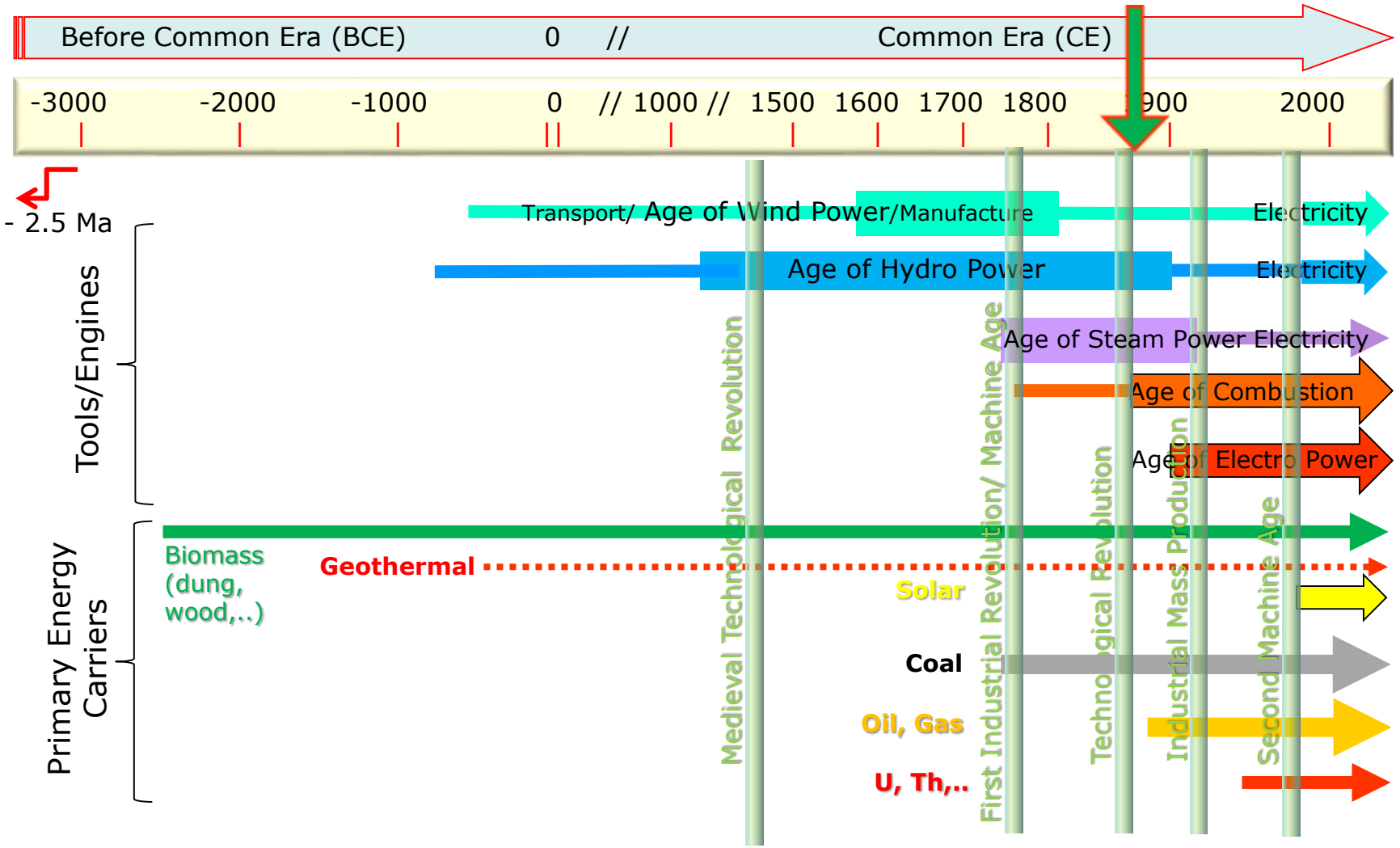
Tools and Fuels in Human History II

Time Line Tools & Fuels (Western Cultures)



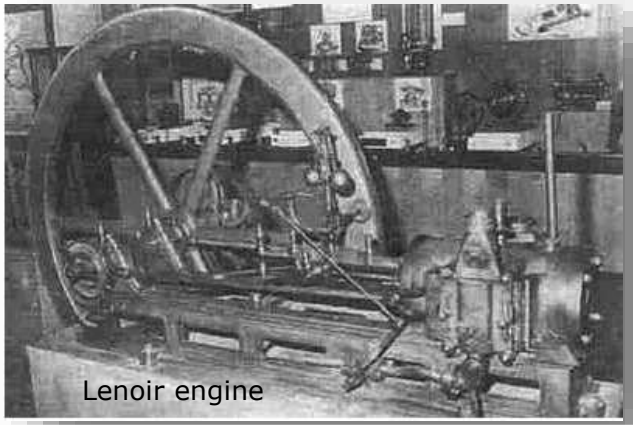
Advent of internal combustine engine, discovery of crude oil as fuel, S&T of electro-magnetism→electricity as carrier, nuclear power

The Internal Combustion Engine

Nicolaus Otto
1832-1891

Karl Benz
1844-1929

Internal combustion engine built by Jean Joseph Etienne Lenoir (Paris, 1860).
Double-acting engine running on illuminating gas (18 liter, 2 hp, 4% efficiency).
Nicolaus Otto saw engine on visit to Paris.

