEWABLE ENERGY	dams can disrupt natural seasonal changes in the river, and ecosystems can be destroyed
constant water due to regulation of the dam's water flow	production of green house gases due to plant decay in the dam (after flooding)
control of flooding & recreational activities can be provided	
turbines can be shut down and turned on instantly (where thermal plants take hours, and nuclear plants can take days) → peaking power easily provided	
very few breakdowns	

BIOFUELS

biofuels are fuels made from recently living organisms. They can be divided into three categories:

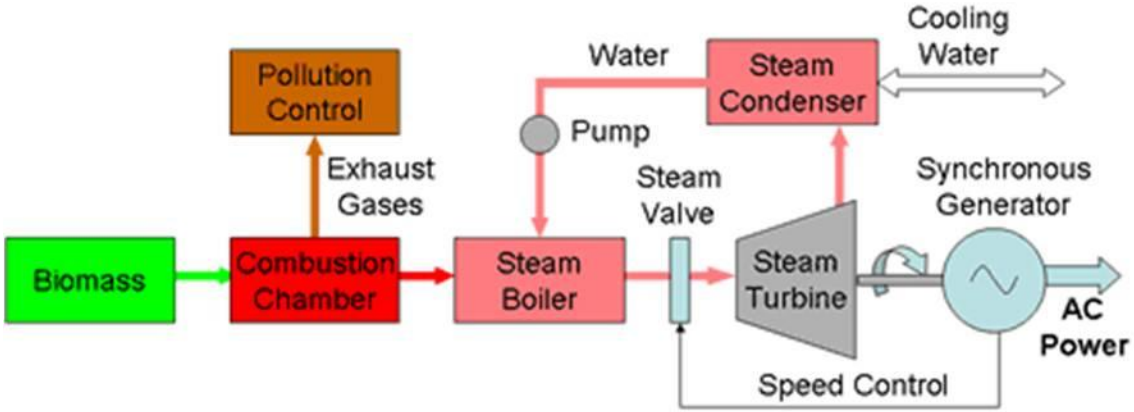
- **first-generation biofuels** are made largely from edible sugars and starches.
- **second-generation biofuels** are made from nonedible plant materials.
- **third-generation biofuels** are made from algae and other microbes.

diesel generator in Egypt

a diesel engine converts the diesel fuel's energy into mechanical energy in the form of rotation of a shaft. The shaft turns a generator to produce electrical energy

CHANGE DIESEL FOR BIOFUELS

Vegetable Oil Generator - 50 Hz from organic Mechanic



Electricity Generation Powered by Biomass

chemical ⇒ heat ⇒ mechanical ⇒ electrical energy

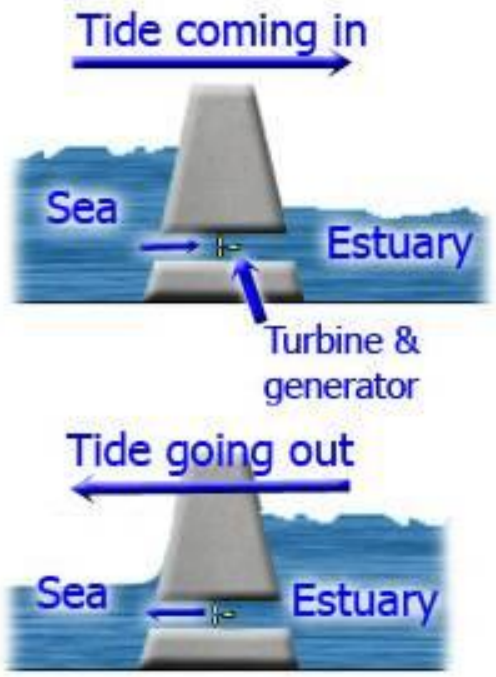
BIOFUELS – PRO AND CONS

NOTE: this is an emerging technology

ADVANTAGES	DISADVANTAGES
biofuels are carbon neutral (amount of carbon dioxide created by the burning = CO_2 absorption capacity of the plants)	planting crops to make biofuels → loss of habitat for various species of animals and plants.
RENEWABLE ENERGY	farmers may grow crops meant for biofuel production rather than food crops → reduced food production → increase the prices → causes inflation to rise problems for developing countries (estimated that a total of 100 million people may suffer from the increase in the food prices)
possibly less greenhouse gas emissions in comparison to fossil fuels	in production of biofuels nitrous oxide is emitted (greenhouse gas effect)
may be cost efficient	no method of biofuel production has been discovered that does not cause any environmental problems

