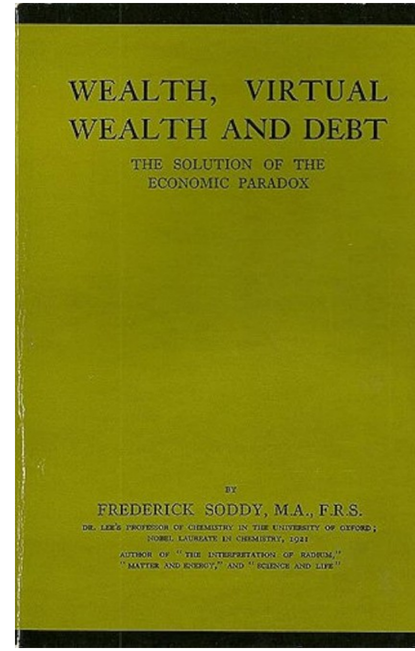
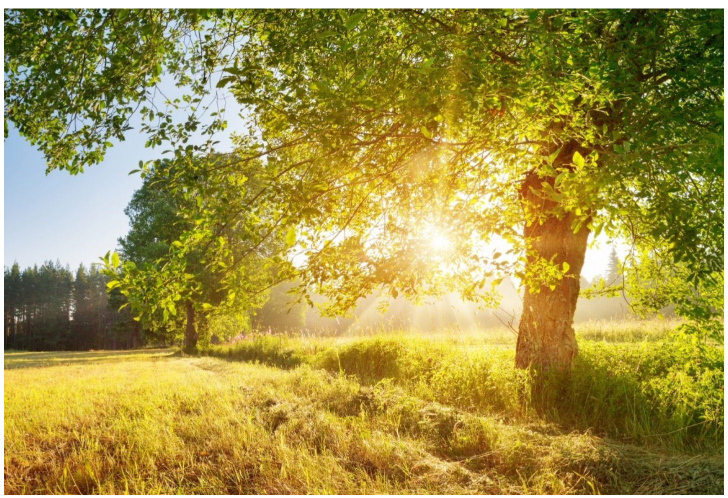
L1.3
Energy Resources:
Past, Present, and Future

"The profound change that then occurred seemed to be rather due to the fact that, for the first time in history, men began to tap a large capital store of energy and ceased to be entirely dependent on the revenue of sunshine. All the requirements of pre-scientific men were met out of the solar energy of their own times. The food they ate, the clothes they wore, and the wood they burnt could be envisaged, as regards, the energy content which gives them use-value, as stores of sunlight. But in burning coal one releases a store of sunshine that reached the earth millions of years ago." Soddy 1926 P 58





Energy in real time (renewable) → ancient, stored sunlight (non-renewable)

The FOSSIL FUEL REVOLUTION!

Energy is the ability to do work

Forms of energy: potential, kinetic, thermal, chemical, electrical, etc.

1st Law of Thermodynamics:

energy cannot be created or destroyed

2nd Law of Thermodynamics:

energy goes from a high quality to a lower quality during each energy transformation; while energy is conserved, it’s ability to do work decreases

The energy available determines what humans can do

- Humans are energy convertors (food to biomass/ maintenance) until we die
- Low-energy convertors rely on renewable, sustainable solar energy
- High-energy convertors rely on non-renewable, unsustainable fossil fuels
- Society has transitioned from low-energy to high-energy convertors and has become dependent on them, even though they are nonrenewable and unsustainable

Surplus energy

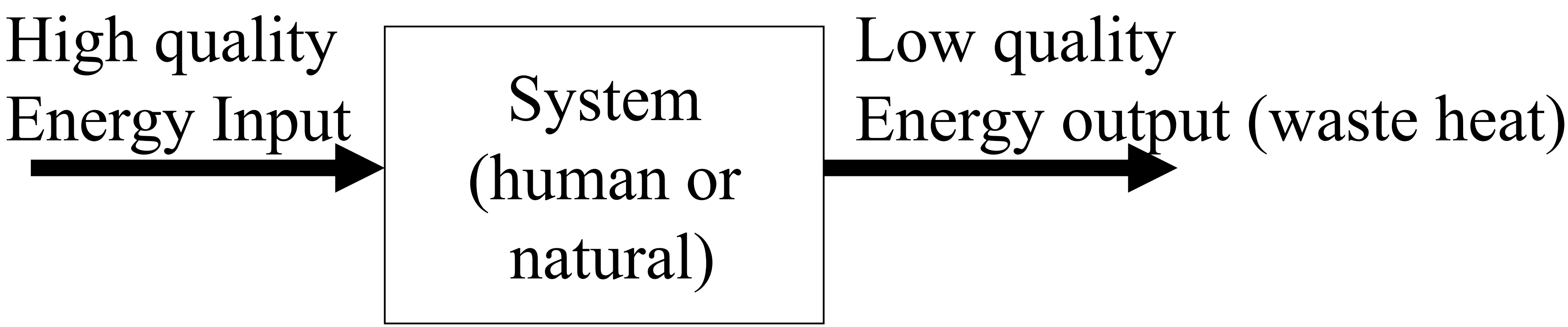
- If the harvest produces enough grain to replace the seed, to supply the amount of energy expended in planting, cultivating, and harvesting the crop, and to get something more: there is surplus energy

- The struggle to create morals which will furnish a rationale for the disposition of surplus energy is probably one of the crucial points of conflict in modern society (Cottrell 1956)

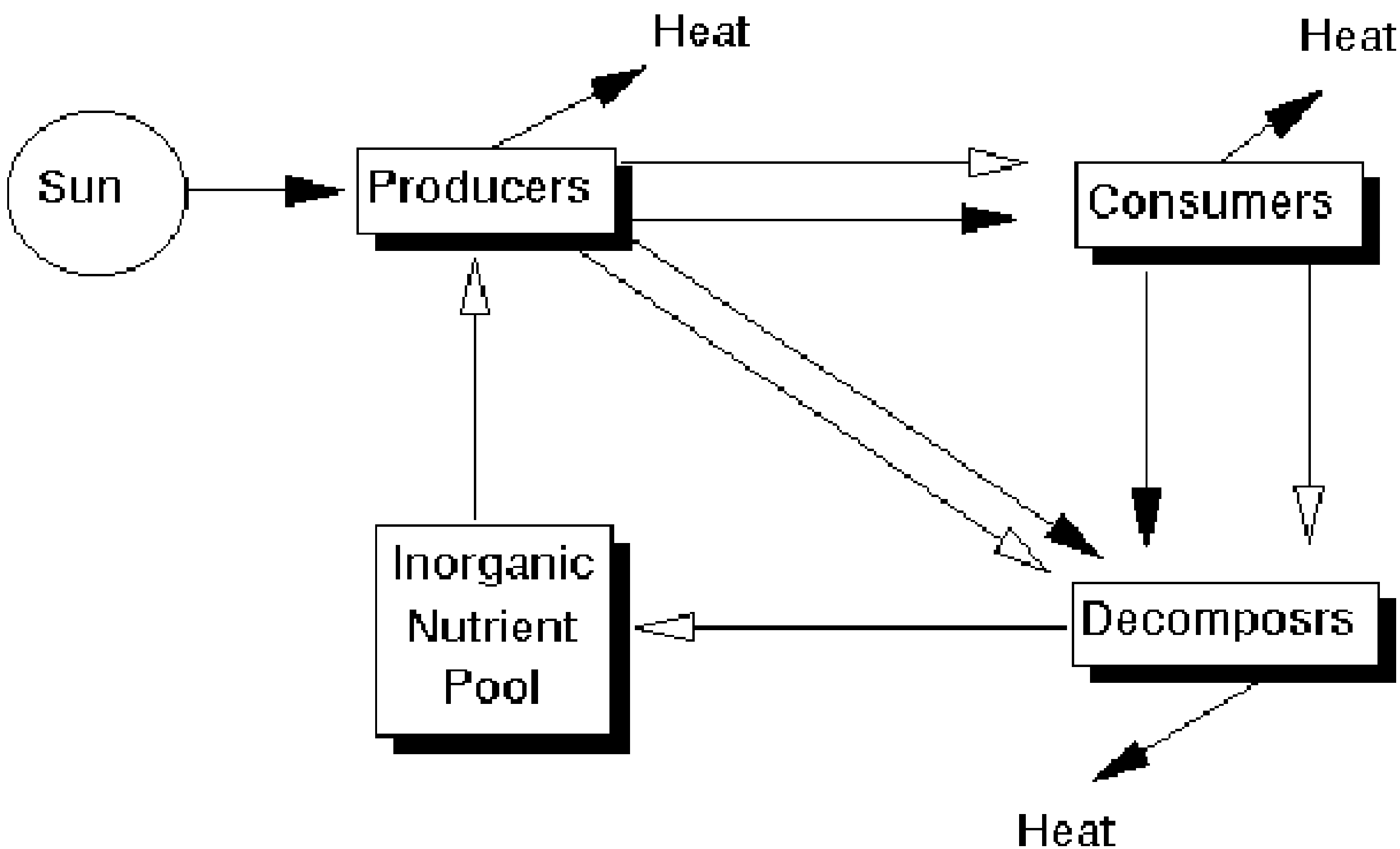
Energy is needed to maintain system structure and complexity

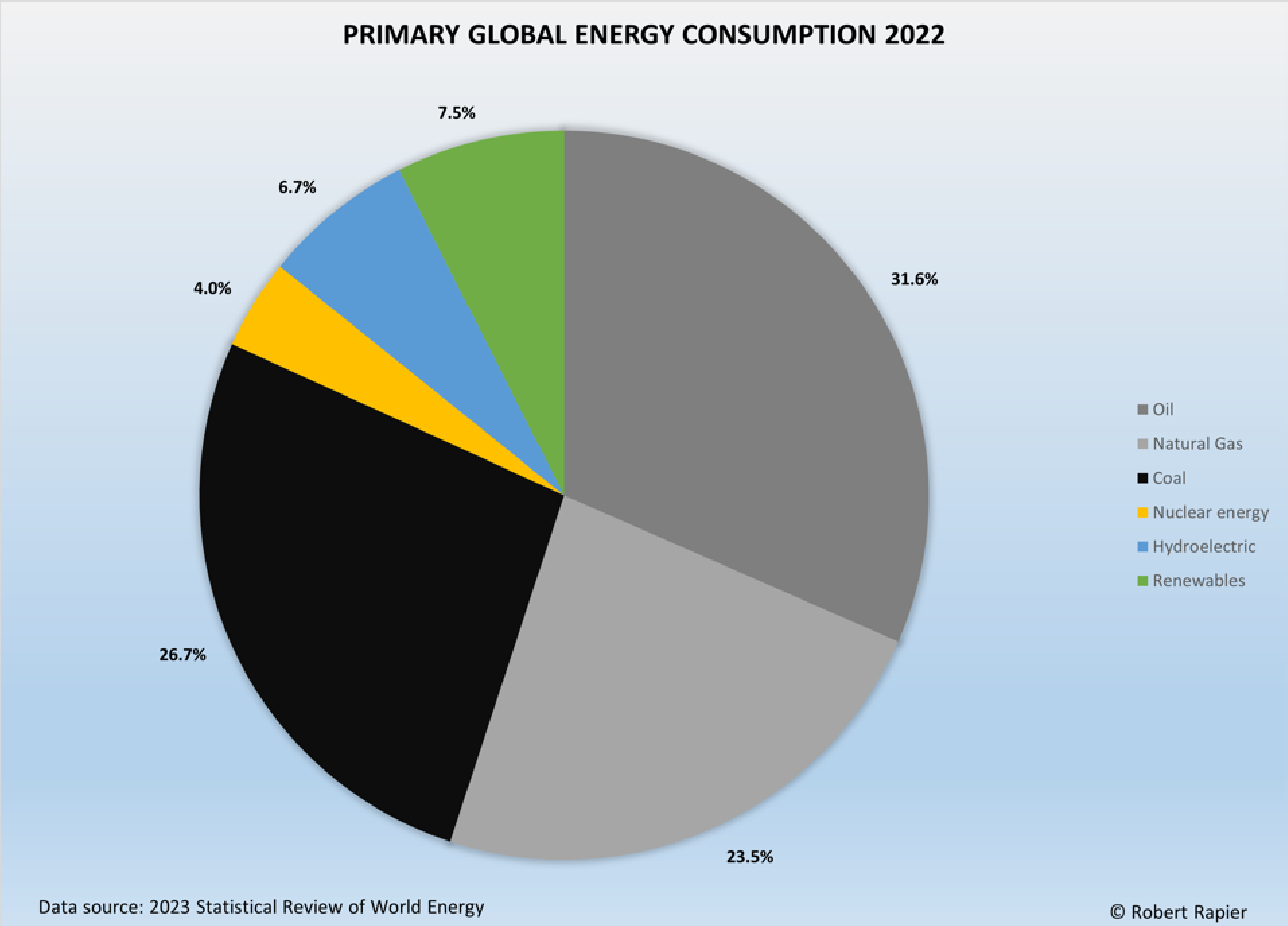
Natural and human systems build and maintain order and organization by taking in high quality energy, using it, and passing degraded energy outside of the system boundary.

Our society is dependent on the energy flows that support it AND having a sink for the waste.



Simplified Ecosystem





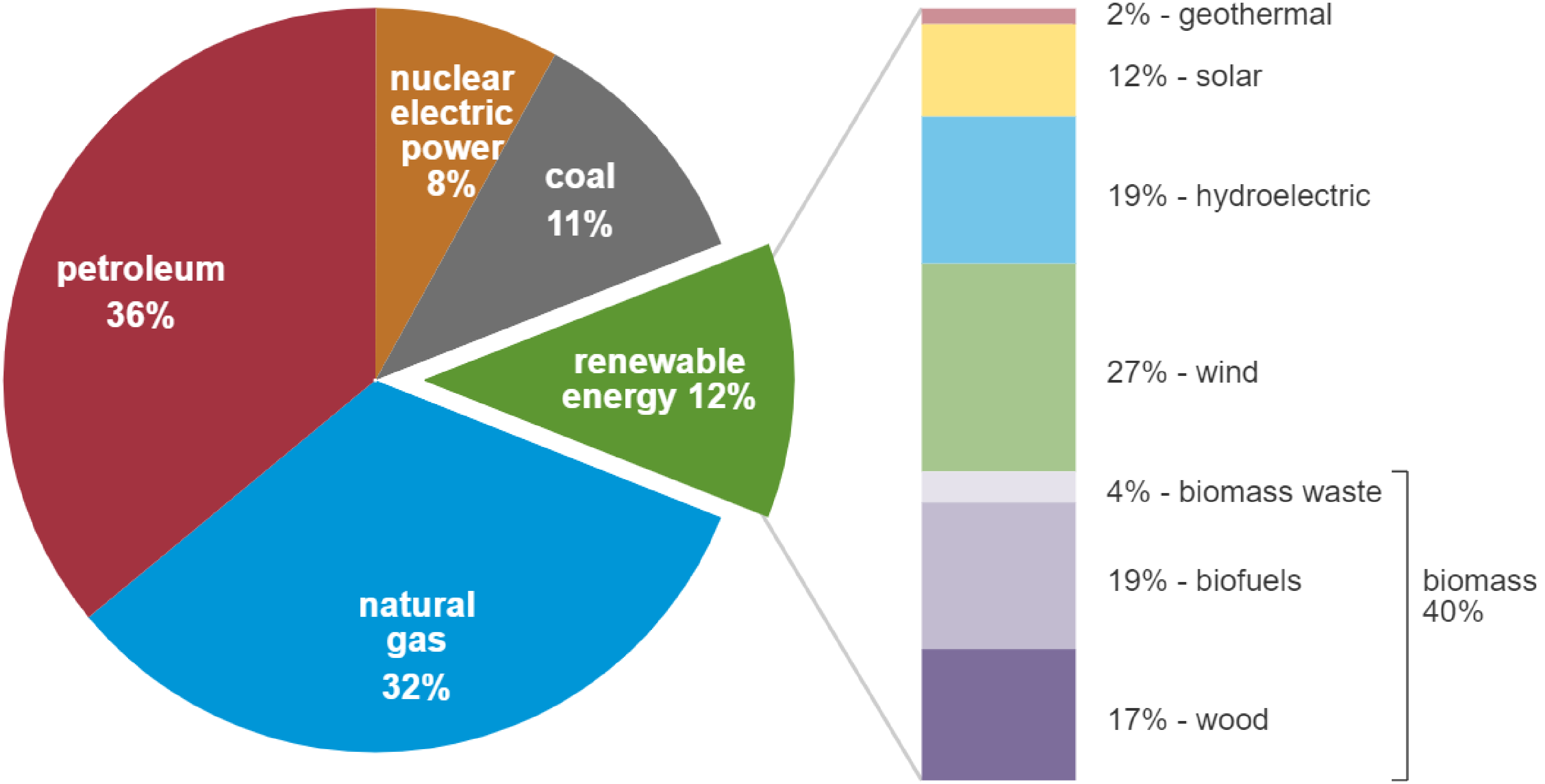
PRIMARY GLOBAL ENERGY CONSUMPTION 2022
7.5%
6.7%
4.0%
31.6%
26.7%
23.5%
Oil
Natural Gas
Coal
Nuclear energy
Hydroelectric
Renewables
Data source: 2023 Statistical Review of World Energy
© Robert Rapier