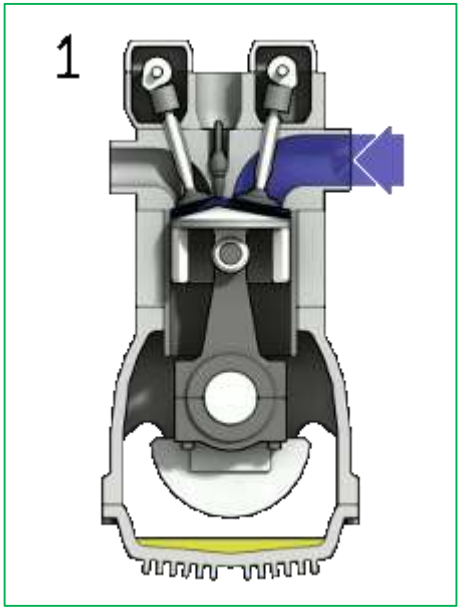


Lenoir engine

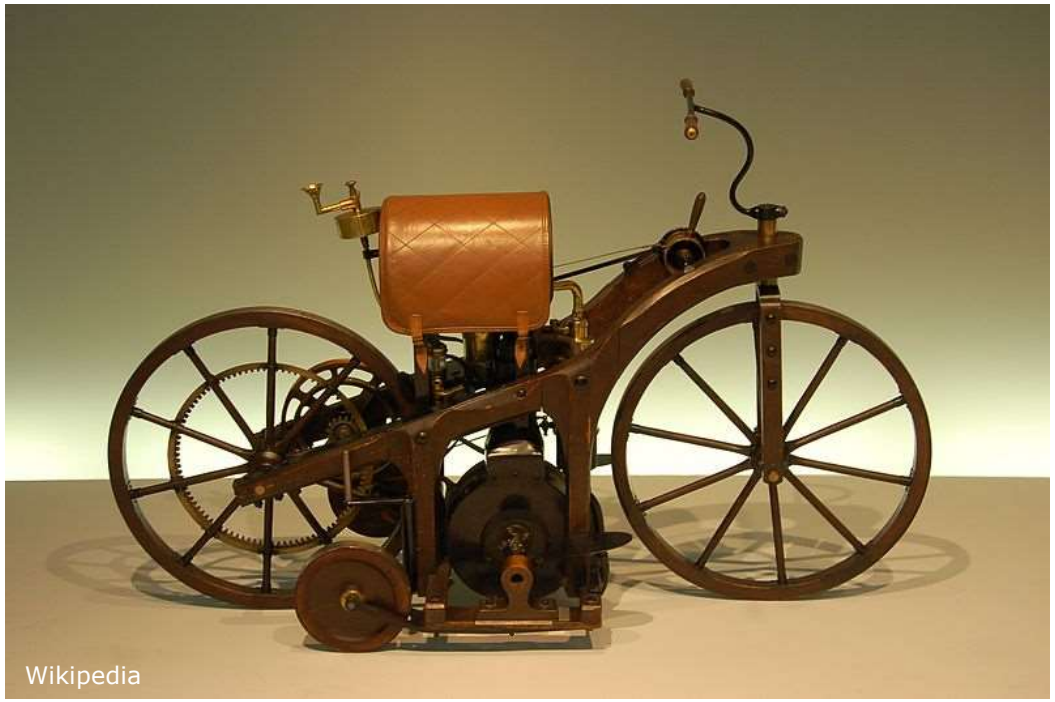
First practical automobile Karl Benz:Mannheim, 1885.

1876: Otto and Langen created first internal combustion engine with compression of fuel mixture prior to combustion.
→ higher efficiency.
Piston, cylinder intake & exhaust valves, camshaft.

Modern Otto Motor



Early Liquid Transportation Fuels


Wikipedia

1885 Daimler "Petroleum Reitwagen" = motor bike with Otto engine, hot-tube ignition, fuel= ligroin. Fuel used until the early 1900s.

Replaced by petroleum gasoline → (Petrol, gas, Benzin,..)

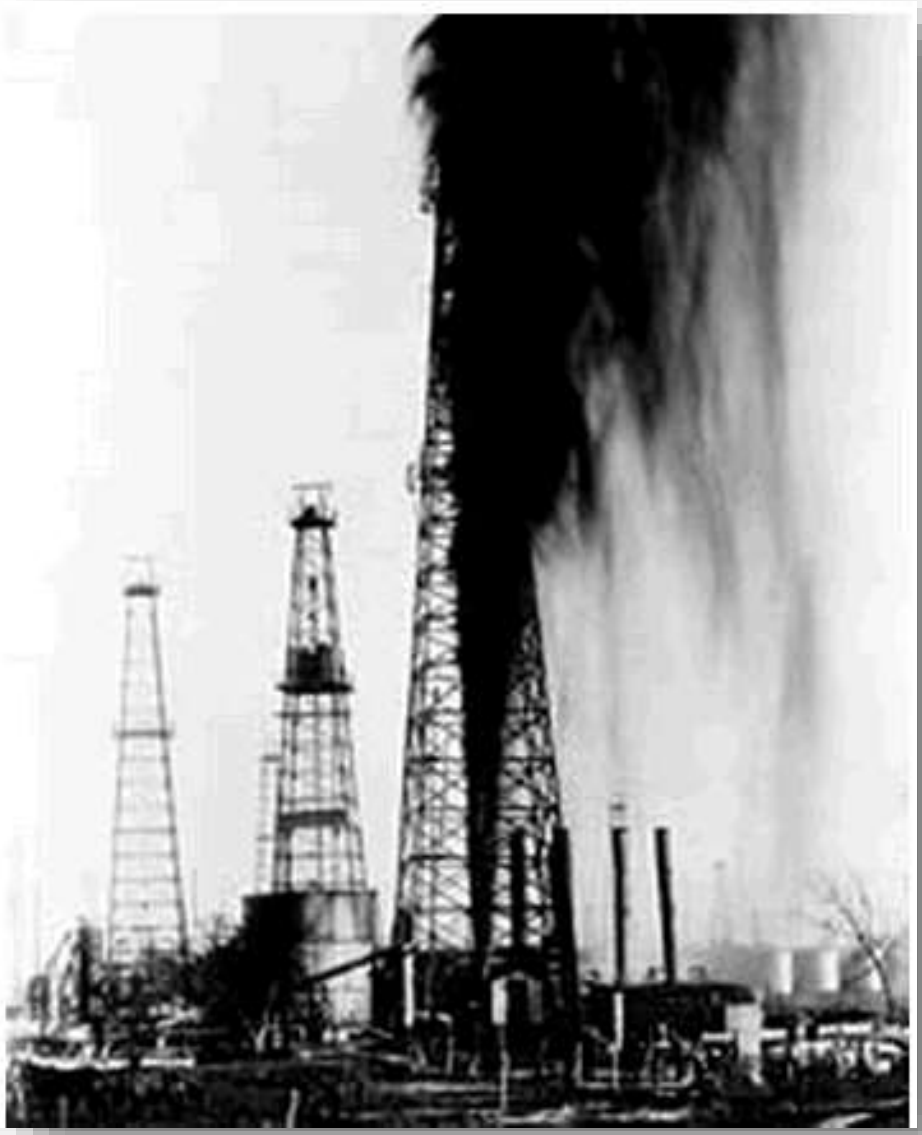

Gasoline filled jar, Wikipedia

Ligroin mixture of various volatile, highly flammable, hydrocarbon mixtures used chiefly as nonpolar solvents. Obtained in fractionated distillation of petroleum/oil.

Consistency: C_7 to C_{11} (55% paraffins, 30% monocycloparaffins, 12% alkylbenzenes, and 2% dicycloparaffins).

Boiling point(s) 60^0C- 90°C. Refined saturated hydrocarbon (petroleum) fraction, similar to petroleum ether, a laboratory solvent.

Discovery of a Potent Fuel: Oil



The discovery of oil in Texas in the late 1800s/early 1900s ushered in a new era: the liquid-fuel era.
Cheap oil provided the basis for the development and operation of the Western industrial society in 20th - 21st centuries.

Businessman/amateur geologist Patillo Higgins founded unsuccessful Gladys City Oil, Gas and Manufacturing Co.

1901: Mining engineer Anthony Lucas found oil under a salt-dome formation near Beaumont/TX
Photograph of Lucas gusher at Spindletop.