TIDAL POWER

NOTE: this is an emerging technology mostly in research phase



tidal power station in the Rance estuary in northern France, near St. Malo (built in 1966)

- **a dam (called a "barrage") is built across a river estuary**
- **when the tide goes in and out, the water flows through tunnels in the dam and power turbines**

mechanical ⇒ electrical energy

Source: darvill.clara.net

WAVE POWER

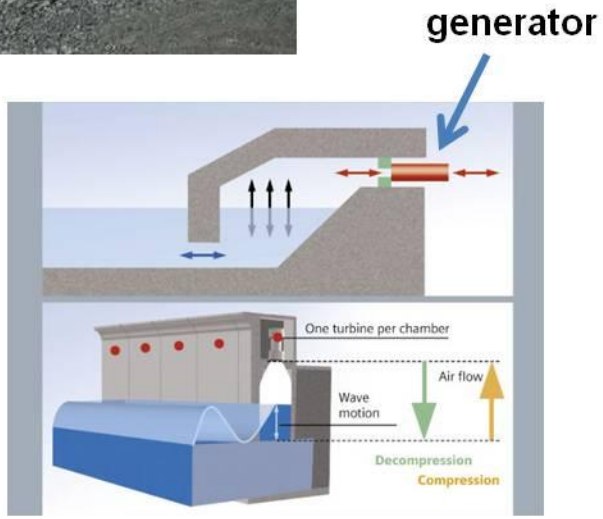
NOTE: this is an emerging technology mostly in research phase

principle:

- ocean waves are a powerful source of energy
- the problem is that it's not easy to harness this energy and convert it into electricity in large amounts

two commercial examples

Wavegen operate a commercial wave power station on the Scottish island of Islay

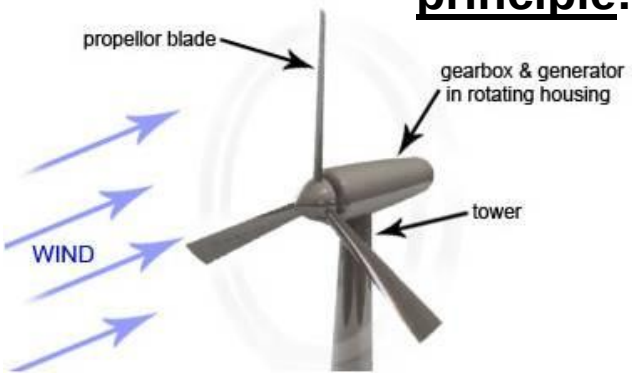


Pelamis Wave Power are developing an offshore method to generate electricity from waves

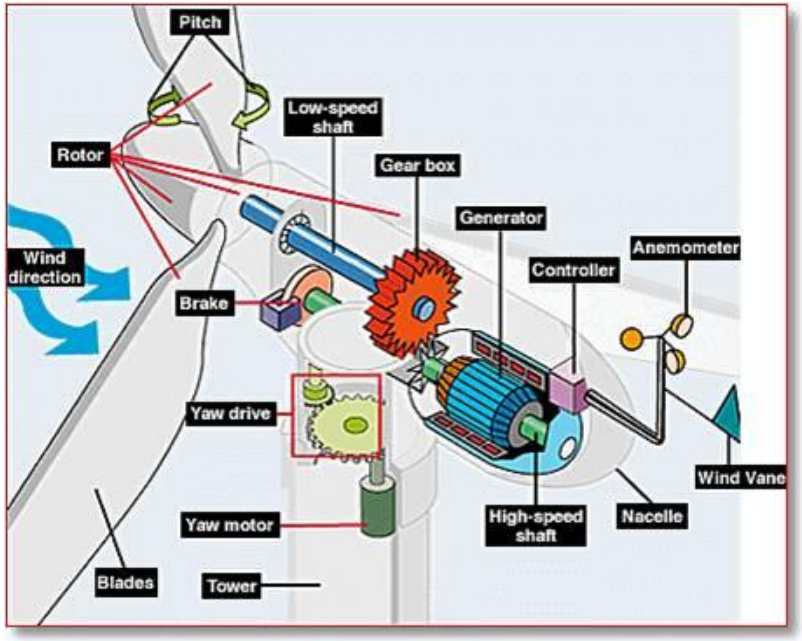
long, hinged tube (length of about 5 railway carriages) bobs up and down in the waves, as the hinges bend they pump hydraulic fluid which drives generators.