U.S. primary energy consumption by energy source, 2021

total = 97.33 quadrillion
British thermal units (Btu)

total = 12.16 quadrillion Btu

102,689 Petajoules



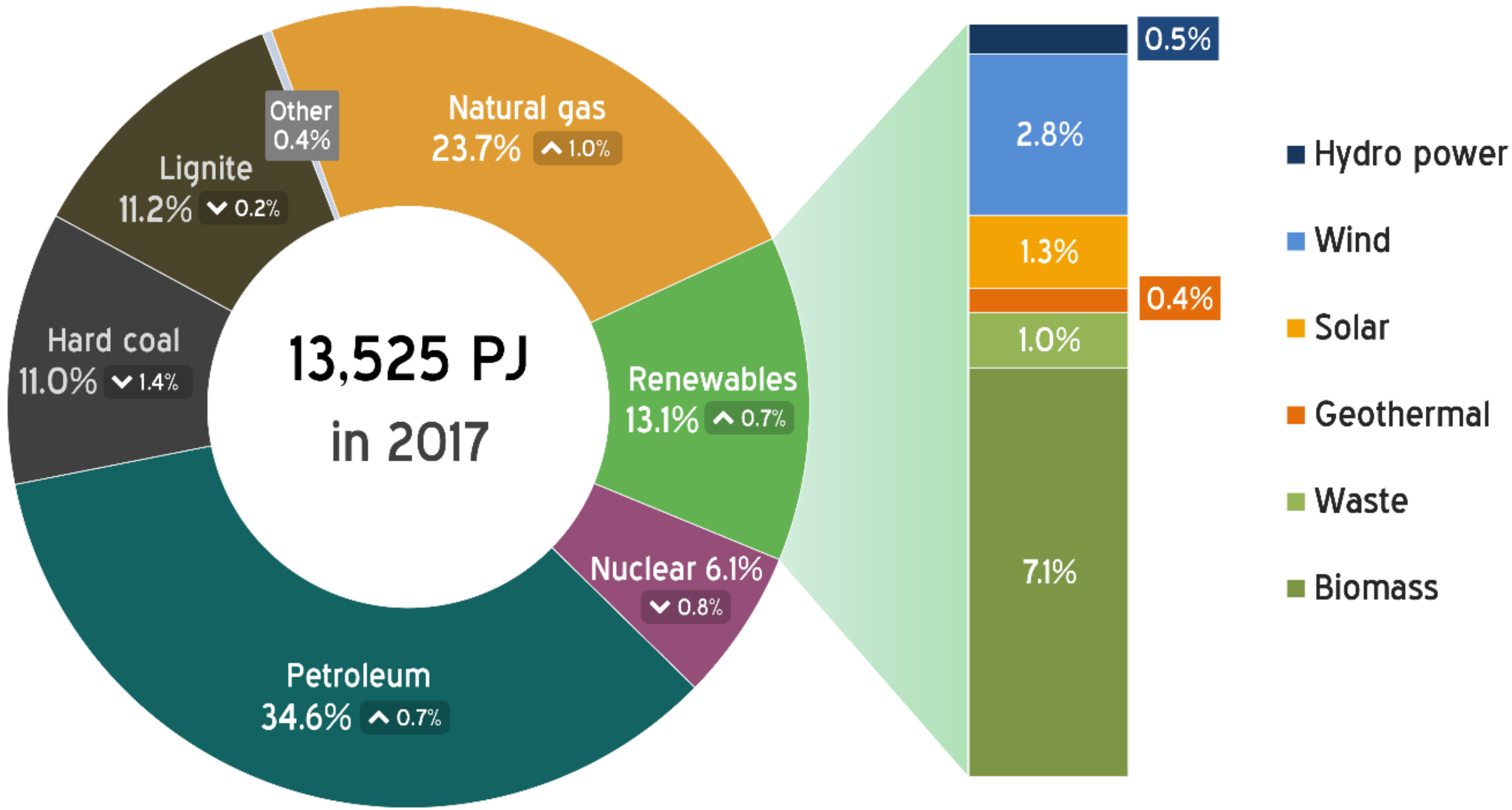
Data source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2022, preliminary data

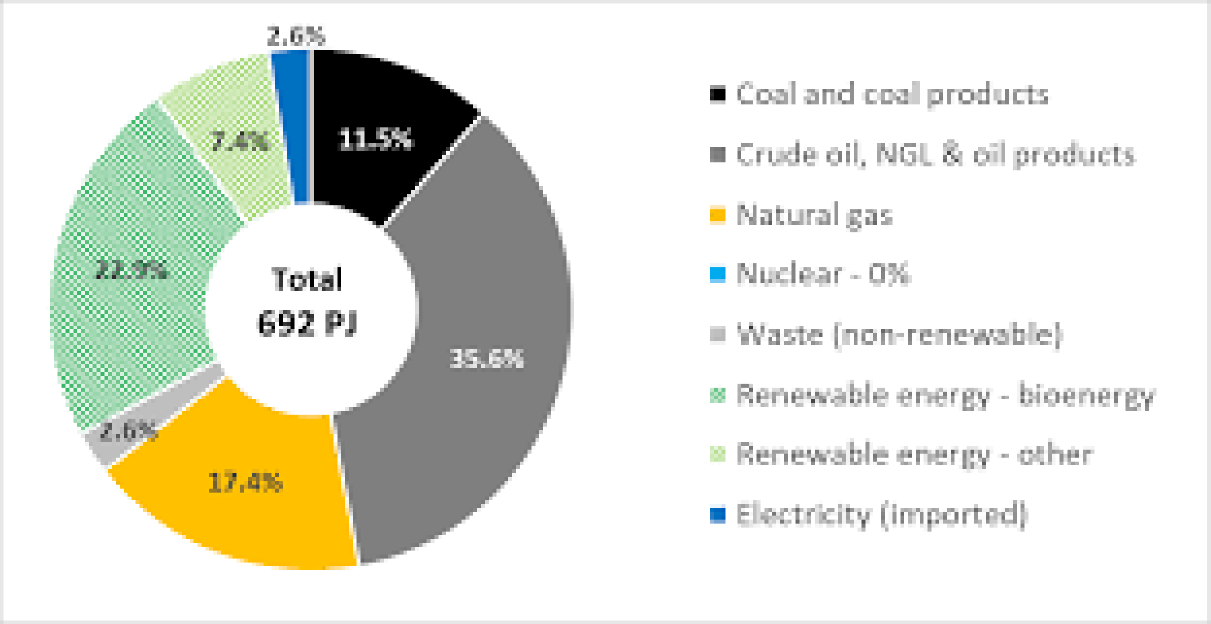
Note: Sum of components may not equal 100% because of independent rounding.

Primary energy consumption mix in Germany 2017

in petajoules & percent

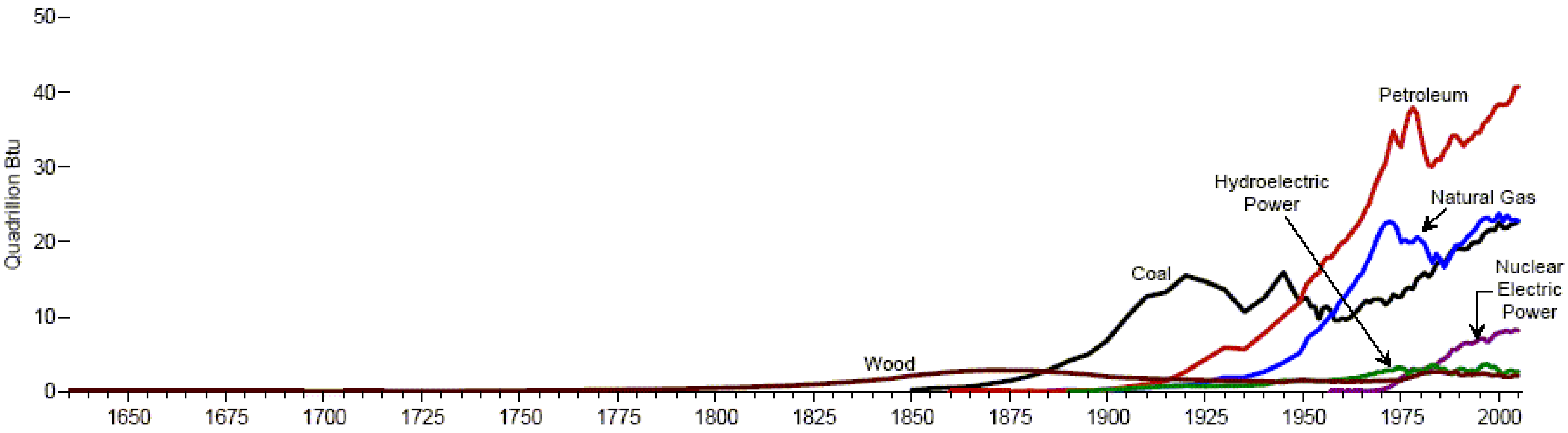
Source: AGEB, ZSW

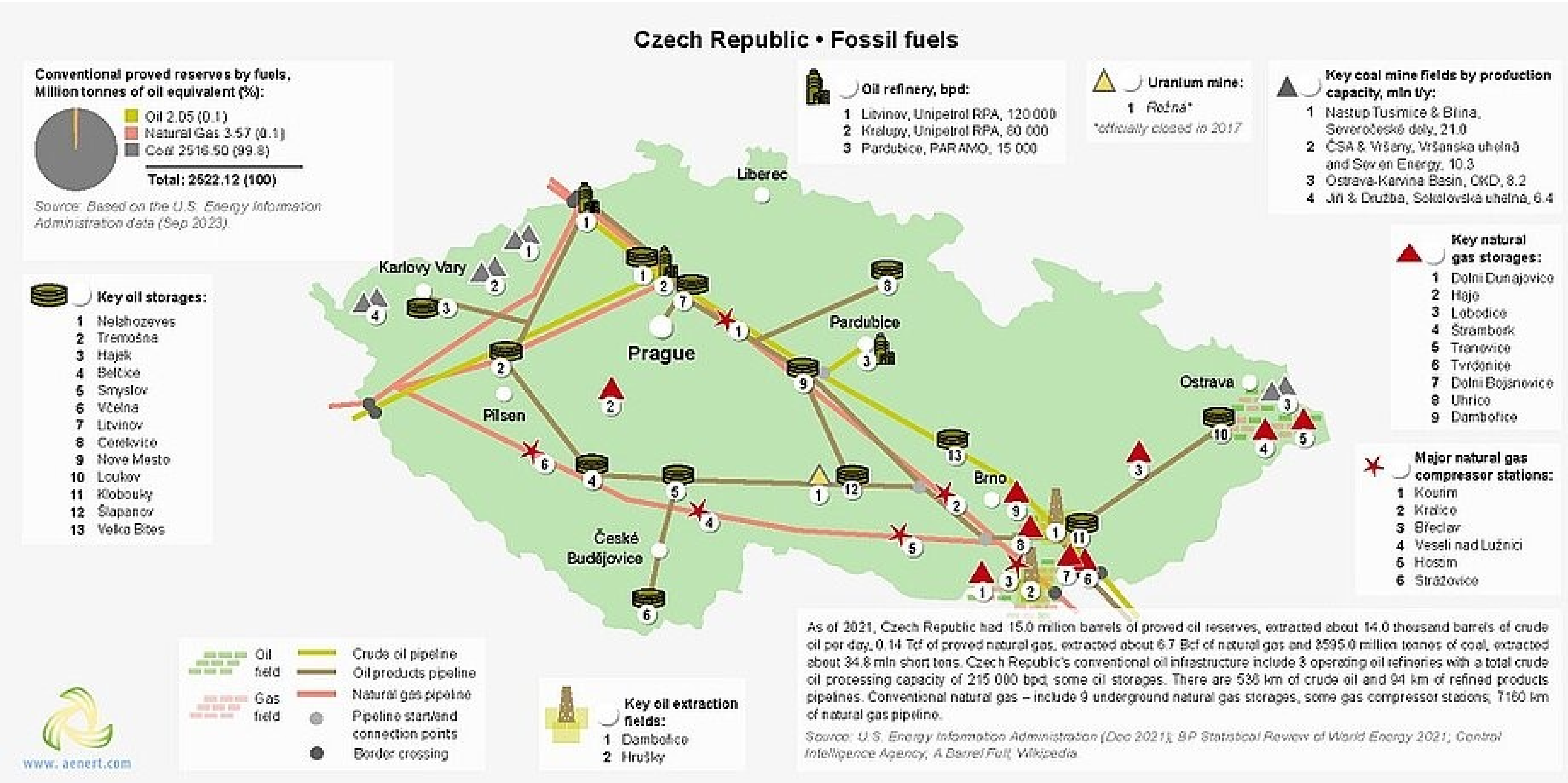




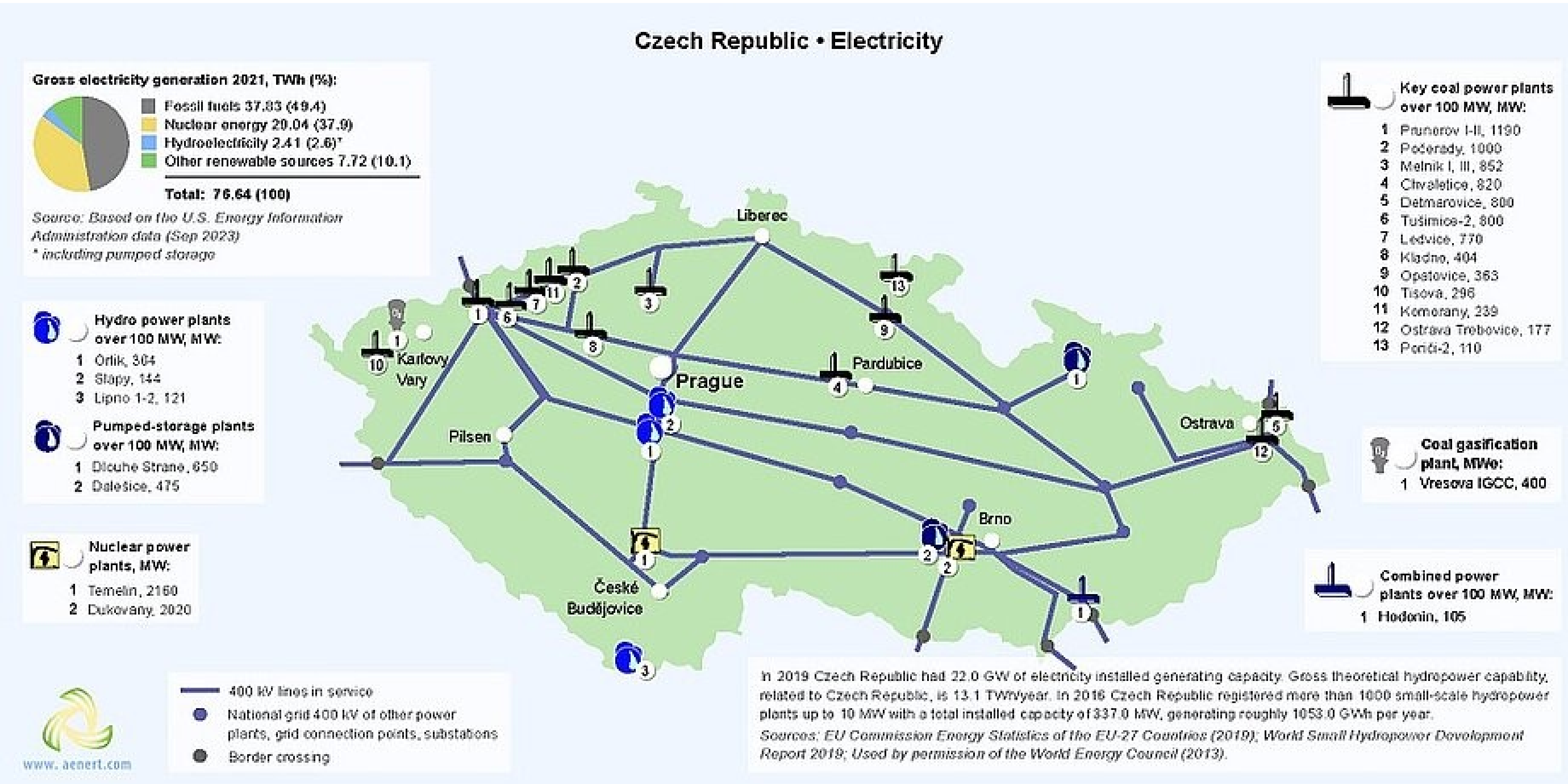
Total primary energy supply in Denmark in 2016
(Source: World Energy Balances © OECD/IEA 2018)