"Black Gold" boom → 285 active oil wells

Early companies Humble (now Exxon),
Texas Company (Texaco)
Magnolia Petroleum Company (Mobil).

Fossil oil replaced wale oil for lighting and ligroin for transportation fuel.

Major oil exporting countries: Saudi Arabia, Venezuela, Russia, Canada.

Prolific Oil Fields (Ghawar/Saudi-Arabia)

Oil-Roots of Modern Middle-East:Saudi-Arabia

February 14, 1945,
Meeting FDR-Ibn Saud
on USS Quincy

MORE GAS BURNS near stabilizer plant (foreground) at Abqaiq field, where toxic gas is removed before crude oil can be safely shipped. Gases are piped off and set afire (left, center). The process is wasteful but necessary since there is no commercial use for gas in Arabia

American oil company convoy on Arabian peninsula (1949). End of British dominance.

LIFE Magazine Mar 28, 1949

ARAMCO

AN ARABIAN-AMERICAN PARTNERSHIP DEVELOPS DESERT OIL AND PLACES U.S. INFLUENCE AND POWER IN MIDDLE EAST

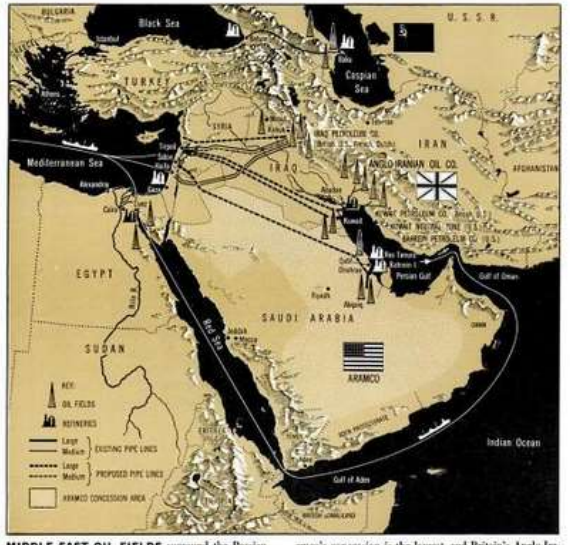
PHOTOGRAPHS FOR LIFE BY DAVID DOUGLAS DUNCAN

In May 1933, when the camel grass was fresh on Arabia's desert, the King of Saudi Arabia entered into a contract selling oil rights in a vast area of his kingdom to the Standard Oil Co. of California. An American listed "visible assets" thus gained as "a lot of sand, a lot of heat, a lot of flies and a great deal of faith." Yet this spring, 16 years later, the result of that contract and faith is a spectacular example of American enterprise at work abroad. It is called "Aramco"—the Arabian American Oil Company—and is pictured in the next 15 pages.

Aramco in its larger aspects could be a prototype of the kind of thing President Truman had in mind in his "bold new program" of American guidance for "underdeveloped areas." In its second decade of active operation, Aramco is the biggest Middle East oil producer and one of the largest in the world. It already has altered the daily lives of many of the subjects of a primitive kingdom and projected U.S. interest into an area which was until lately a domain of British power. It involves one of the biggest single investments—$250 million—of private capital abroad and currently earns a huge operating profit which Aramco justifies by pointing to such risks as the vagaries of the times in the Middle East, the proximity of the Russians (850 miles north) and the ceaseless ups and downs of international oil politics (*p. 79*).

Now owned by four major U.S. oil companies (Standard of California, the Texas Co., Standard of New Jersey, Socony-Vacuum), Aramco has lured some 3,600 Americans to work in Saudi Arabia in five years. Aramco's growth has agitated lesser competitors in U.S. oil, inspired congressional investigations of oil prices and set pundits on guard against "oil diplomacy." Aramco operates in an area holding 42% of the world's known oil reserve. It is therefore at once a strategic resource and concern of the U.S. Only recently, when the U.S. Air Force's *Lucky Lady II* flew nonstop around the world, her second refueling was over Dhahran, Aramco's headquarters town. The U.S. government is now negotiating to retain limited rights in Dhahran's airfield, which the U.S. Army built in 1946.

Aramco's visible achievements in Saudi Arabia can be a subject of justifiable U.S. pride. In the search for the oil which keeps the 20th Century world moving, its operation has set a stimulating new pace. It has projected the century of technology into and beyond an ancient world.



MIDDLE EAST OIL FIELDS surround the Persian Gulf. Map shows their ownership, refineries, pipelines. Aramco's concession is the largest, and Britain's Anglo-Iranian the area's pioneer—Britain acquired control in 1914.

Iran, Iraq, Libya

1920s-40s: Anglo-Persian Oil Company (APOC, now BP) bought oil concessions from Persian monarchy, owned rights to drill and prospecting, found great Persian oil resources, paid royalties (on profits) to state. Important for British WWII efforts.

1940s-50s regional anti-colonialism and democratic movement.

1951: Mohammed Mossadegh was elected democratically as Prime Minister. Nationalization of oil industry.

1953: Mossadegh overthrown in coup d'etat, supported by US. Shah Reza Pahlavi installed. US influence increased at the expense of British interests.

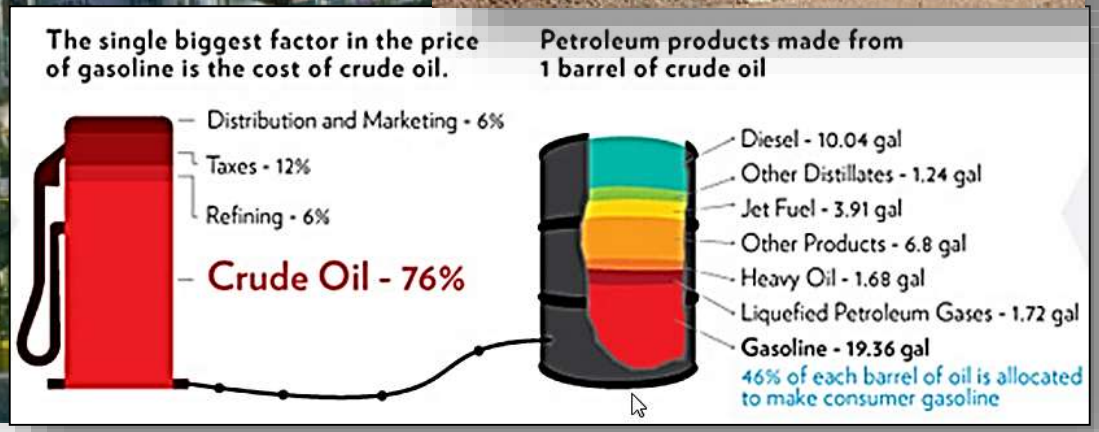
1979: Overthrow of Shah, Ayatollah Khomeini → Islamic Republic.