mechanical ⇒ electrical energy

WIND POWER



<u>principle</u>: wind blows the propeller round, which turns a generator to produce electricity



Source: US Department of Energy

Source: Darling Wind Farm, South Africa

the more towers, the more wind, and the larger the propellers, the more electricity is generated

<u>requirements</u>: strong, steady winds

↓

high towers, at coastal areas, at the tops of rounded hills, open plains and gaps in mountains - places where the wind is strong and reliable, also offshore

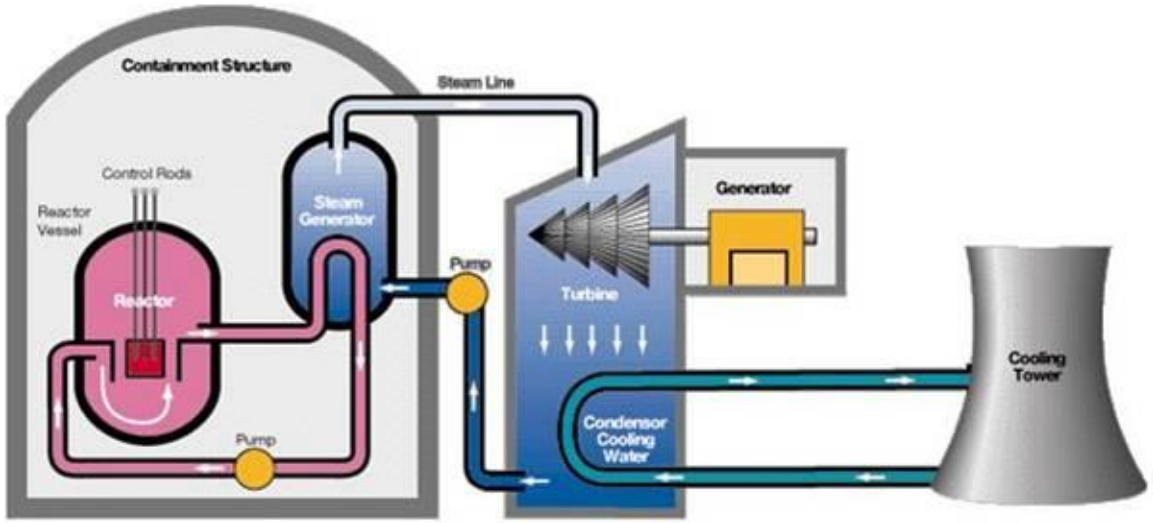
mechanical ⇒ electrical energy

WIND POWER – PRO AND CONS

ADVANTAGES	DISADVANTAGES
wind is free, no need for fuel	wind is not always available
RENEWABLE ENERGY	altering landscape, eyesore
no waste or greenhouse gases	negative environmental impact: • constant, low, "swooshing" noise • can kill birds
agricultural use of land beneath is possible	high maintenance
supply of energy to remote areas	high installation costs

NUCLEAR POWER

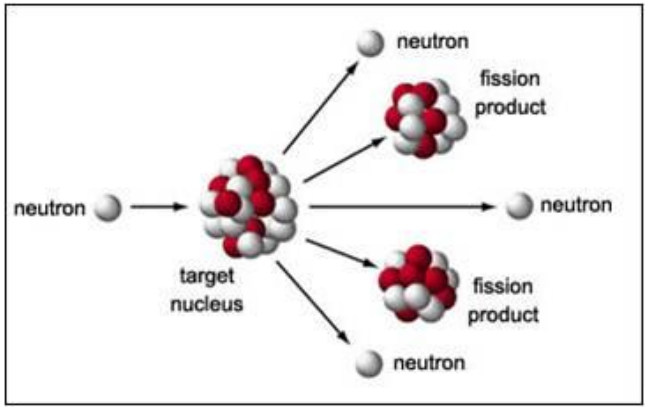
principle: nuclear power stations similar to fossil fuel-burning stations, except that the power comes from nuclear fission



Koeberg nuclear plant (South Africa)

$^{235}U + 1 \text{ neutron} \rightarrow 2 \text{ neutrons} + {}^{92}Kr + {}^{142}Ba + \text{ENERGY}$

nuclear fission is the process of splitting atoms (and gaining energy) and appears in a chain reaction