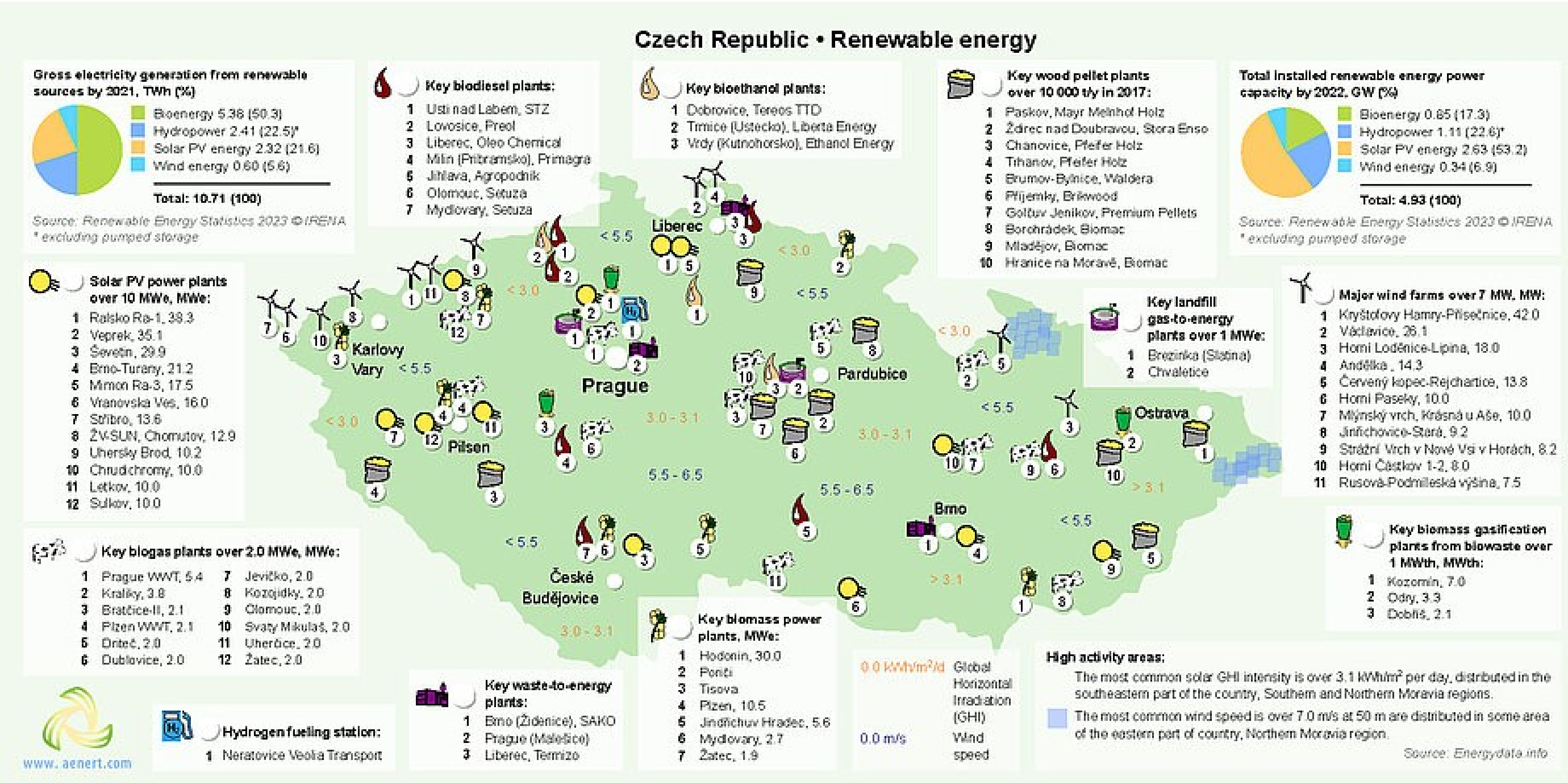
Energy Consumption by Source, 1635-2006





aenert.com/countries/europe/energy-industry-in-the-czech-republic/


Czech Republic • Electricity
Gross electricity generation 2021, TWh (%):
Fossil fuels 37.83 (49.4)
Nuclear energy 29.04 (37.9)
Hydroelectricity 2.41 (2.6)*
Other renewable sources 7.72 (10.1)
Total: 76.64 (100)
Source: Based on the U.S. Energy Information Administration data (Sep 2023)
* including pumped storage
Hydro power plants over 100 MW, MW:
1 Orlik, 364
2 Slapy, 144
3 Lipno 1-2, 121
Pumped-storage plants over 100 MW, MW:
1 Dlouhe Strane, 650
2 Dalesice, 475
Nuclear power plants, MW:
1 Temelin, 2160
2 Dukovany, 2020
Key coal power plants over 100 MW, MW:
1 Prunerov I-II, 1190
2 Počerady, 1000
3 Melnik I, III, 852
4 Chvaletice, 820
5 Detmarovice, 800
6 Tušimice-2, 800
7 Ledvice, 770
8 Kladno, 404
9 Opatovice, 363
10 Tisova, 296
11 Komorany, 239
12 Ostrava Trebovice, 177
13 Poriči-2, 110
Coal gasification plant, MWe:
1 Vresova IGCC, 400
Combined power plants over 100 MW, MW:
1 Hodonin, 105
Liberec
Karlovy Vary
Prague
Pardubice
Pilsen
Ostrava
Brno
České Budějovice
400 kV lines in service
National grid 400 kV of other power plants, grid connection points, substations
Border crossing
www.aenert.com
In 2019 Czech Republic had 22.0 GW of electricity installed generating capacity. Gross theoretical hydropower capability, related to Czech Republic, is 13.1 TWh/year. In 2016 Czech Republic registered more than 1000 small-scale hydropower plants up to 10 MW with a total installed capacity of 337.0 MW, generating roughly 1053.0 GWh per year.
Sources: EU Commission Energy Statistics of the EU-27 Countries (2019); World Small Hydropower Development Report 2019; Used by permission of the World Energy Council (2013).


Czech Republic • Renewable energy
Gross electricity generation from renewable sources by 2021, TWh (%)
Bioenergy 5.38 (50.3)
Hydropower 2.41 (22.5)*
Solar PV energy 2.32 (21.6)
Wind energy 0.60 (5.6)
Total: 10.71 (100)
Source: Renewable Energy Statistics 2023 © IRENA
* excluding pumped storage
Key biodiesel plants:
1 Usti nad Labem, STZ
2 Lovosice, Preol
3 Liberec, Oleo Chemical
4 Milin (Pribramsko), Primagra
5 Jihlava, Agropodnik
6 Olomouc, Setuza
7 Mydlovary, Setuza
Key bioethanol plants:
1 Dobrovice, Tereos TTD
2 Trmice (Ustecko), Liberta Energy
3 Vrdy (Kutnohorsko), Ethanol Energy
Key wood pellet plants over 10 000 t/y in 2017:
1 Paskov, Mayr Melnhof Holz
2 Ždírec nad Doubravou, Stora Enso
3 Chanovice, Pfeifer Holz
4 Trhanov, Pfeifer Holz
5 Brumov-Bylnice, Waldera
6 Přijemky, Brikwood
7 Golčův Jeníkov, Premium Pellets
8 Borohrádek, Biomac
9 Mladějov, Biomac
10 Hranice na Moravě, Biomac
Total installed renewable energy power capacity by 2022, GW (%)
Bioenergy 0.85 (17.3)
Hydropower 1.11 (22.6)*
Solar PV energy 2.63 (53.2)
Wind energy 0.34 (6.9)
Total: 4.93 (100)
Source: Renewable Energy Statistics 2023 © IRENA
* excluding pumped storage
Solar PV power plants over 10 MWe, MWe:
1 Ralsko Ra-1, 38.3
2 Veprek, 35.1
3 Ševetín, 29.9
4 Brno-Turany, 21.2
5 Mimon Ra-3, 17.5
6 Vranovská Ves, 16.0
7 Stříbro, 13.6
8 ŽV-SUN, Chomutov, 12.9
9 Uhersky Brod, 10.2
10 Chrudichromy, 10.0
11 Letkov, 10.0
12 Sulkov, 10.0
Key landfill gas-to-energy plants over 1 MWe:
1 Brezinka (Slatina)
2 Chvaletice
Major wind farms over 7 MW, MW:
1 Kryštofovy Hamry-Přísečnice, 42.0
2 Václavice, 26.1
3 Horní Loděnice-Lipina, 18.0
4 Andělka, 14.3
5 Červený kopec-Rejchartice, 13.8
6 Horní Paseky, 10.0
7 Mlýnský vrch, Krásná u Aše, 10.0
8 Jiříchovice-Stará, 9.2
9 Strážní Vrch v Nové Vsi v Horách, 8.2
10 Horní Částkov 1-2, 8.0
11 Rusová-Podmileská výšina, 7.5
Key biogas plants over 2.0 MWe, MWe:
1 Prague WWT, 5.4
2 Kraliky, 3.8
3 Bratčice-II, 2.1
4 Plzen WWT, 2.1
5 Drited, 2.0
6 Dublovice, 2.0
7 Jevíčko, 2.0
8 Kozojidky, 2.0
9 Olomouc, 2.0
10 Svaty Mikulaš, 2.0
11 Uherčice, 2.0
12 Žatec, 2.0
Key biomass gasification plants from biowaste over 1 MWth, MWth:
1 Kozomín, 7.0
2 Odry, 3.3
3 Dobříš, 2.1
Key biomass power plants, MWe:
1 Hodonin, 30.0
2 Poriči
3 Tisova
4 Plzen, 10.5
5 Jindřichuv Hradec, 5.6
6 Mydlovary, 2.7
7 Žatec, 1.9
Key waste-to-energy plants:
1 Brno (Židenice), SAKO
2 Prague (Malešice)
3 Liberec, Termizo
Hydrogen fueling station:
1 Neratovice Veolia Transport
0.0 kWh/m²/d Global Horizontal Irradiation (GHI)
0.0 m/s Wind speed
High activity areas:
The most common solar GHI intensity is over 3.1 kWh/m² per day, distributed in the southeastern part of the country, Southern and Northern Moravia regions.
The most common wind speed is over 7.0 m/s at 50 m are distributed in some area of the eastern part of country, Northern Moravia region.
Source: Energydata.info
Liberec
Karlovy Vary
Prague
Pardubice
Ostrava
Pilsen
Brno
České Budějovice
www.aenert.com

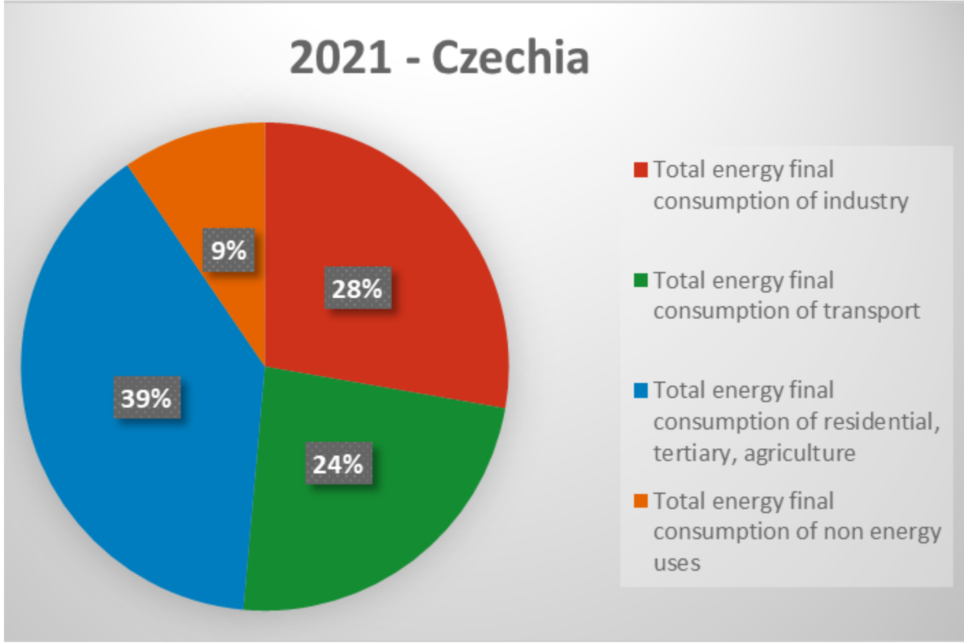
What

Energy end uses:

Heat

Transport

Electricity



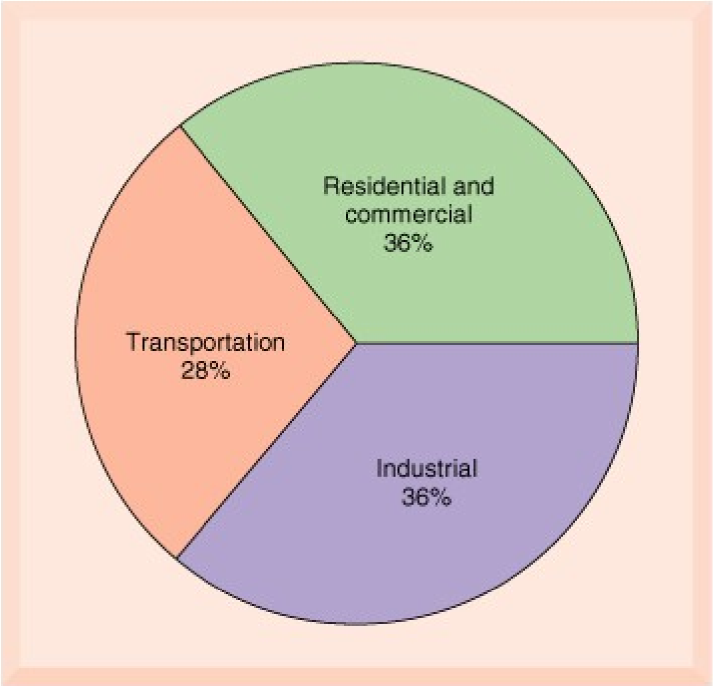
Where

Energy Sectors:

Residential/Commercial

Industrial

Transportation

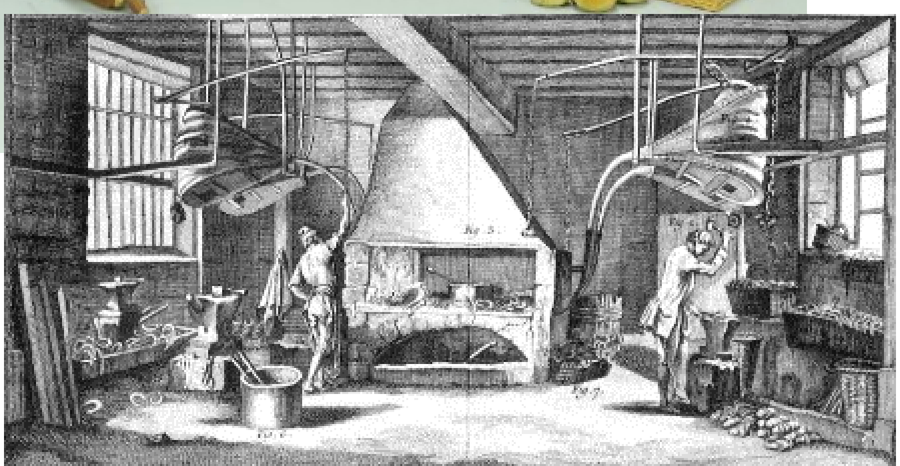


Source: Energy Information Administration, 1998, *Annual Energy Review*, U.S. Department of Energy.