1990: First Gulf War after Saddam Hussein's invasion of Kuweit, accusing it of having illicitly accessed the large Rumaila oil field common to both countries. US led international Operation "Desert Storm" defeated Hussein's forces but left the regime in power.

2003: Second Gulf War, invasion and defeat of Iraq by mostly US forces, citing threats from Hussein's weapons program. Various occupation regimes.
2006:Nouri al-Maliki, Prime Minister (Shia), Sunni insurgency, AlQaeda in Iraq, …
2014: Haider Al-Abadi, Prime minister, inclusive governance

Oil Refinement and Uses

US: 144 oil refineries (none built since 30a)
Process 17 Mbbl/day (fractionated distillation)
Use: mostly transportation, industry, mostly chemical, residential. US gasoline demand 9.3 Mbbl → 12.9 Mbbl (2025)



Natural Gas / GTL Production

New gas-to-liquid facility in Qatar
Remodeling U.S. terminals for export

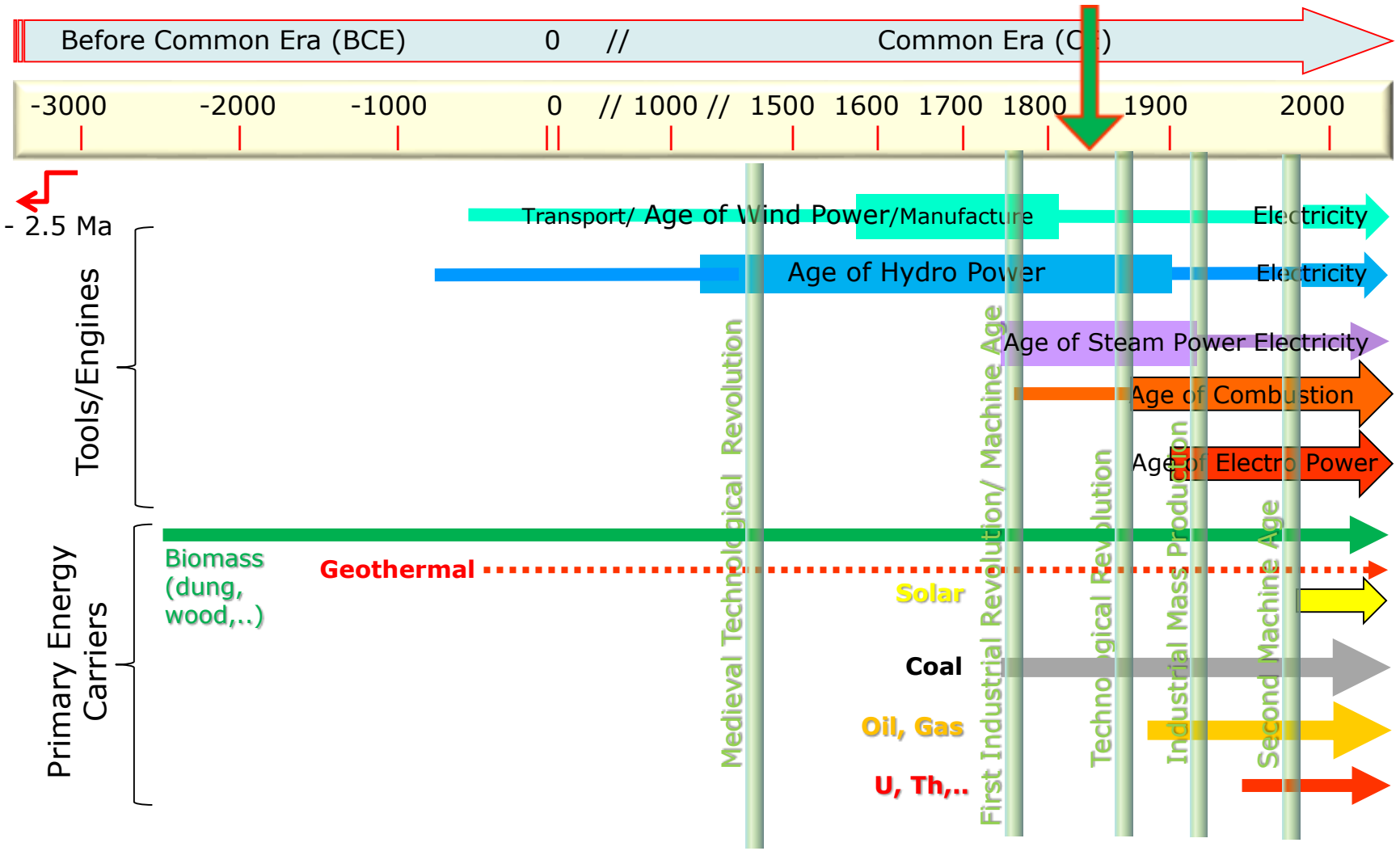
Natural gas ($\approx CH_4$) occurs together with other fossil fuels (e.g., over oil reservoirs, coal beds, shale,..).

Used to be flared, now utilized. Stranded gas gets liquefied (GTL), cooled and under pressure, shipped overseas (Russia → Japan,..).

Currently: "Natural gas revolution" → Fracking

Electrifying discoveries on another technological frontier

Time Line Tools & Fuels (Western Cultures)



Advent of internal combustine engine, discovery of crude oil as fuel, S&T of electro-magnetism→electricity as carrier, nuclear power

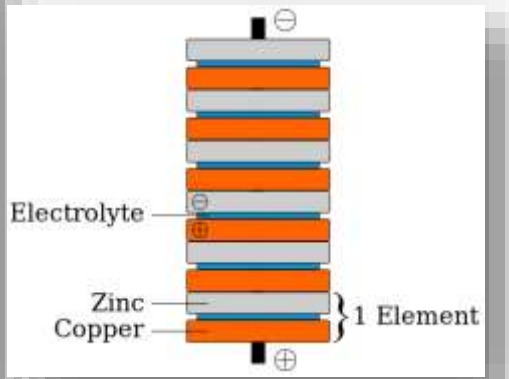
Electricity-Transformative Power


Luigi Galvani
(1737-1798)


Alessandro Volta
(1745-1827)

Static electricity know since ancient times (Thales, 600 BCE). Created by rubbing of amber with animal fur,
Galvani's physiological frog leg experiments.
Volta assisted Galvani, disagreed on nature of electricity.
Volta discovered battery ("Voltaic Pile"), announced March 20, 1800 to Royal Society, London.


Replica of Volta's first battery ("Voltaic Pile") Museum Tempio Voltiano.



Schematics of Voltaic Pile

Stack of pairs of alternating copper (or silver) and zinc discs (electrodes) separated by cloth or cardboard soaked in brine (electrolyte). Electro-motive force (emf, unit=Volt) generated by chemical reaction between metals.