Source: atomic archive.com

How it works: uranium fuel rods (with about 4% fissile ^{235}U isotope) are the energy source
if control rods made of cadmium (an efficient neutron capturer) are fully inserted into the core, fission cannot occur (all neutrons are captured)
raising the control rods $\rightarrow$ controls the chain reaction

NUCLEAR POWER – PRO AND CONS

ADVANTAGES	DISADVANTAGES
energy price as low (similar to coal)	NOT RENEWABLE ENERGY
no greenhouse gas emission	waste is radioactive and therefore dangerous (radioactivity decay only in thousands of years → waste must be sealed up and buried)
large scale energy from small amounts of fuel	expansive safety measures (plant have to sustain earthquakes, flooding, and terrorists attacks)
small amounts of waste	accidents in plants can be a major disasters
reliable power production	

SOLAR POWER

photovoltaic

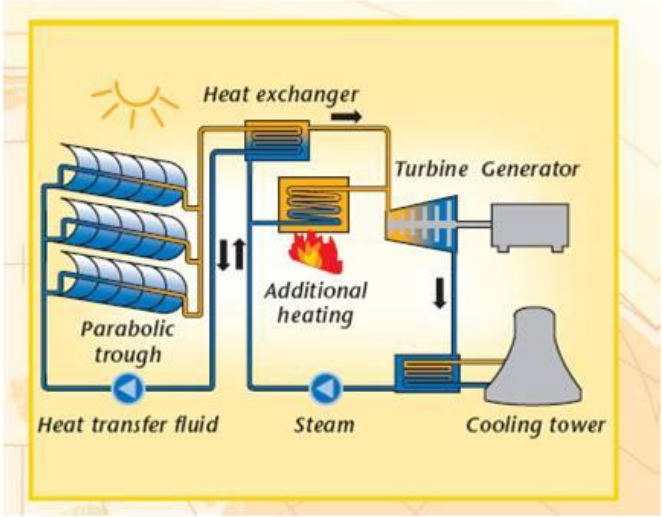
Source: Strasskirchen solarpark (54MW)

one of the 10 biggest PV plants (230,000 crystalline solar modules on an area approximately of the size of 195 soccer pitches)

or somewhat smaller: solar panels on a roof top

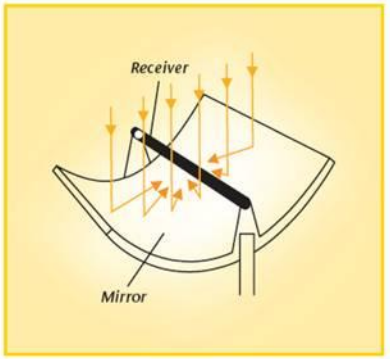
Source: solarnavigator.net

solar thermal



<u>principle</u>:
a solar thermal plants is similar to fossil fuel-burning stations, except that the power comes from the sun

solar radiation is concentrated with mirrors to heat a liquid, with powers a steam turbine



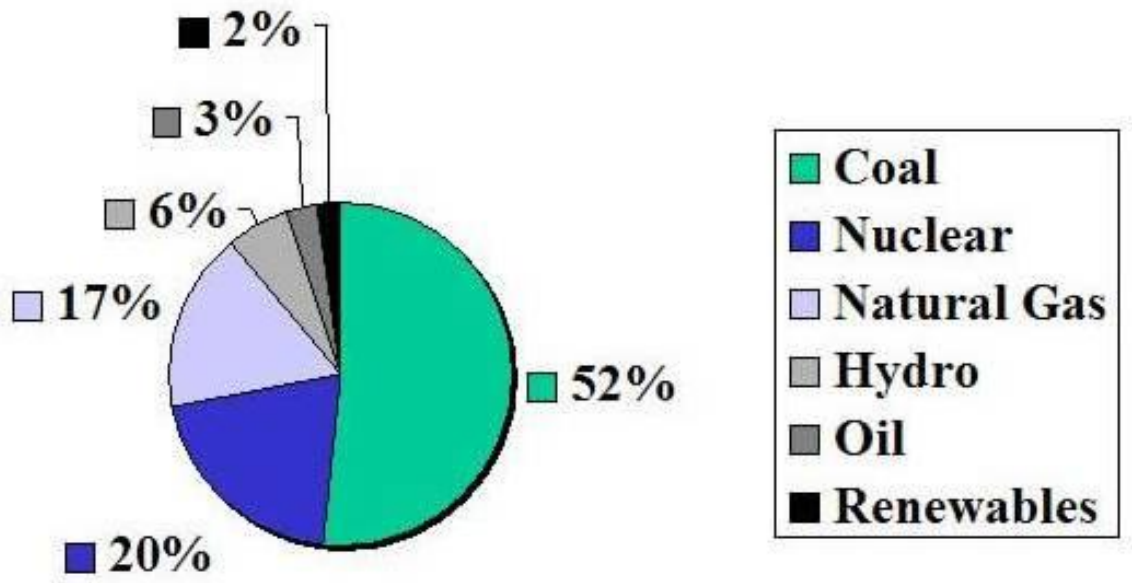
Parabolic mirrors focus the sun's rays onto the receivers