Historical Energy Use

Earlier civilizations used renewable energy sources exclusively

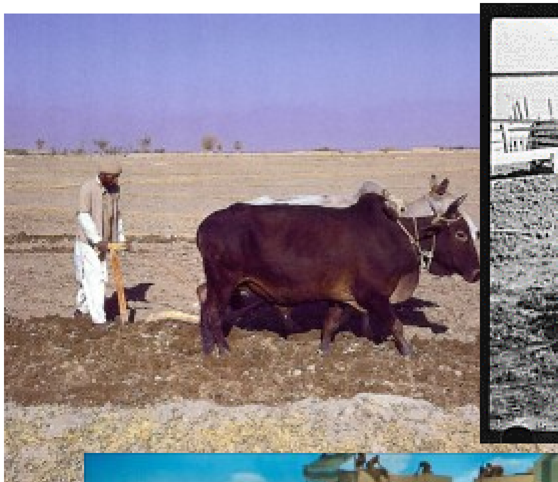
Biomass for heat and cooking



Historical Energy Use

Earlier civilizations used renewable energy sources exclusively

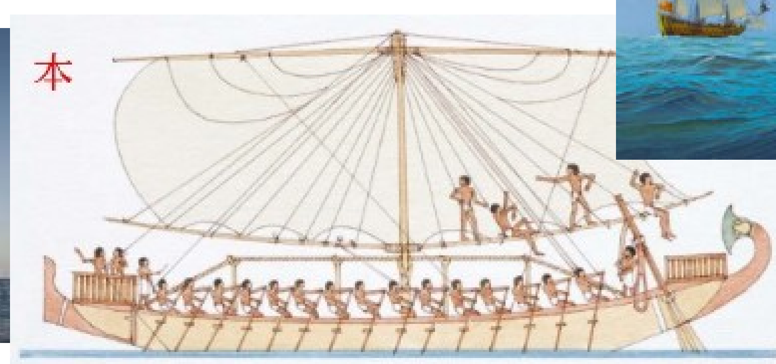
Animal and human energy for labor



Historical Energy Use

Earlier civilizations used renewable energy sources exclusively

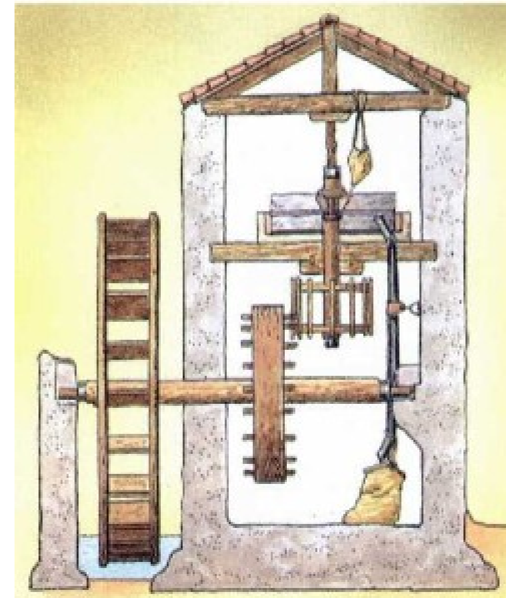
Wind for windmills (pumping) and sailing



Historical Energy Use

Earlier civilizations used renewable energy sources exclusively

Water for watermills (milling)



Harpers Ferry

Historical Energy Use

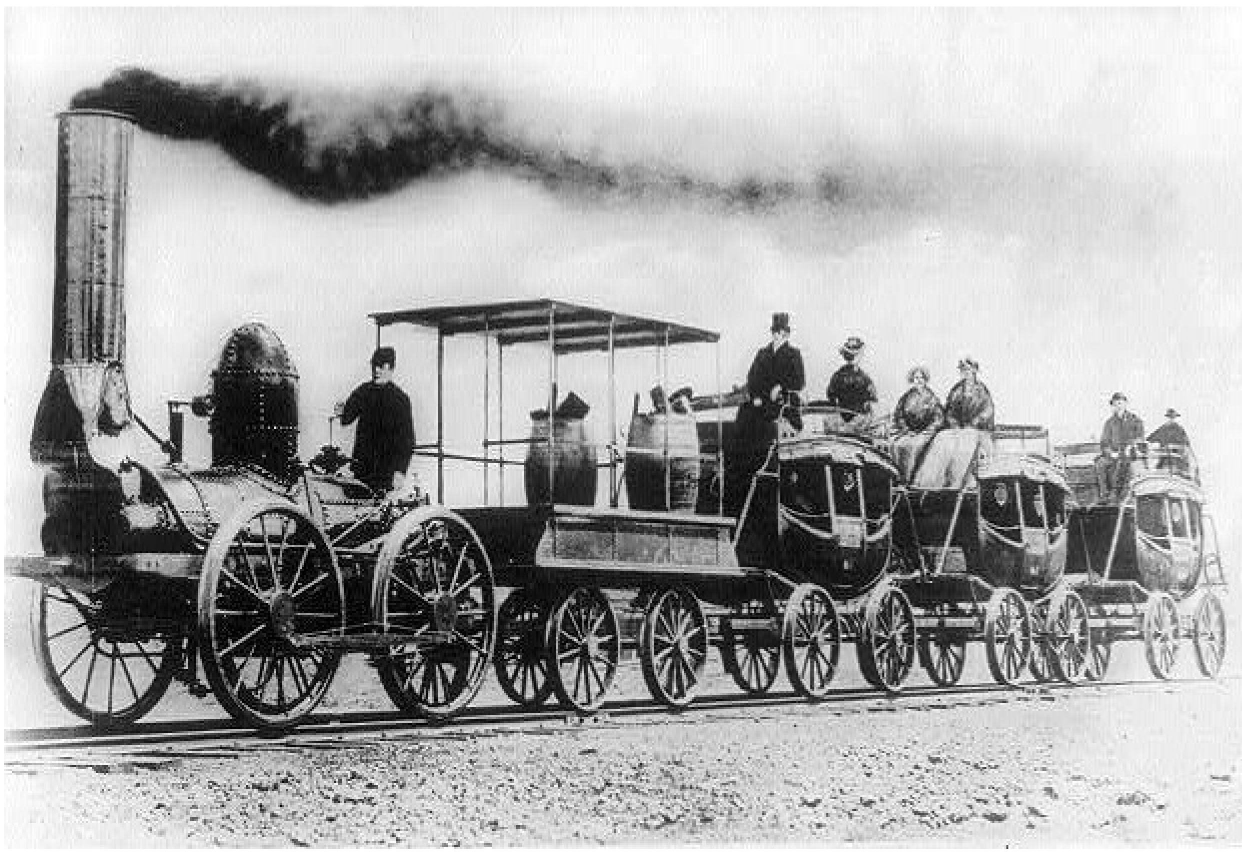
Earlier civilizations used renewable energy sources exclusively

- Biomass for heat and cooking
- Wind for windmills (pumping) and sailing
- Water for watermills (milling)
- Solar for thermal regulation
- Animal and human energy for labor

These sources are renewable with little long-term impact on the environment, but have a generally low energy density.

Energy density is the amount of energy per volume

Industrial Revolution and Steam Engine (James Watt, 1774) greatly increased demand for raw energy (to do work)



DeWitt Clinton Locomotive (1831)

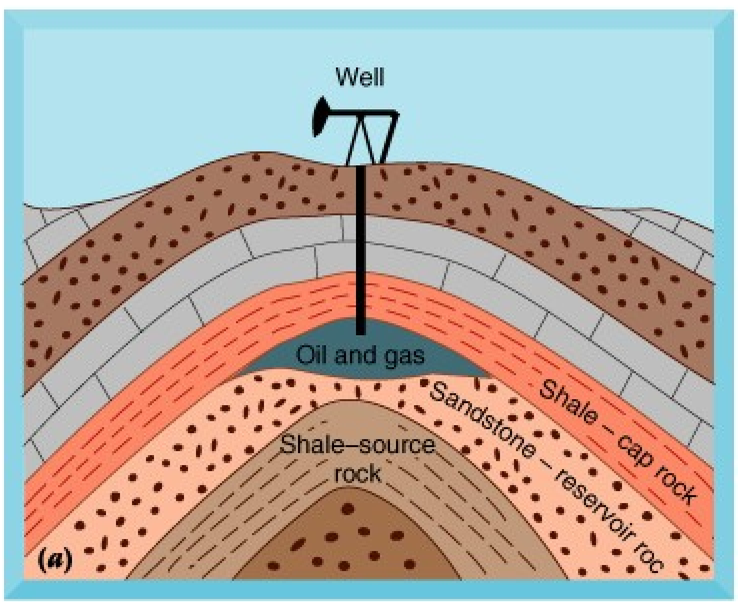
Burning lots of wood! The switch to coal (which was plentiful at the time in England) was to reduce the deforestation.

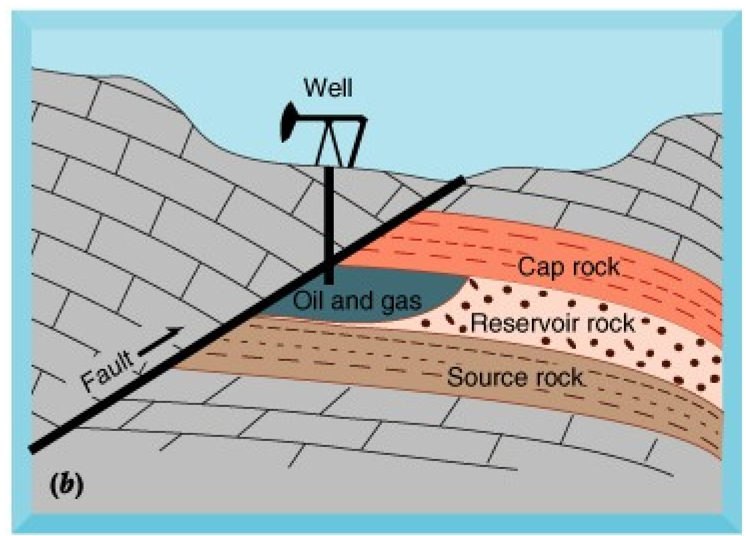
Transition to fossil fuels

Coal – used as early as 13th century, extensive use by mid-19th century, starting in UK and USA