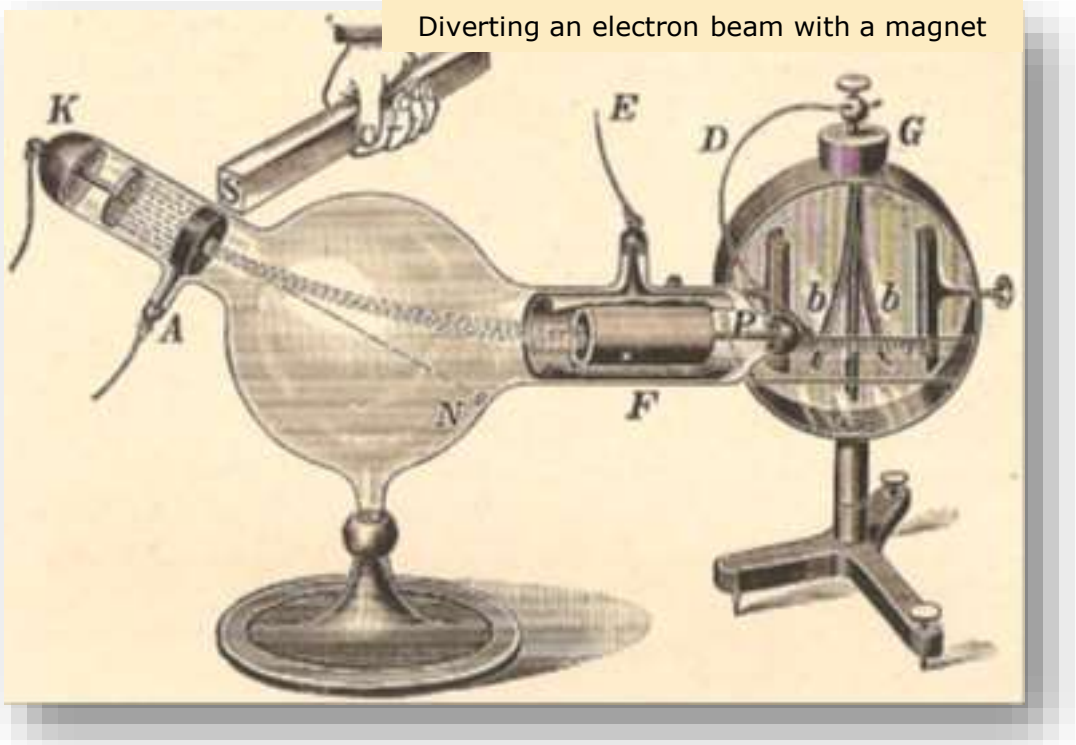
Top and bottom contact wires produce spark when touching. Electric current increases with height of the stack (number of elements).

Electrodynamics

James Clerk Maxwell
(1831-1879)

Developed a unified understanding of electric and magnetic phenomena → Maxwell's equations = set of partial differential equations that, together with the Lorentz force law, form the foundation of classical electrodynamics, classical optics, and electric circuits, much of today's technology.

Diverting an electron beam with a magnet



Particle el. charge q, velocity $\vec{\upsilon}$

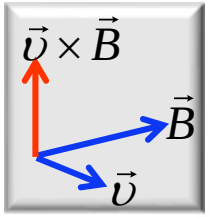
Electric $(\vec{E})$, *magnetic* $(\vec{B})$ *fields*

→ *Lorentz Force*:

$$\vec{F} = q \cdot \left(\vec{E} + \vec{\upsilon} \times \vec{B} \right)$$

Diverts charged particle

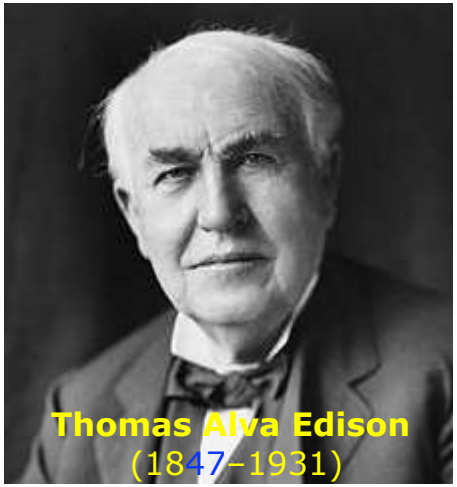
$(electron: q = e)$

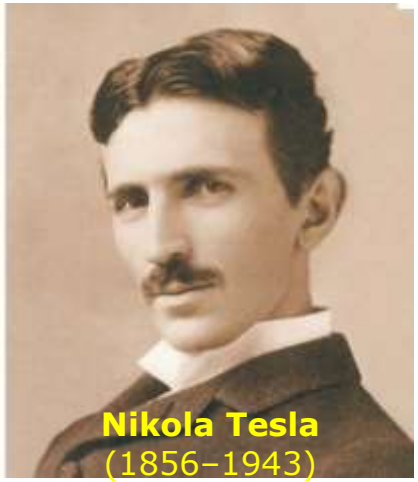


Vector cross product

Moving electric charges *q* across magnetic field direction ($\vec{\upsilon} \perp \vec{B}$) produces a force on the charges → movement = electrical current.

Advent of Hydroelectric Power

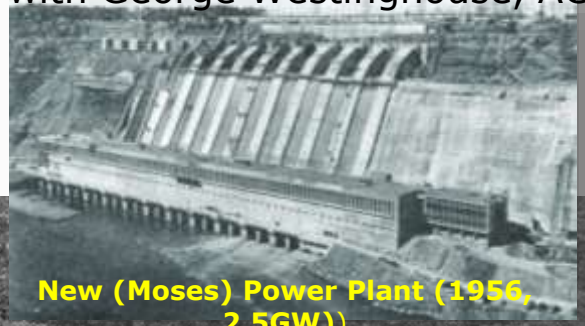

Thomas Alva Edison
(1847–1931)

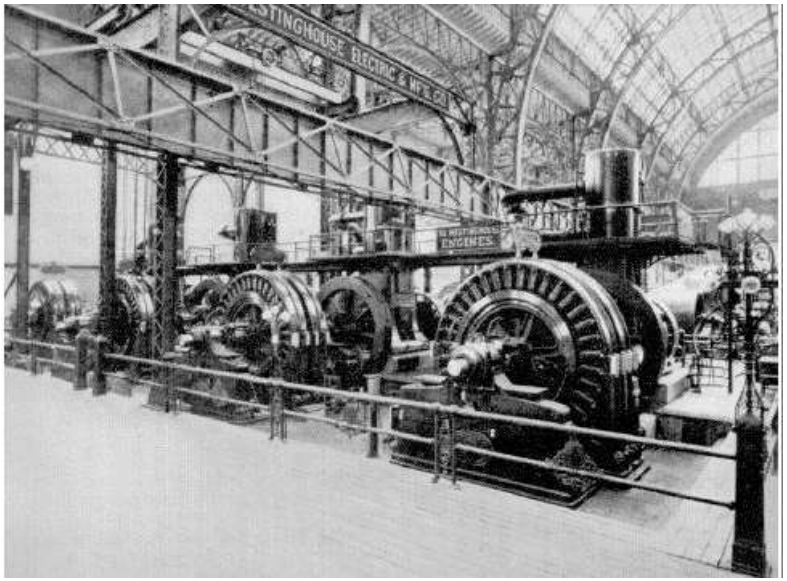

Nikola Tesla
(1856–1943)

Influential inventors of DC (Edison) and AC (Tesla) electrical power transmission over large distances.