Fuentes de Andalucia, Spain

SOLAR POWER – PROS AND CONS

ADVANTAGES	DISADVANTAGES
no noise pollution no greenhouse gases	initial cost of solar panels is high
renewable energy	solar energy is only able to generate electricity during daylight hours
new technologies allow for a more efficient energy production on overcast/dull days	solar farms need large areas
electricity production in remote locations	

ELECTRIC POWER GENERATION IN THE USA



In 2001, total US generation of electricity was 3,777 billion kilowatt-hours. The % of electricity produced from each source of energy is shown above in a pie chart.

Source: Community Science Action Guides

ENERGY COSTS

calculating the per Kilowatt-Hour cost of energy

construction cost per kWh + production costs per kWh + decommissioning costs per kWh (nuclear only)

=

total cost per kWh.

calculating the per Kilowatt-hour construction cost of a project

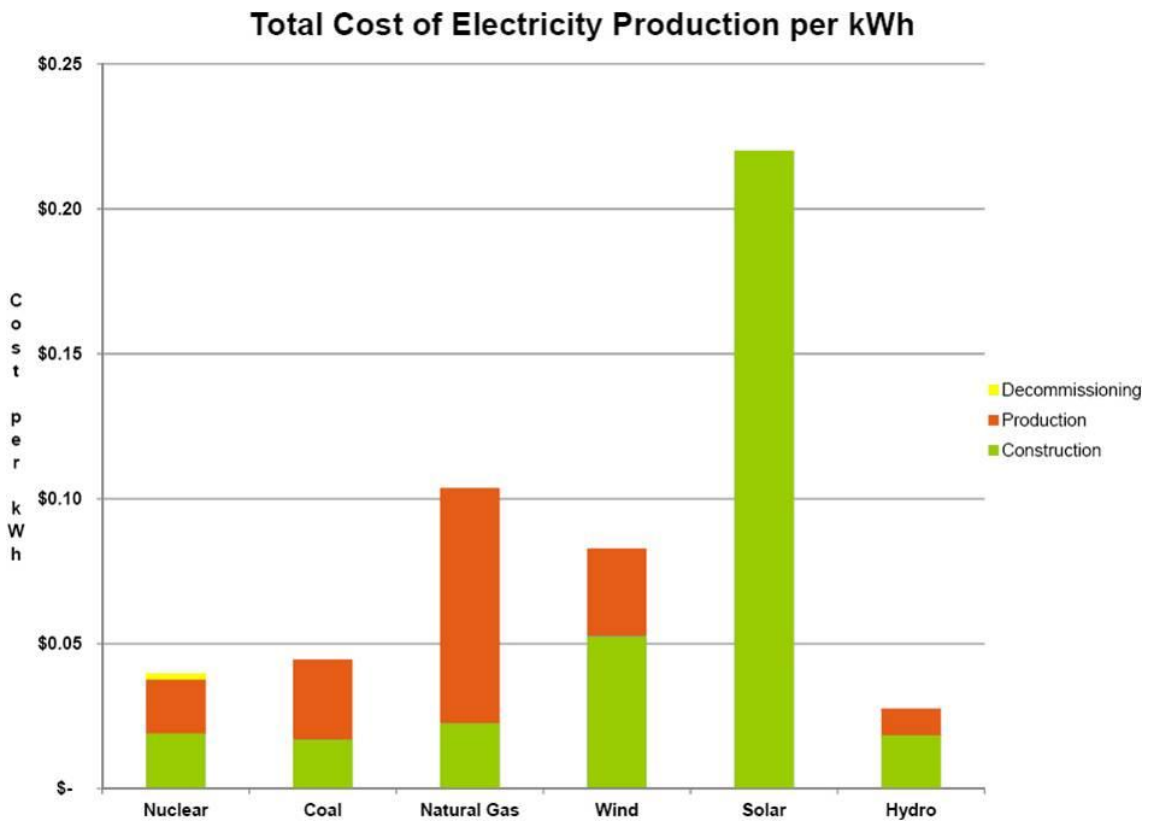
[(MW rating x 1,000) x Useful Life x (Capacity Factor x 8,760)]