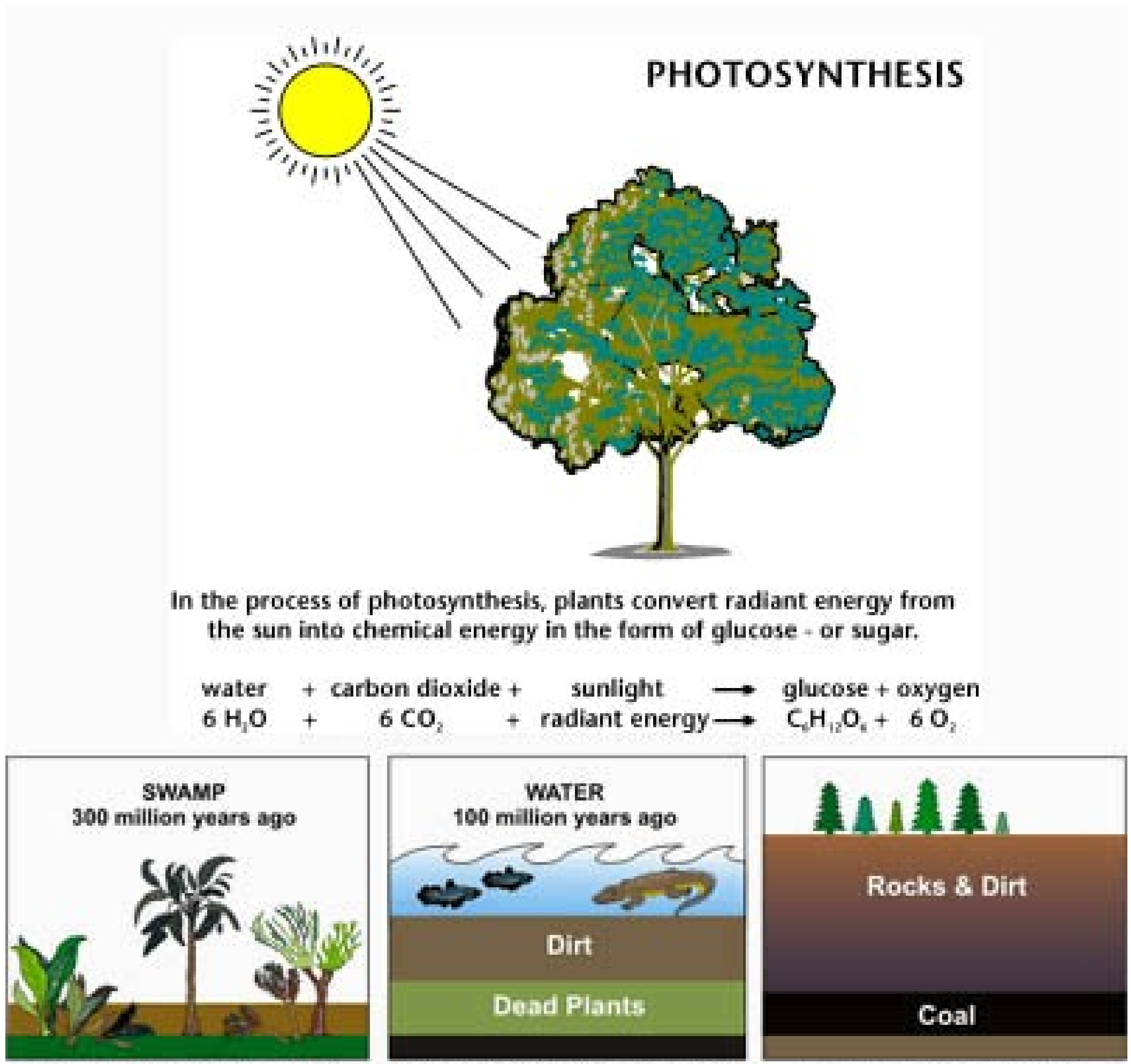
Oil – used mid-late 19th century

Natural Gas – used late 19th century, big boom after WWII





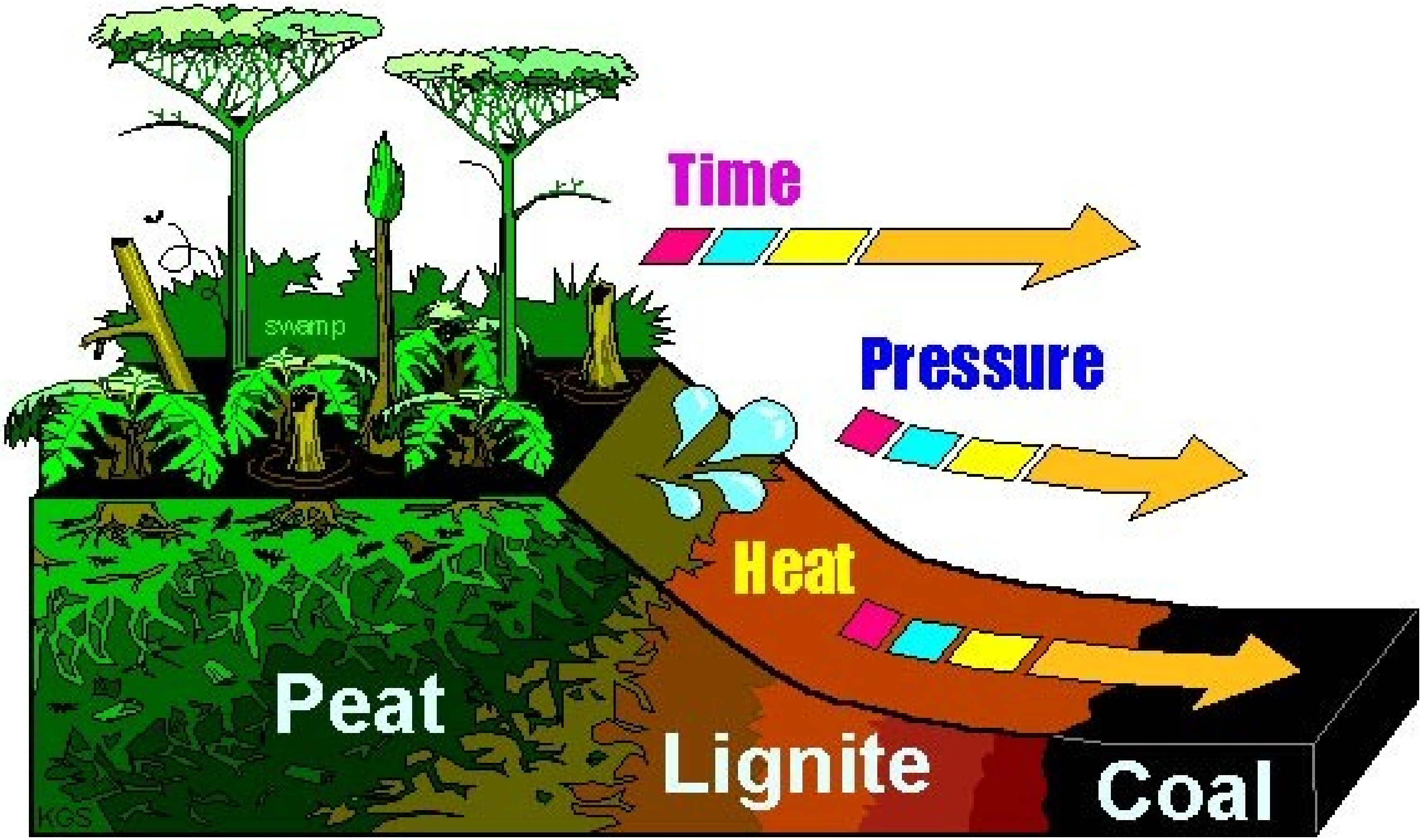
Fossil Fuels are derived from partially decomposed organic materials transformed in Earth's crust by pressure, heat and bacterial processes. It takes millions of years for these organisms to chemically change into fossil fuels.



Before the dinosaurs, many giant plants died in swamps.

Over millions of years, the plants were buried under water and dirt.

Heat and pressure turned the dead plants into coal.



Coal formation

Coal – four basic types of coal rated by its carbon (energy) and sulfur content

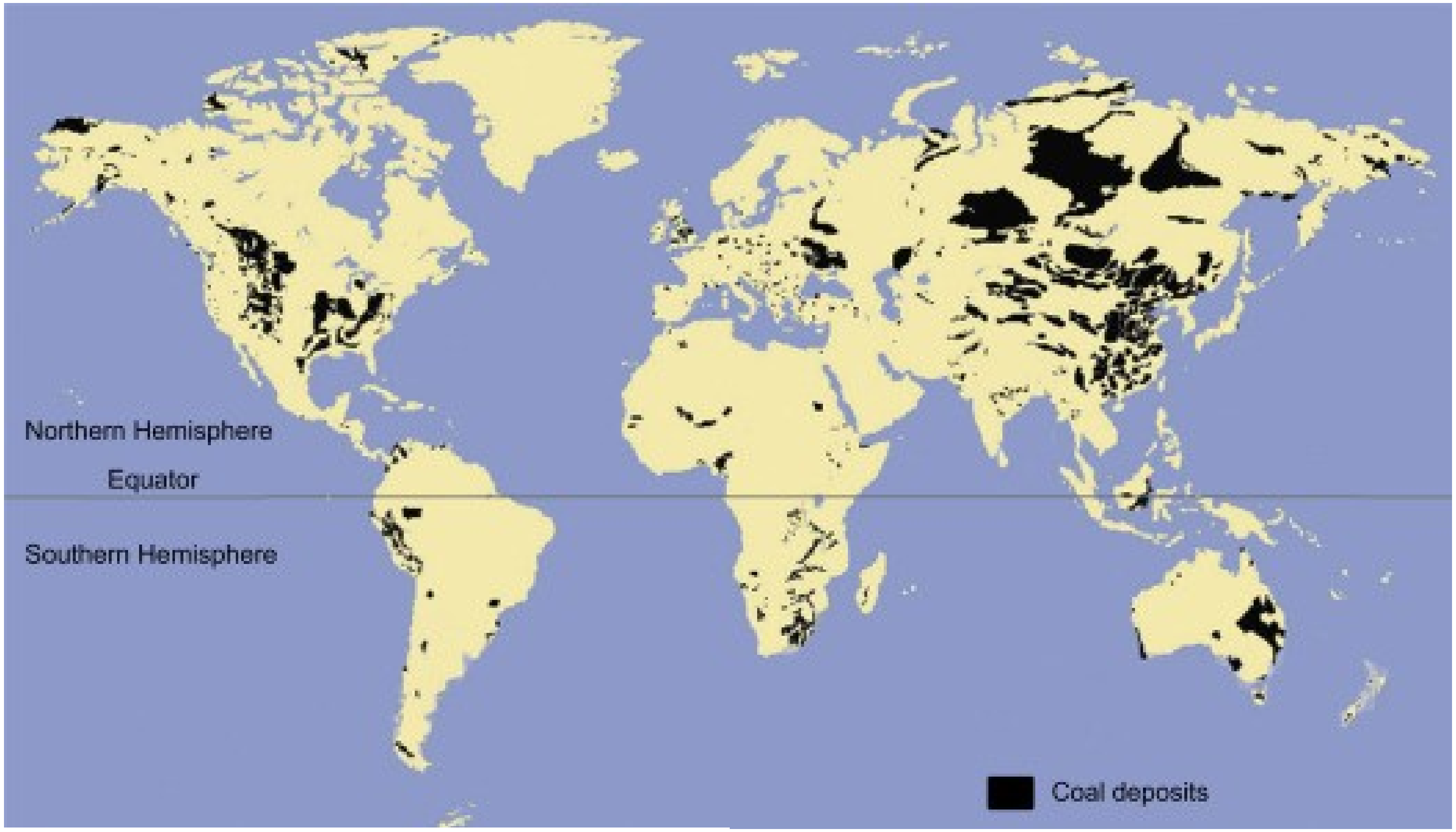
	Energy (MJ/kg)	Sulfur
Anthracite	High (>32)	Low
Bituminous	Med-High (30-32)	High
Subbituminous	Low-Med (19-30)	Low
Lignite	Low (14-19)	Low

Firewood (16 MJ/kg)

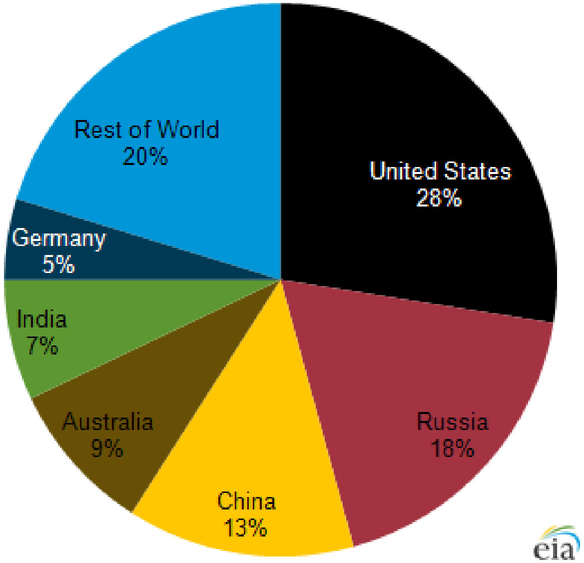
Charcoal (30 MJ/kg)

Natural Gas (39 MJ/m^3)

Crude Oil (45-46 MJ/kg)



Global share of recoverable coal reserves



Electricity Generation

whether from fossil fuels, nuclear, renewable fuels, or other sources - is usually* based on the fact that:

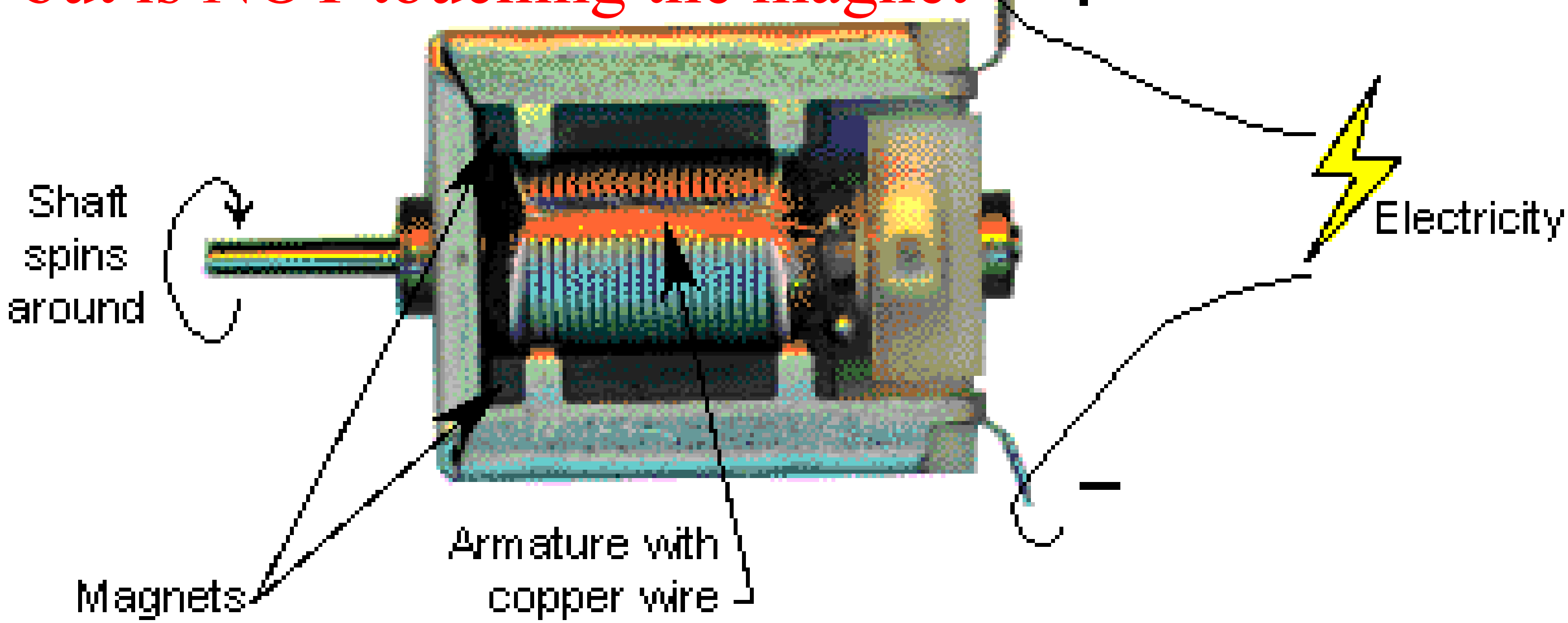
"When copper wire is moving through a magnetic field, an electric current is generated in that wire."

www.hawaii.gov/dbedt/ert/electgen.html

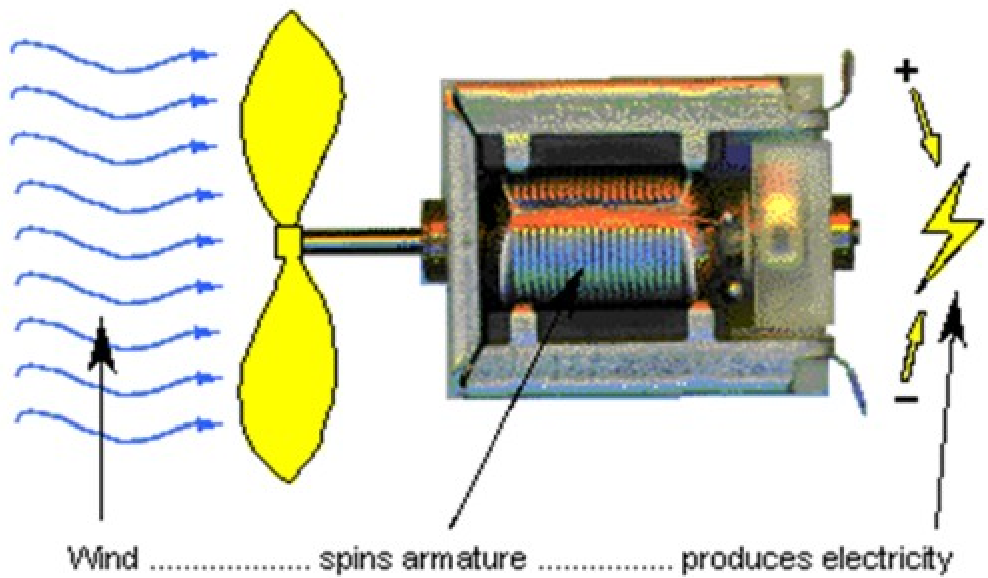
* exceptions are electrochemistry (batteries) and photovoltaic effect

In the picture, the shaft and armature (with copper wire) spin around. The magnets are on the outside (they don't move). Electricity, at the "+" and "-" terminals, is shown in the picture as a lighting bolt.