Electrical lighting, wireless radio,….
Power wars (→ J.P. Morgan).

1895: Built 1. hydro electric power station (Niagara, with George Westinghouse, AC)

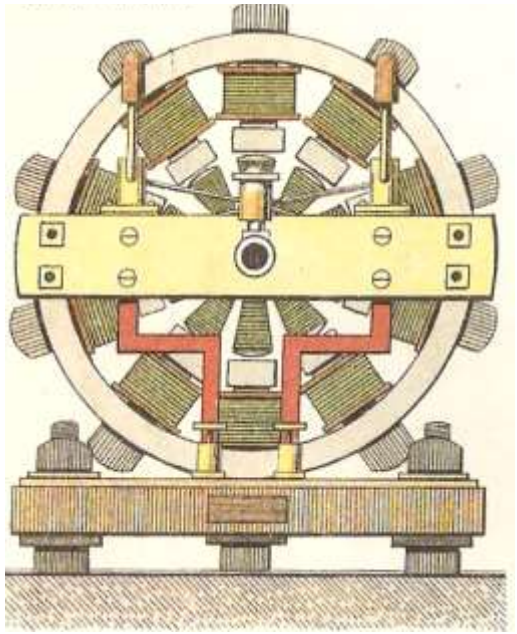

New (Moses) Power Plant (1956, 2.5GW))




Old (Adams) Power Plant (1895, 37 MW))

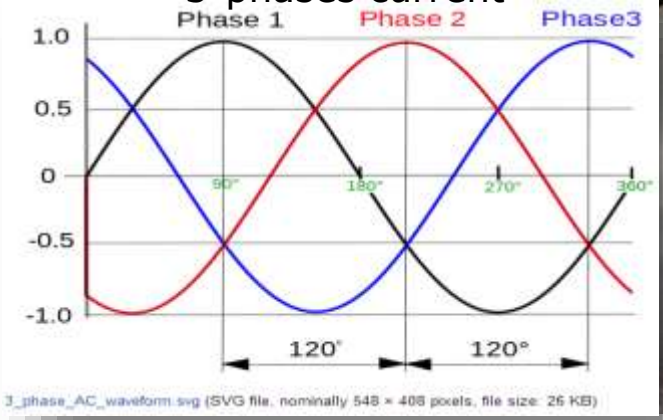
Start of new chapter in hydropower
→ many hydro-electric power plants

Electro-Motors and Dynamos



Modern alternator (dynamo) at a power station (Iolotan hydroelectric power station on Murghab River).

3-phases current

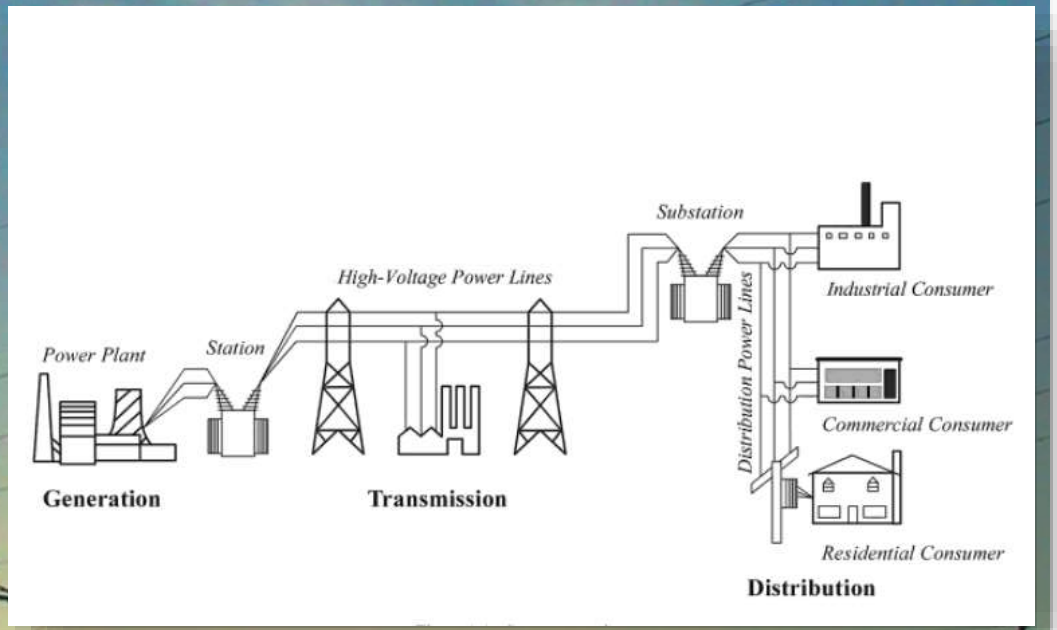


3_phase_AC_waveform.svg (SVG file, nominally 548 × 408 pixels, file size: 26 KB)

Modern alternator (dynamo) @ Iolotan hydroelectric power station (on Murghab River).

The Electrical Grid

USA, 2000: 160,000 miles of AC HV (>110kV)