Note:
the MW rating is multiplied by 1,000 to convert to kW and capacity factor by 8,760 to convert to number of hours of energy produced in a year.

per kilowatt-hour production costs:

estimates from NEI2008 data

nuclear: $0.019
coal: $0.027
natural Gas: $0.081
wind: $0.030
hydroelectric: $0.009
solar: no estimate found



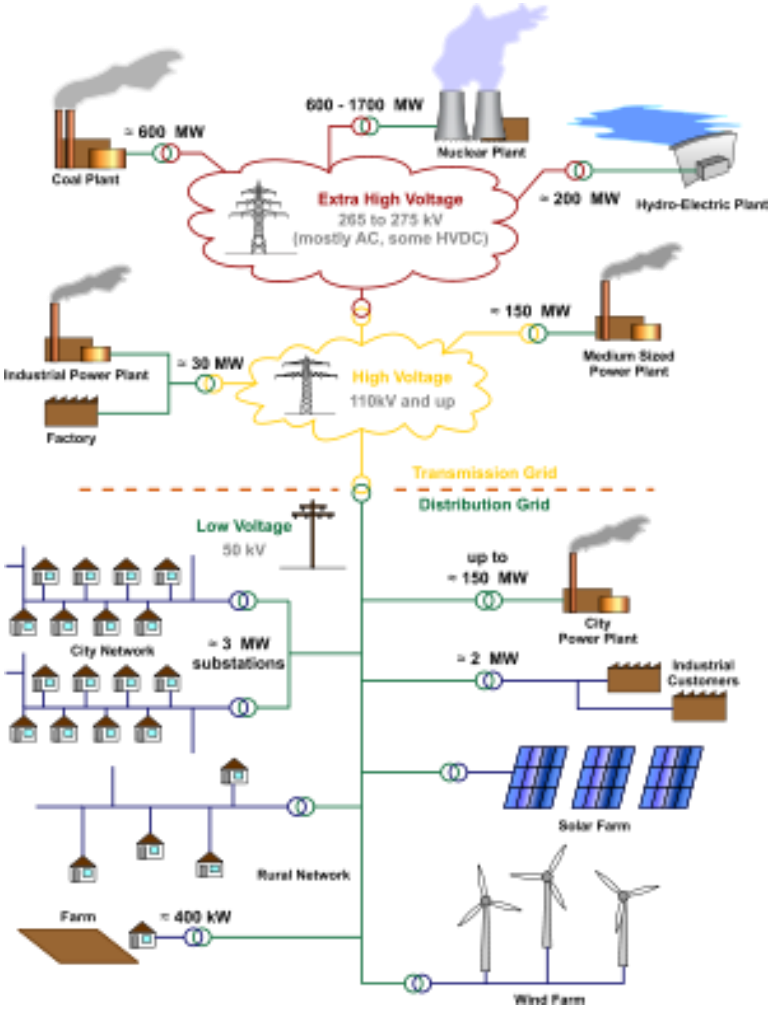
source: http://nuclearfissionary.com

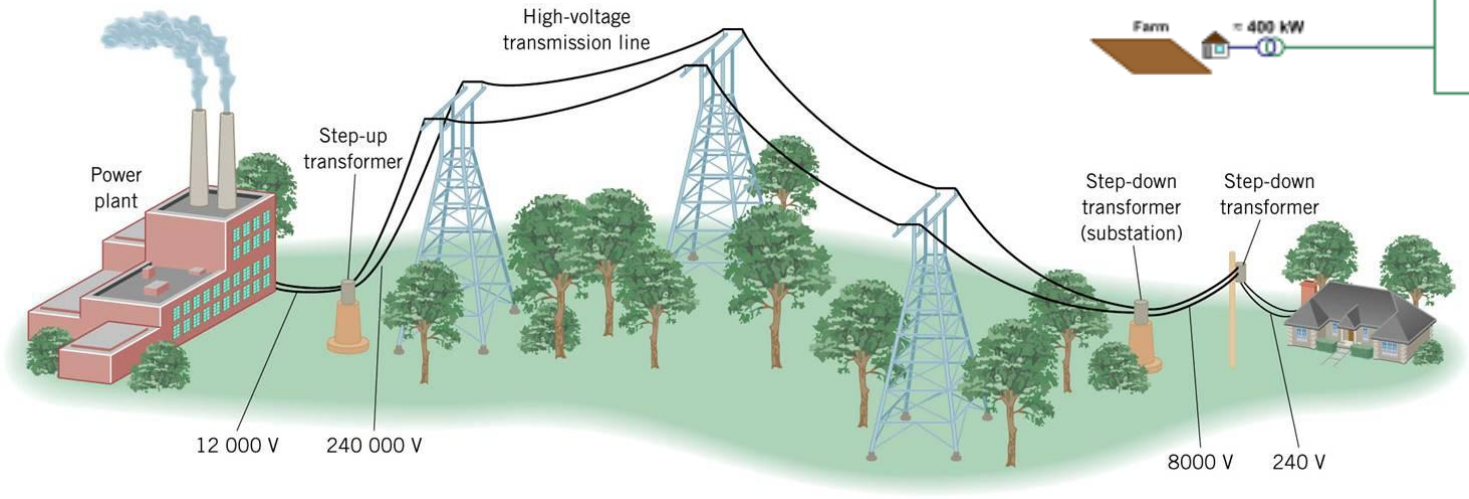
ENERGY DISTRIBUTION

<u>power grid</u> supplies electricity to (industrial, commercial and private) consumers through interconnected networks