The wire is in the presence of the magnetic field, but is NOT touching the magnet



Generator produces electricity

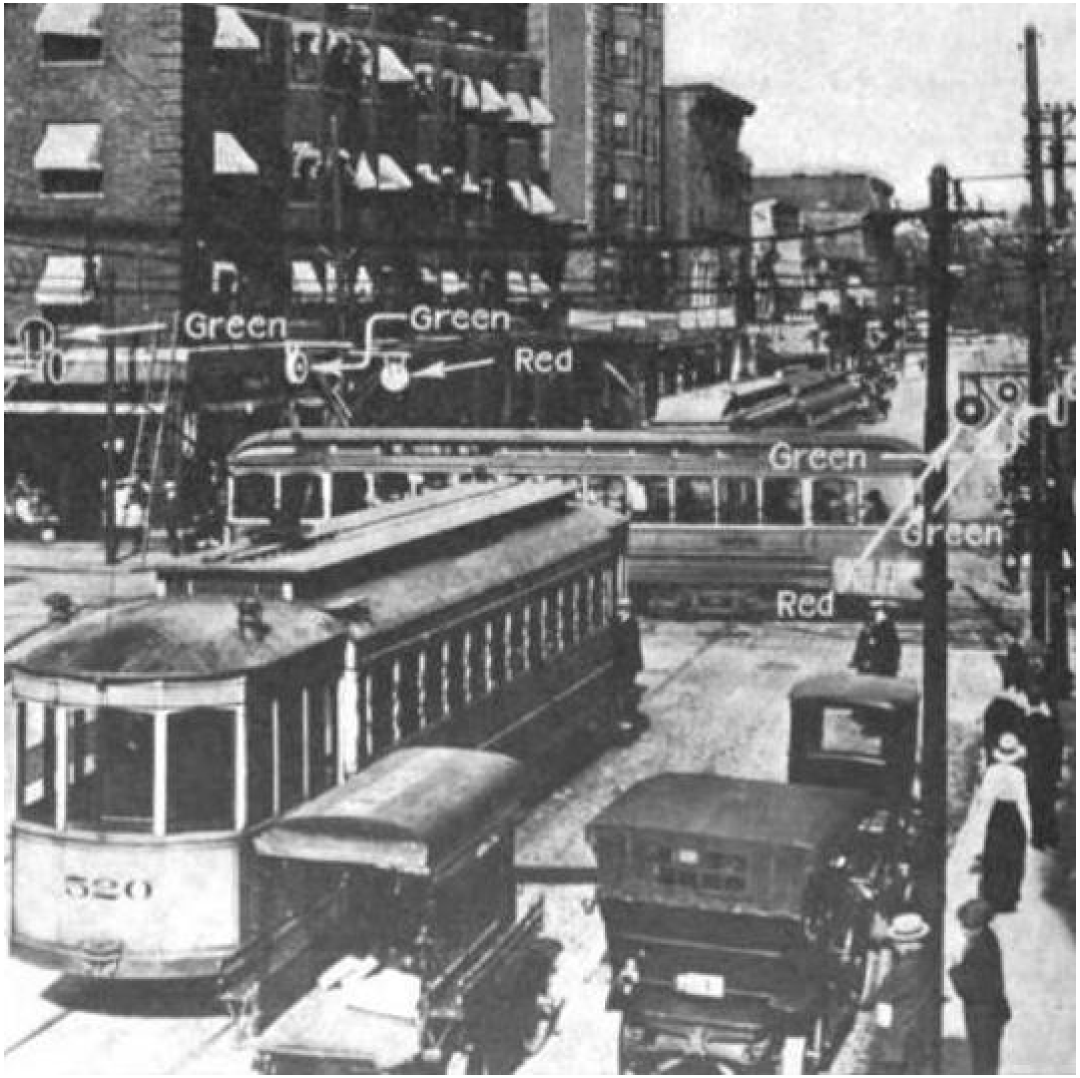


In 1870s, invention of incandescent light bulb led to lighting being one of the first publicly available applications of electricity.

NYC 1882

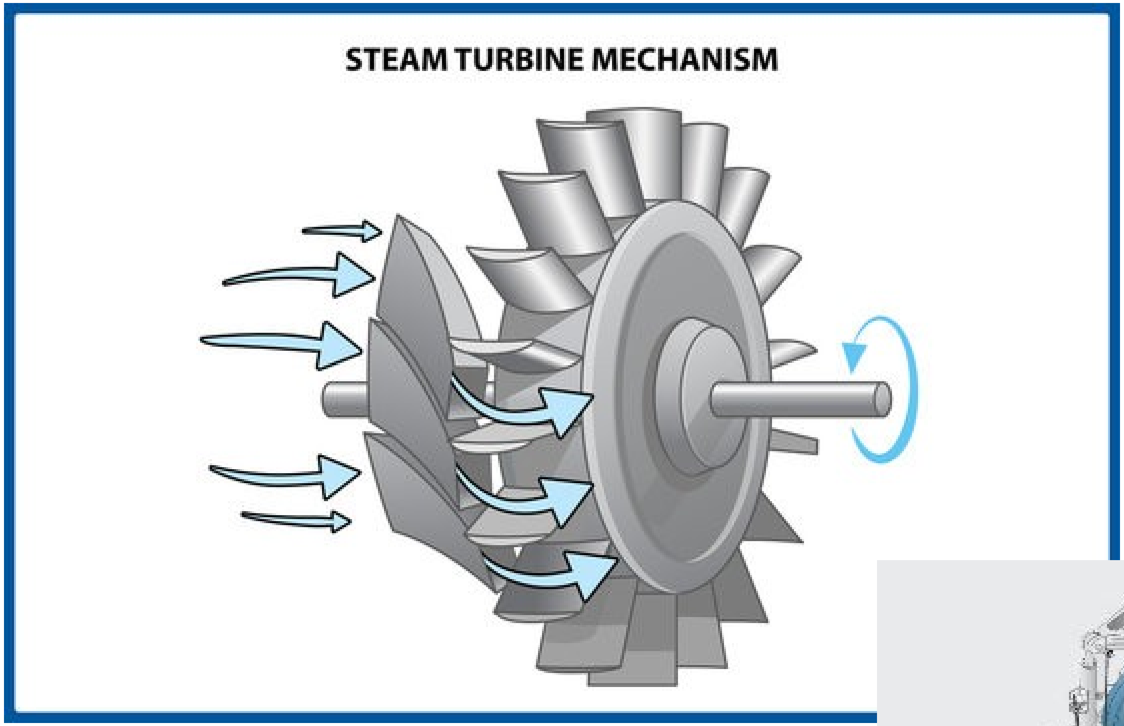
Mahen Theatre in 1882 was one of the first public buildings in the world lit entirely by electric light.

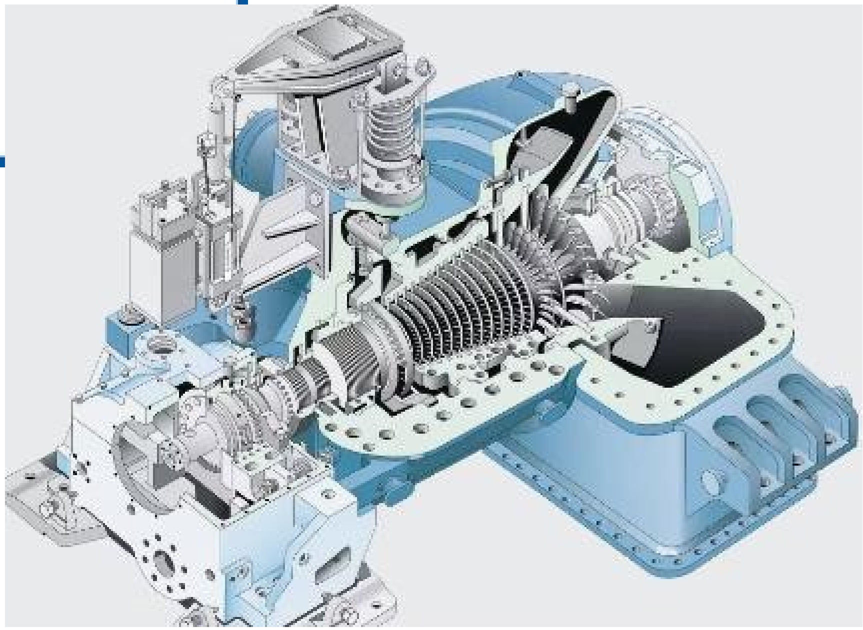
Electric trolley
Electric traffic light



1914

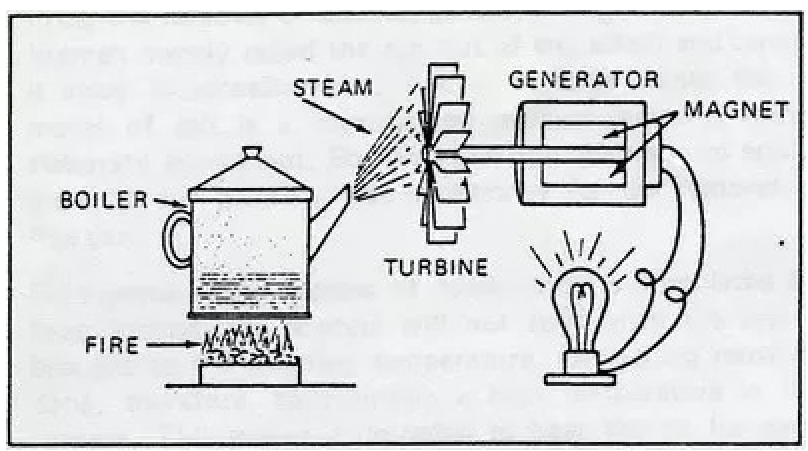
Steam turbine – 1884 – generates about 80 percent of electric power in the world

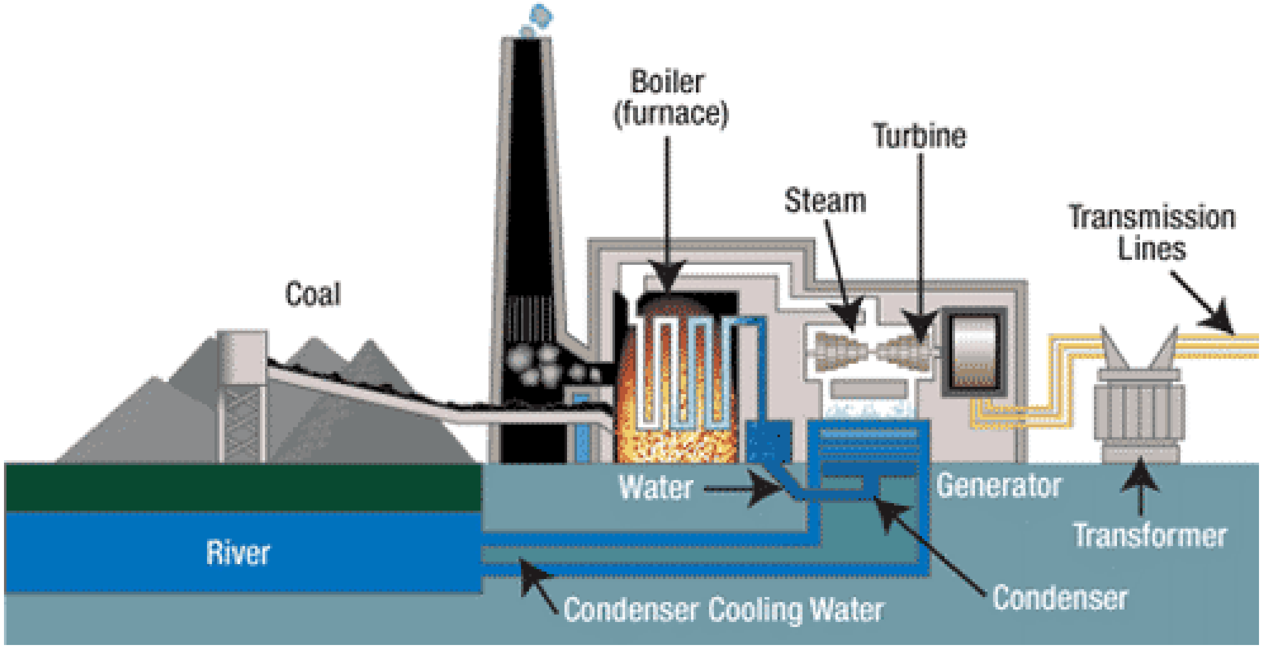




So **where do all the different energy sources** come in? It's all a question of how to get (and keep) the system moving (i.e., how to keep the copper wire spinning around).

In a **steam power plant**, fuels (such as petroleum, coal, or biomass) are burned to heat water which turns into steam, which goes through a turbine, which spins...*turning the copper wire (armature) inside the generator and generating an electric current.*





Electric generators are essentially very large quantities of copper wire spinning around inside very large magnets at very high speeds.

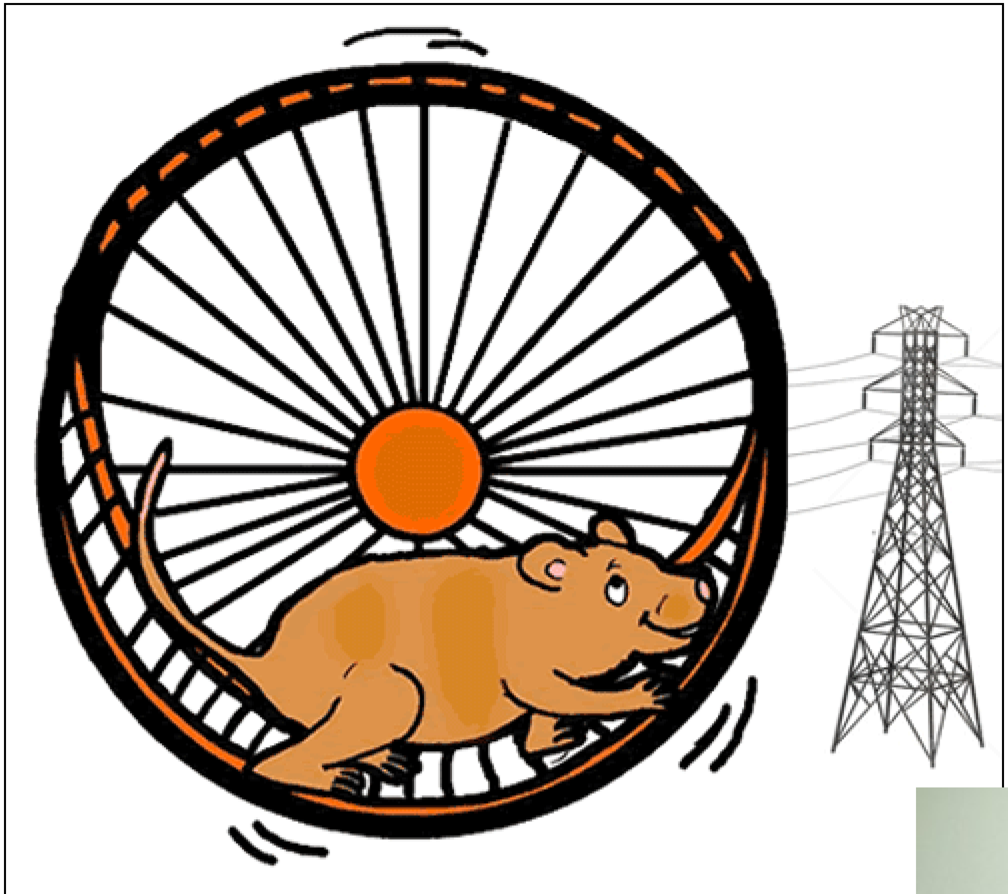
A commercial utility electric generator -- for example, a 180-megawatt generator is 20 ft in diameter, 50 ft long, and weighs >50 tons. The copper coils (called the "armature") spin at 3600 rpm. Although the principle is simple (copper wire and magnets), it's not necessarily easy!

In a **nuclear** power plant, nuclear reactions create heat to heat water, which turns into steam, which goes through a turbine, which spins...*turning the copper armature inside the generator and generating an electric current.*

In a **wind turbine**, the wind pushes against the turbine blades, causing the rotor to spin...*turning the copper armature inside the generator and generating an electric current.*

In a **hydroelectric turbine**, flowing (or falling) water pushes against the turbine blades, causing the rotor to spin...*turning the copper armature inside the generator and generating an electric current.*

The different energy sources just provide energy to do the same basic thing...*turning the copper armature inside the generator and generating an electric current*.