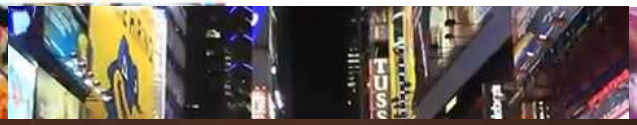


Uses of Electricity

Manufacturing Industry

Home Entertainment

Household Appliances
Refrigerating/
Air conditioning/Heating



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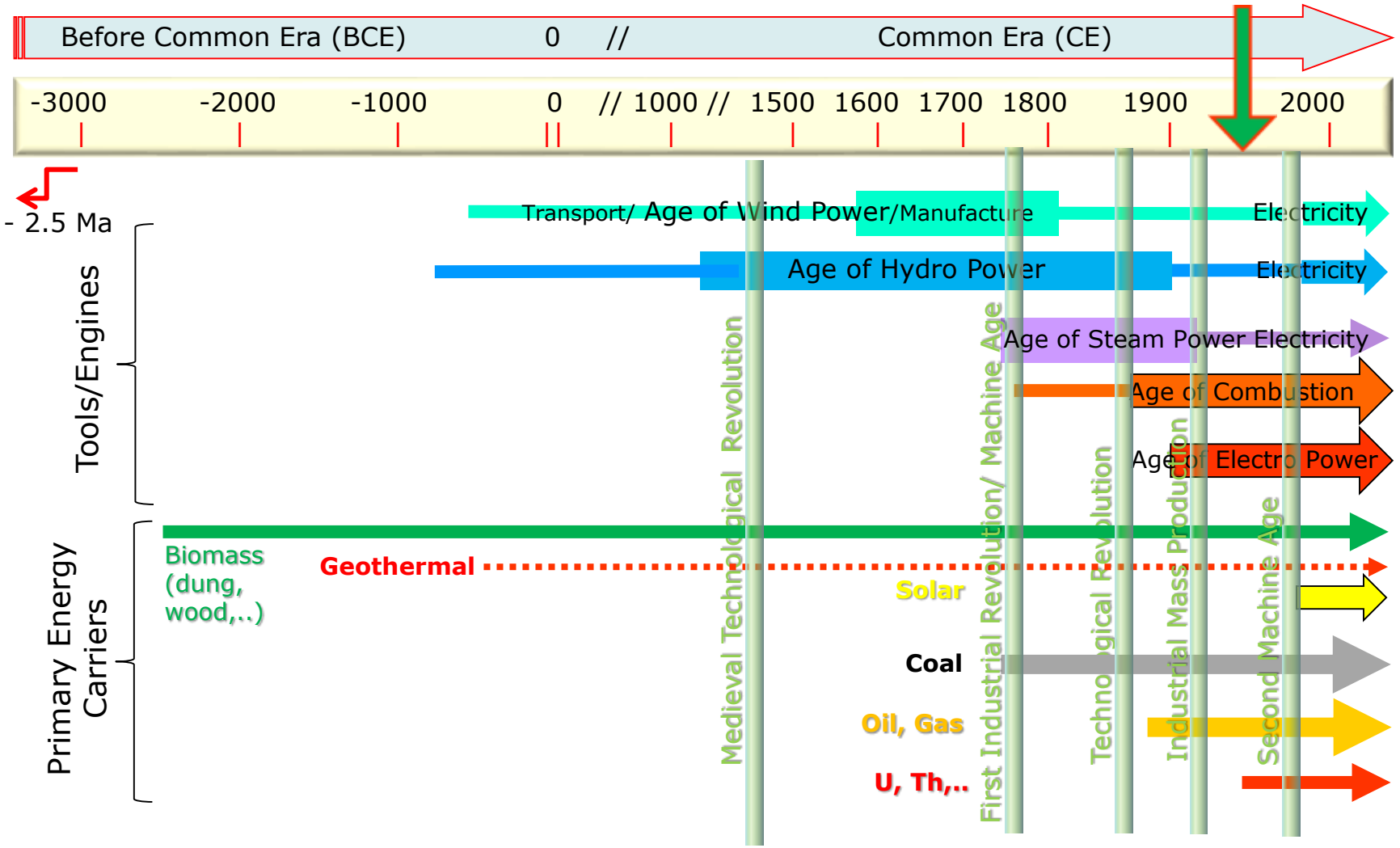


Advent of internal combustine engine, discovery of crude oil as fuel, S&T of electro-magnetism→ electricity as carrier, produced using nuclear power, harvest solar radiation (PV, thermal).

The Nuclear Age

1938: Otto Hahn, Fritz Strassmann & Lise Meitner discovered nuclear fission while searching for heavy elements (n+U → ?).

Mass defect:

$M_{(N,Z)} < N \cdot M_n + Z \cdot M_p$ → $\Delta Mc^2 = 2 \cdot B(A/2=N/2+Z/2) - B(A=N+Z)$

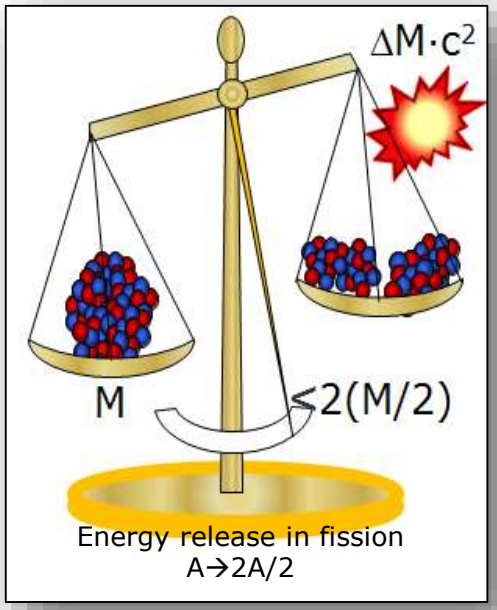
In re-arrangement of nucleons in nuclei $\Delta B = \Delta M \cdot c^2$ released.

Release of enormous energies :

$$M\left(^{236}U\right) = 47\,mg \xrightarrow[fission]{\Delta M = M \times 10^{-3}} \Delta E = 47\,\mu g \cdot c^2 \approx 4 \cdot 10^9\,J$$

$$M(TNT) = 1t \xrightarrow[combustion]{\Delta M = M} \Delta E \approx 4 \cdot 10^9\,J$$

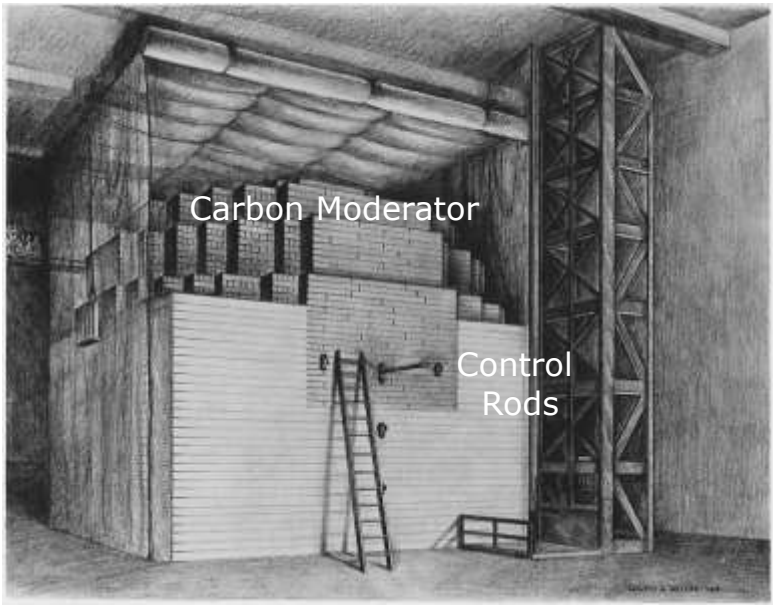
Einstein: equivalence mass = energy **$E = M \cdot c^2$**



Energy release in fission A→2A/2

Enrico Fermi (1901 - 1954)