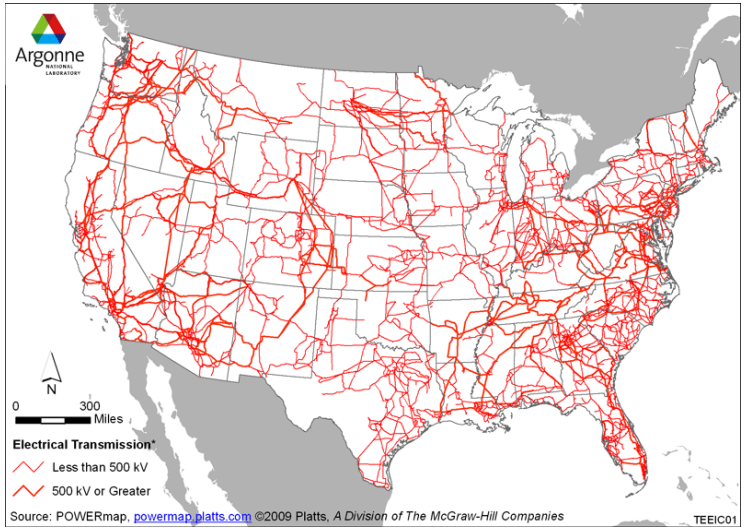
<u>the grid consists of</u>:

- **power generating plants**
- **transformers (low to high; and high to low voltage**
- **transmission lines (high and low voltage)**

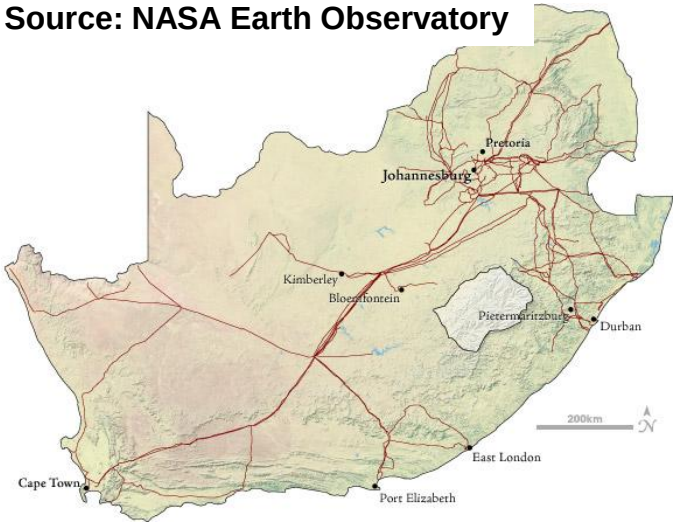




HIGH VOLTAGE TRANSMISSION LINES



Source: NASA Earth Observatory



high voltage, long distance transmission lines in South Africa

Source: Government of Canada

high voltage, long distance transmission lines in Canada