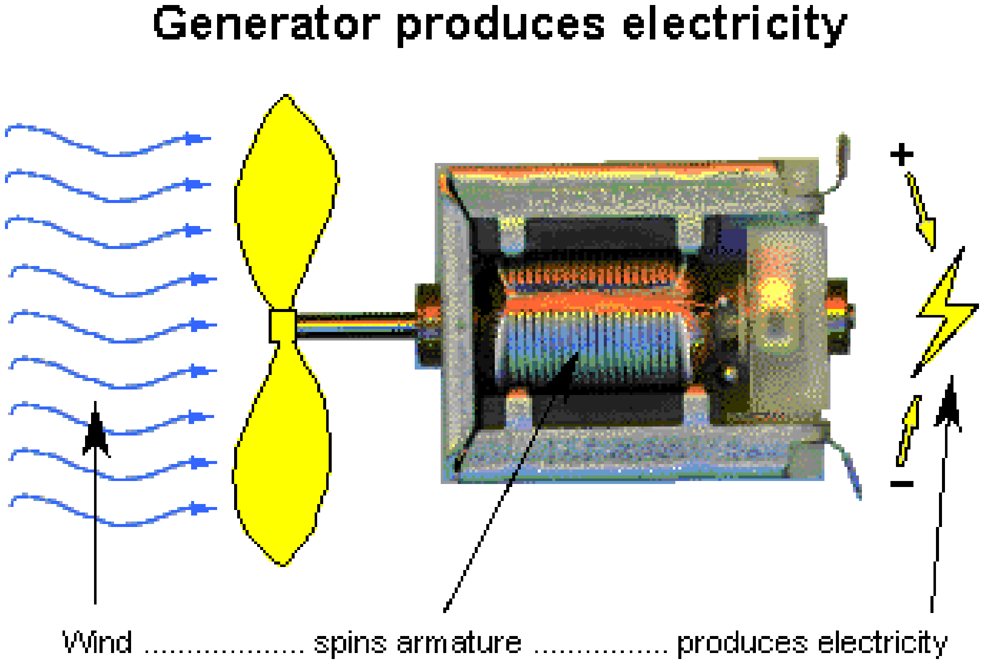
Hamsters

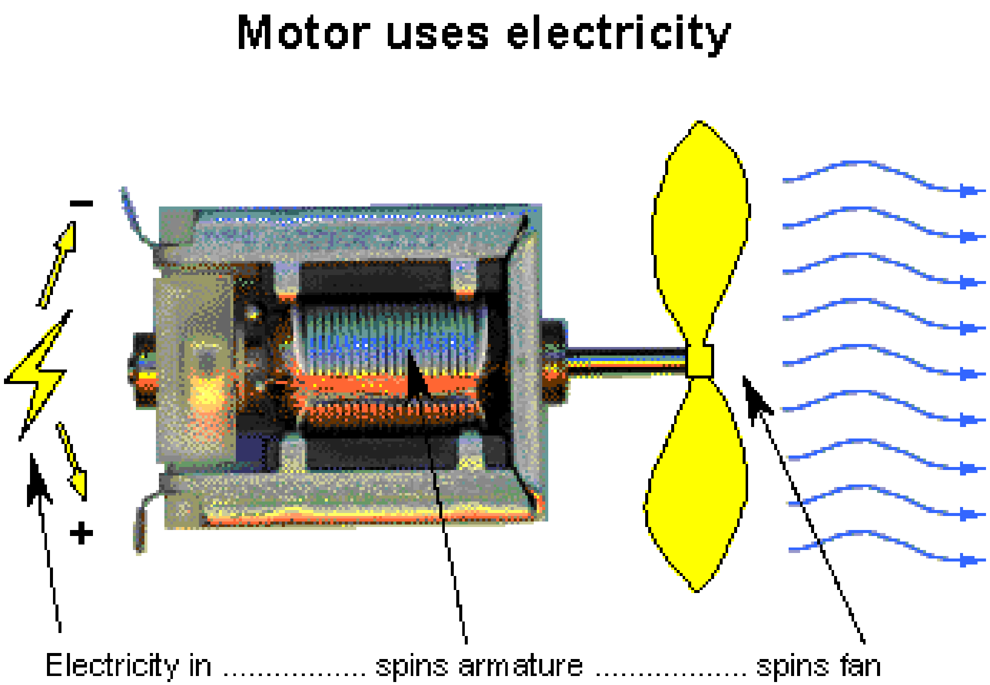
Humans

A "generator" and "motor" are essentially the same thing: what you call it depends on whether electricity is going into the unit or coming out of it.

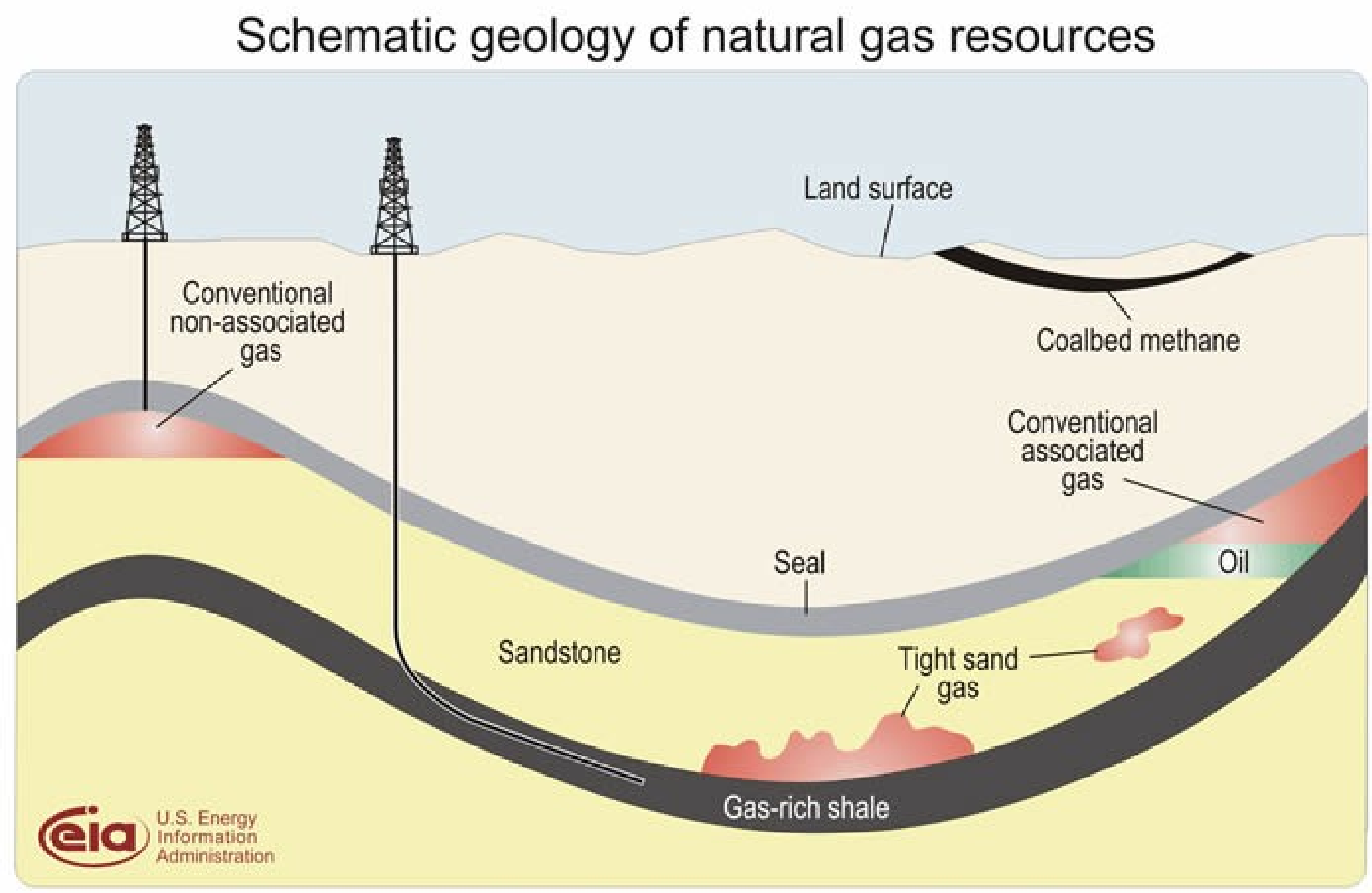
A generator produces electricity. In a generator, something causes the shaft and armature to spin. Lots of things can be used to make a shaft spin. It doesn't matter what's used to spin the shaft - the electricity that's produced is the same.

A motor uses electricity. The electric current causes the armature and shaft to spin.

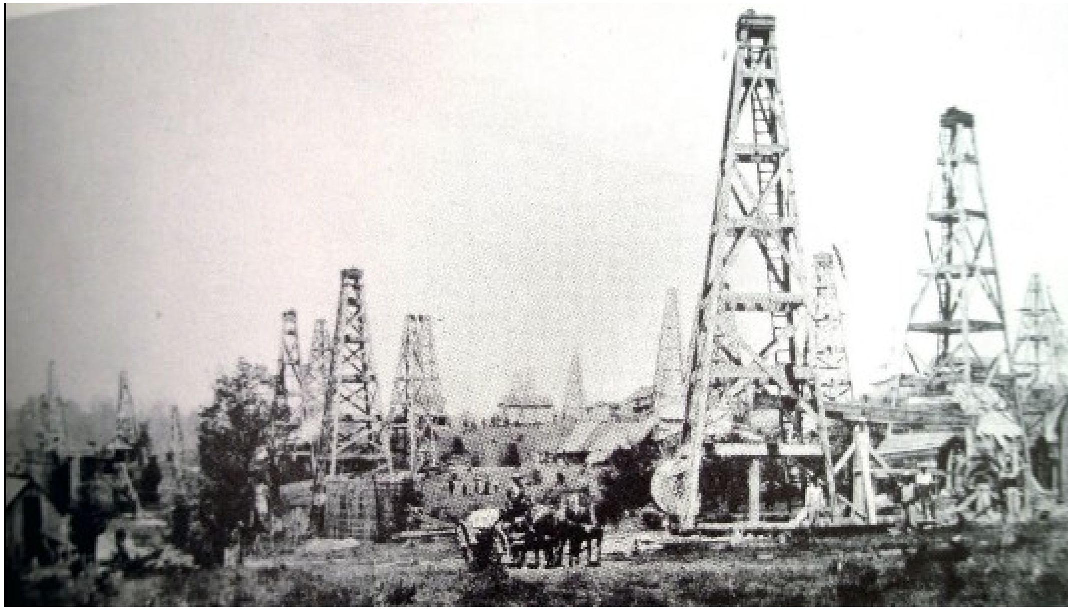


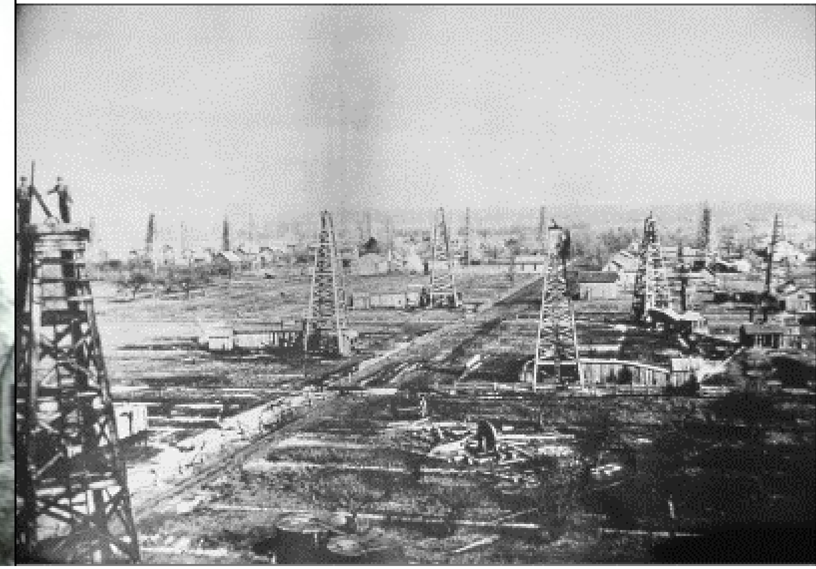


Original Col. Drake Well, August 27, 1859
Titusville, Pa



Conventional gas is easier to extract
Tight gas or shale gas must spend energy to extract





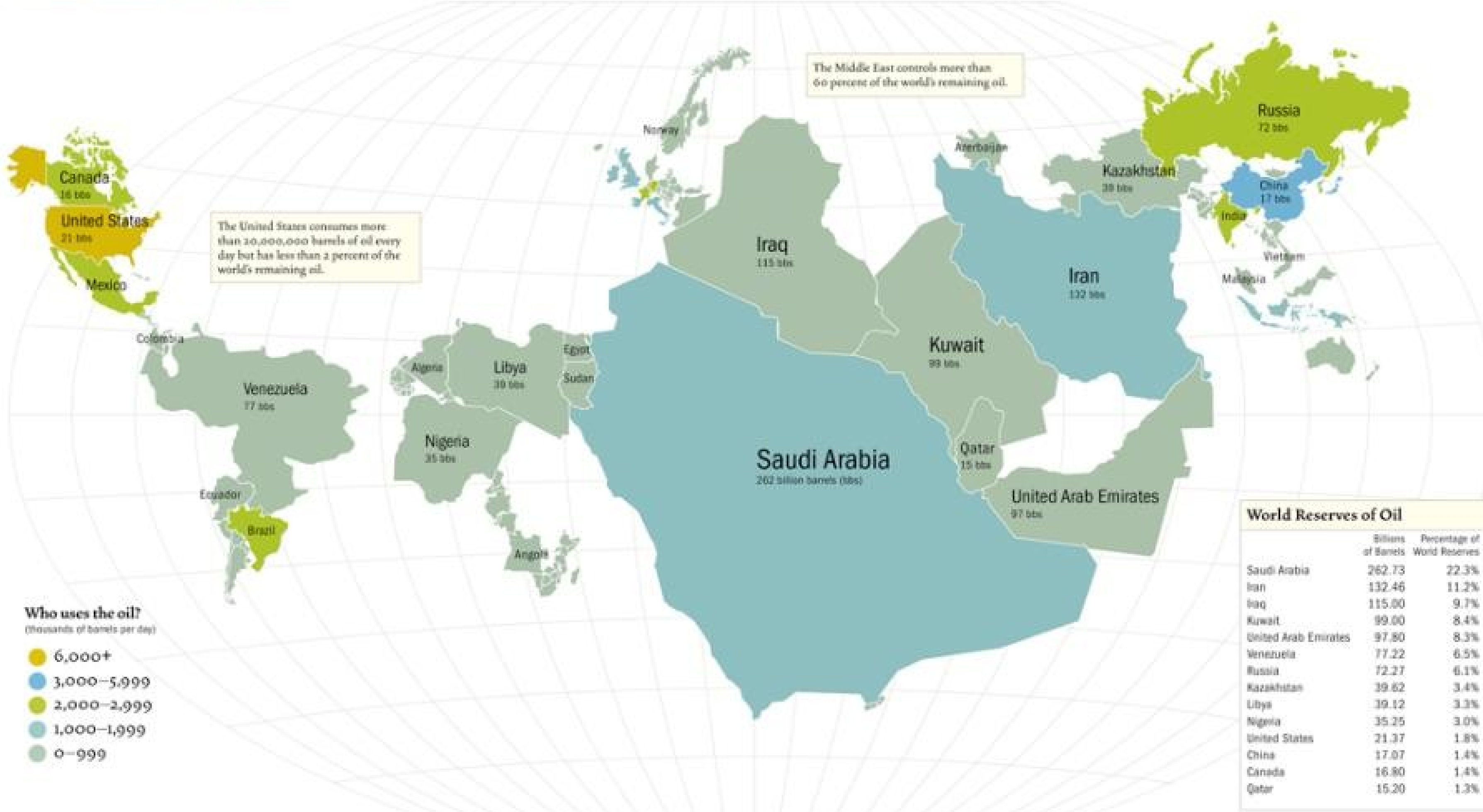
Early Pennsylvania oil industry (1860s) Ohio oil rush (1885)

Kilgore oil field in East Texas (1930s)