Fermi's nuclear reactor CP-1 → at Chicago, 1st operation: Dec. 2, 1942

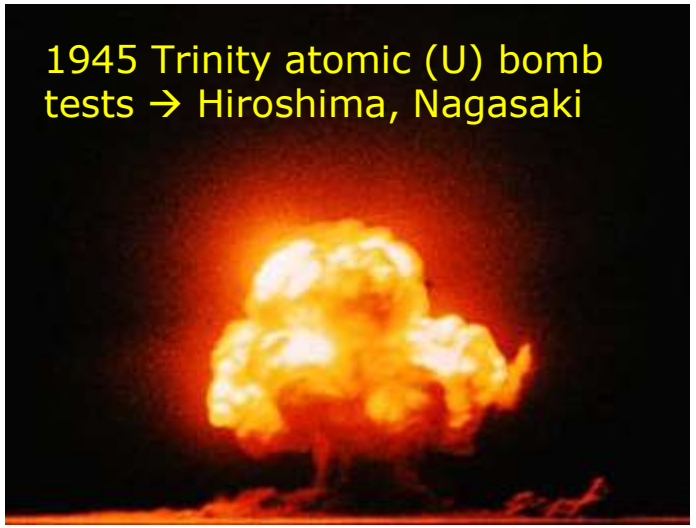


Nuclear Power Applications

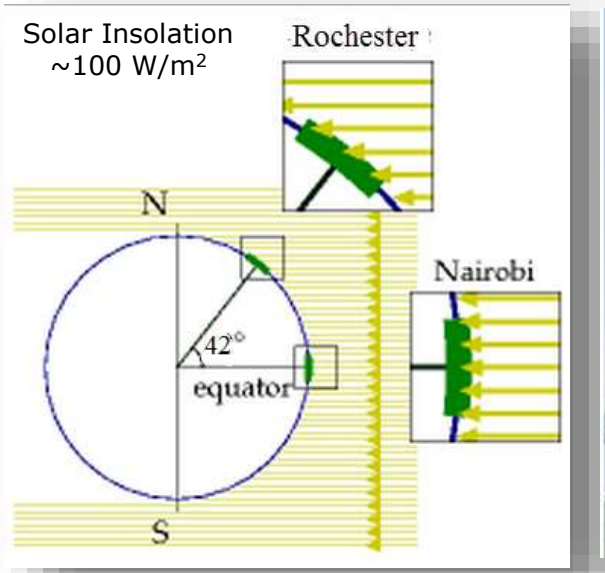
1939-45: Weaponization programs in Germany and USA ("Manhattan Project"). →

Cold War nuclear arms race 1945 – 1991 (SU ↓)
> 1958 peaceful applications of atomic energy IAEA.

Nuclear reactors for base load electricity.
USA: 103 NPPT built during 1970s/1980s
Lifetime > 60 a



Solar Power

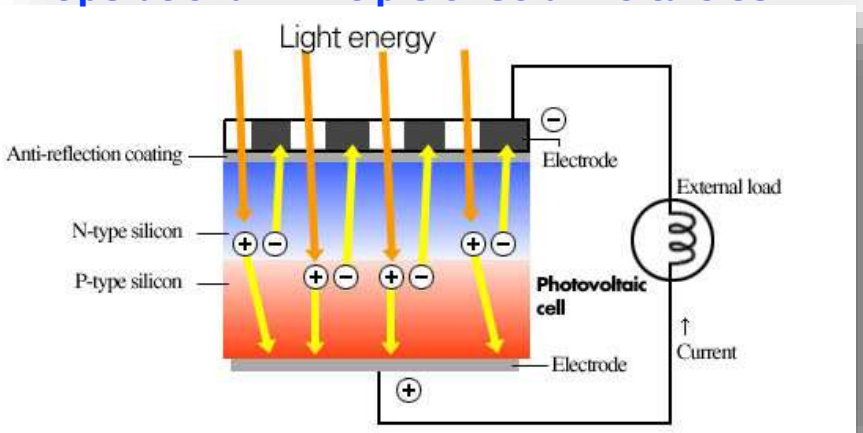


Concentrated Solar Power:

Focus IR radiation (heat) on water or salt containing boiler tank (in tower).

Solucar PS-10 water @ 50 bar, 285 °C.

Operational Principle of Solar Voltaic Cell



Schematic diagram: Nisshin Electric Co., Ltd.

Solar Park Mühlhausen/Bavaria/Germany
P_{peak}=6.3 MW, <P>=5 W/m².

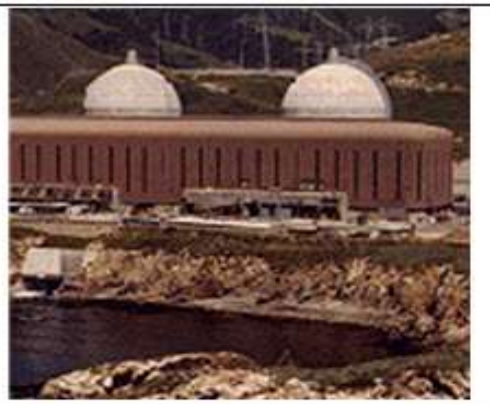
Present and Future of Solar Power

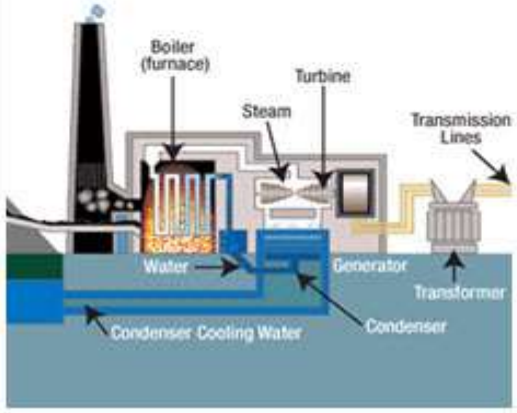
International Space Station
Photo: NASA

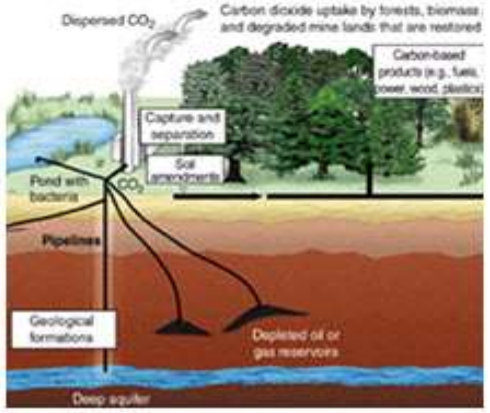
Solar Impulse-Aircraft powered by solar cells on wings.
July 2012 (flew 4,000 miles Europe-Africa)

Photo Solar Impulse/Jean Revillard

Technological Choices (To "Keep The Lights On")







Credits

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Images:

Several colored drawings and sketches of historic interest have been taken from
W. Weiler, *Physikbuch*, J.F. Schreiber, Esslingen & München, 1910.
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Wikipedia has been the source for historic photographs and for portraits of scientists and inventors.