Notice complete lack of concern for the landscape/environment

Saudi Arabia oil production

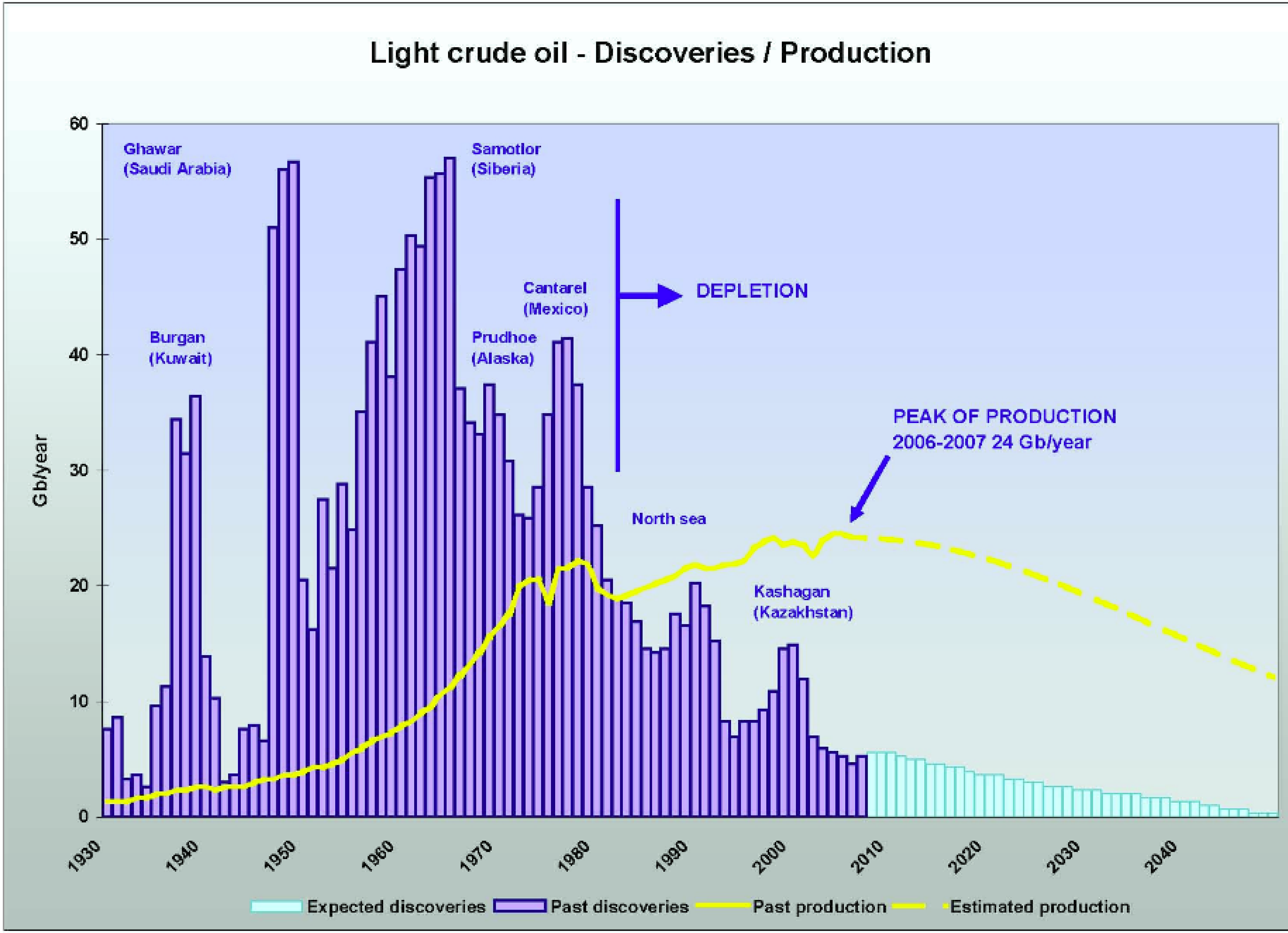
Who has the oil?



World Reserves of Oil

	Billions of Barrels	Percentage of World Reserves
Saudi Arabia	262.73	22.3%
Iran	132.46	11.2%
Iraq	115.00	9.7%
Kuwait	99.00	8.4%
United Arab Emirates	97.80	8.3%
Venezuela	77.22	6.5%
Russia	72.27	6.1%
Kazakhstan	39.62	3.4%
Libya	39.12	3.3%
Nigeria	35.25	3.0%
United States	21.37	1.8%
China	17.07	1.4%
Canada	16.80	1.4%
Qatar	15.20	1.3%

Each country's size is proportional to the amount of oil it contains (oil reserves); Source: *BP Statistical Review Year-End 2004* & Energy Information Administration



Light crude oil - Discoveries / Production
Gb/year
0
10
20
30
40
50
60
Ghawar
(Saudi Arabia)
Burgan
(Kuwait)
Samotlor
(Siberia)
Prudhoe
(Alaska)
Cantarel
(Mexico)
DEPLETION
North sea
Kashagan
(Kazakhstan)
PEAK OF PRODUCTION
2006-2007 24 Gb/year
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
Expected discoveries
Past discoveries
Past production
Estimated production

Size and Speed matter
Kinetic Energy = ½ mv^2

- Ford Expedition weight 5,692 lbs = 2582 kg

- Honda Fit weight 2,648 lbs =1201 kg

- 55 mph = 24.59 m/s
- 780,627 J Expedition at 55 mph
- 363,103 J Fit at 55 mph

- 75 mph = 33.53 m/s
- 1,451,421 J Expedition at 75 mph
- 675,119 J Fit at 75 mph

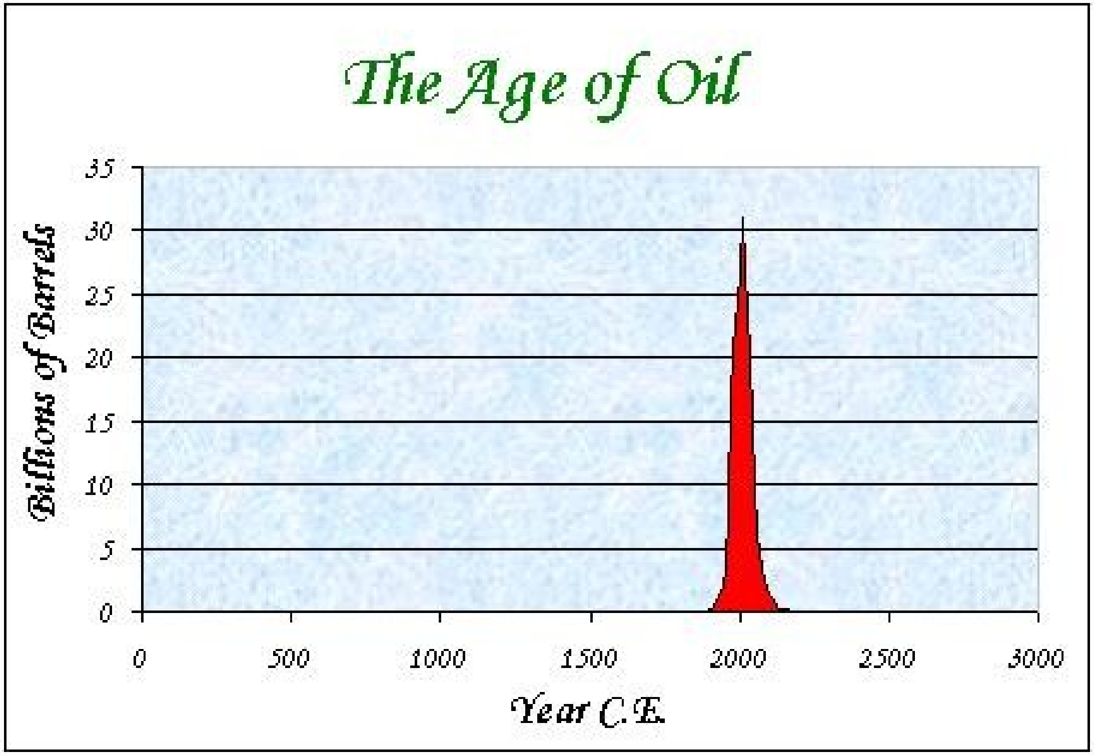
[Gas prices around the world]

Fuel-efficient driving techniques

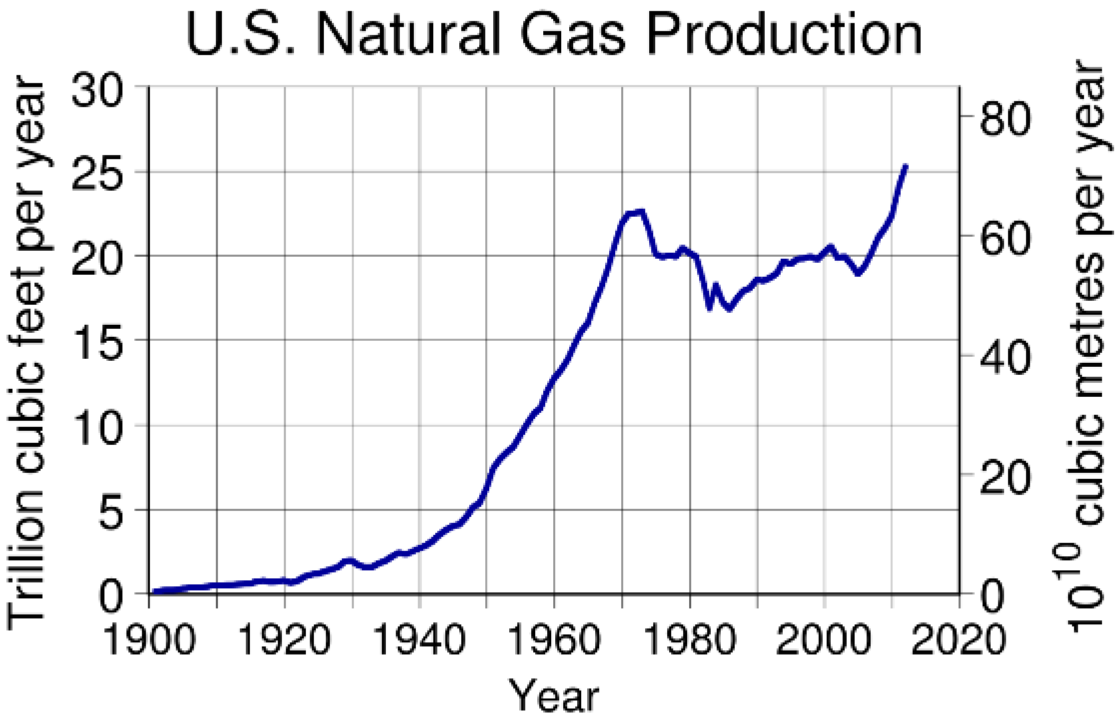
- **1. Accelerate gently – don’t spill your coffee!**
- **2. Maintain a steady speed**
- **3. Anticipate traffic**
- **4. Avoid high speeds**
- **5. Coast to decelerate**

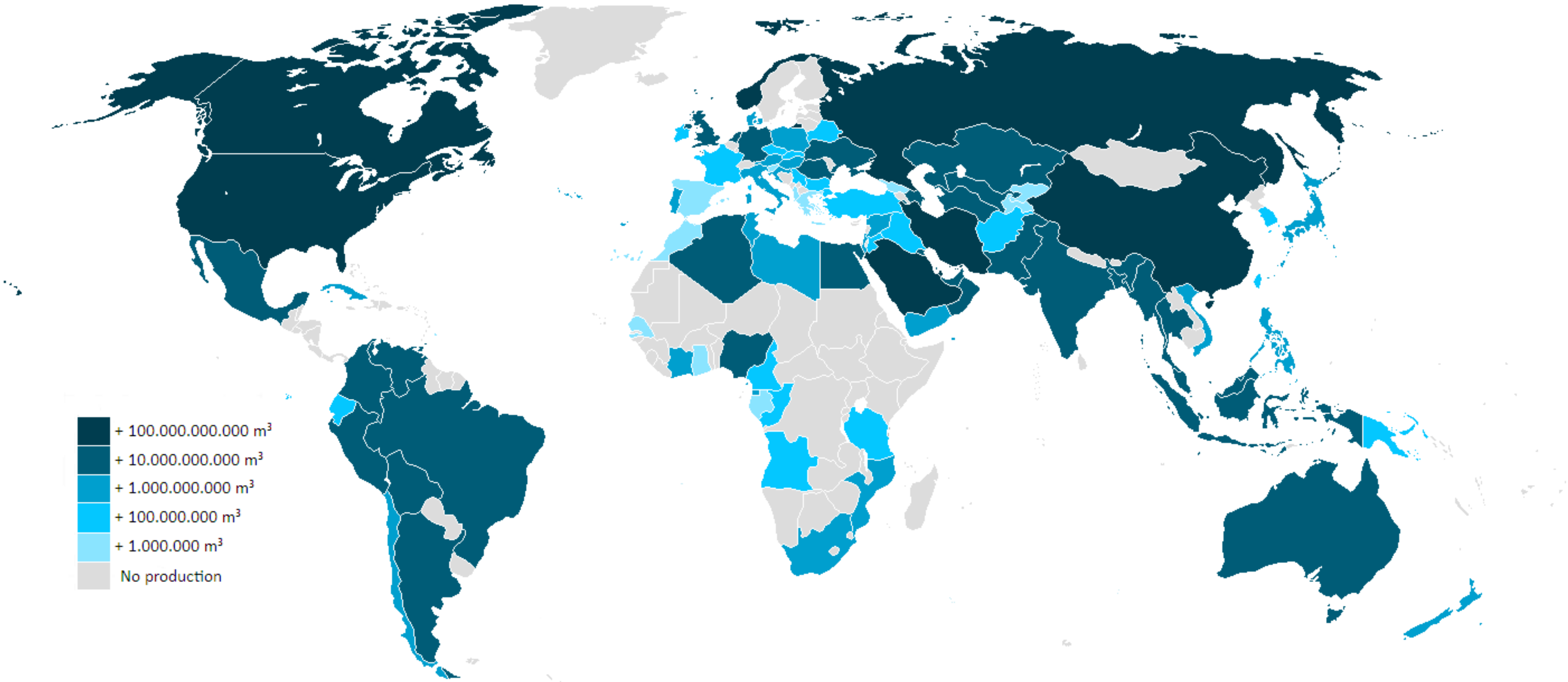
- **Avoid idling your vehicle**
- **Measure your tire pressure every month**
- **Don’t carry unnecessary weight**
- **Remove roof or bicycle racks**
- **Use air conditioning sparingly**
- **Use a fuel consumption display**
- **Track your fuel consumption -** Challenge yourself to refill as seldom as possible.
- **Plan ahead Combine trips**
- **Drive less** - Best way reduce fuel consumption is to drive less (walk, bike, mass transit, car pool).
- **Challenge yourself**

www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation-alternative-fuels/personal-vehicles/fuel-efficient-driving-techniques/21038



M.K. Hubbert’s view of the oil age over the long-term


U.S. Natural Gas Production
Trillion cubic feet per year
0
5
10
15
20
25
30
1900
1920
1940
1960
1980
2000
2020
Year
0
20
40
60
80
10^{10} cubic metres per year



Natural gas extraction by countries in cubic meters per year around 2013

Natural gas is more globally distributed

Environmental Impacts of Fossil Fuel Use

Environmental impacts of fossil fuel use

Recovery – land disruption, loss of habitat, surface water pollution, air pollutants, land subsidence

Off-shore oil drilling –oil seepages, aesthetic degradation

Refining – spills leaks, soil and groundwater pollution

Delivery – Spills

Use CO_2 – emission, air pollution (smog), acid rain

BOTH SUPPLY AND USE ISSUES
WITH FOSSIL FUEL RESOURCES

Summary

- Energy is needed for all work/activities in society, economy and life
- Mostly we use fossil fuels
  - They form as stored solar energy from millions of years ago
  - They are responsible for the vast complex and convenient society we currently live in
  - They are non-renewable and thus limited in supply
  - Unevenly spread around the world
  - Use of them has severe environmental impacts