LECTURE # 8

RENEWABLE ENERGY (cont'd)

ENERGY RESOURCES

Fossil	**Renewable**	**in Development**
Coal	**Solar**	Nuclear
Oil	**Wood**	Geothermal
Gas	**Hydraulic**	Biomass
	Wind	Biogas

WATER POWER

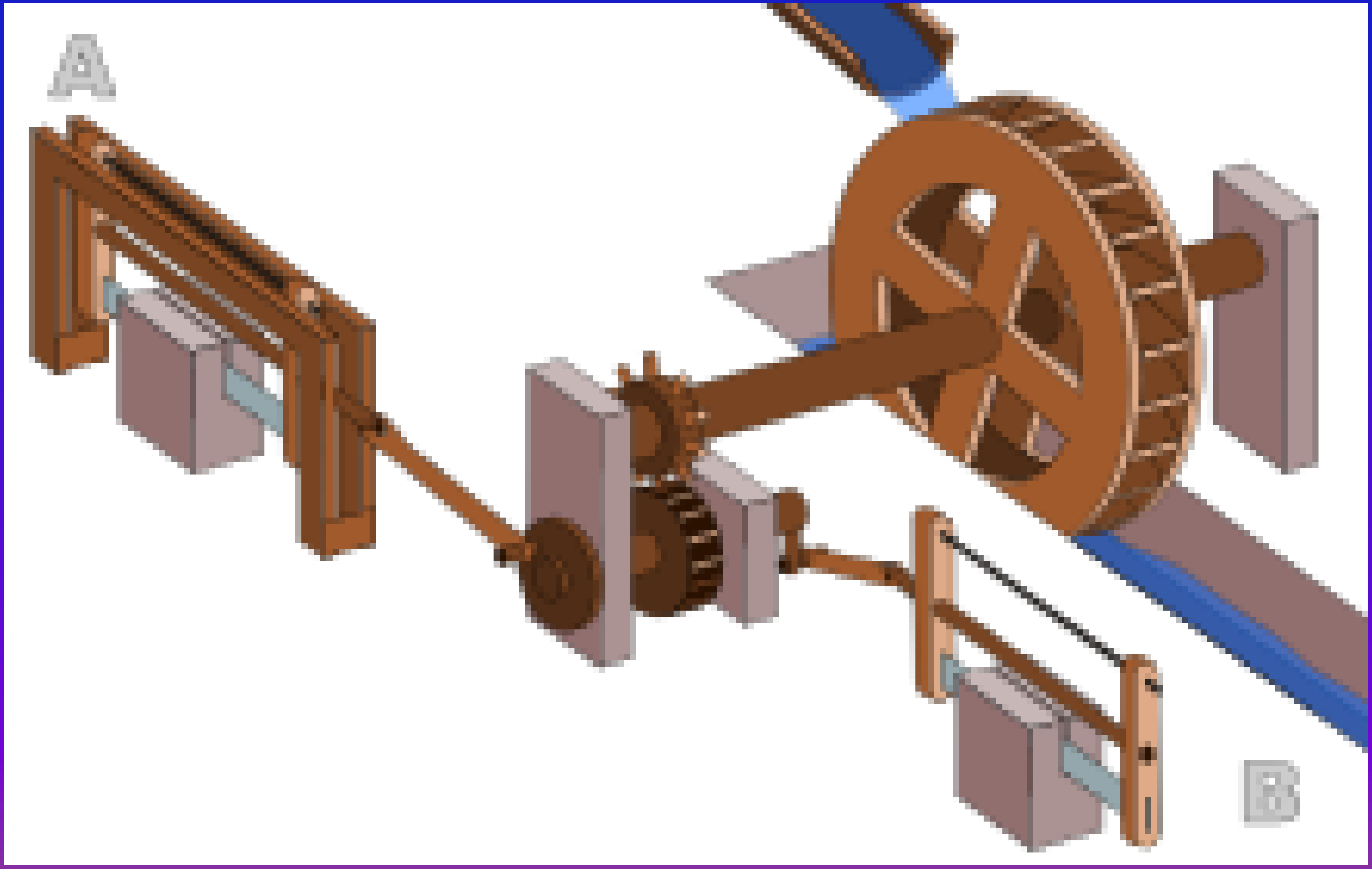
WATER POWER

Known since antiquity

Used in **watermills**

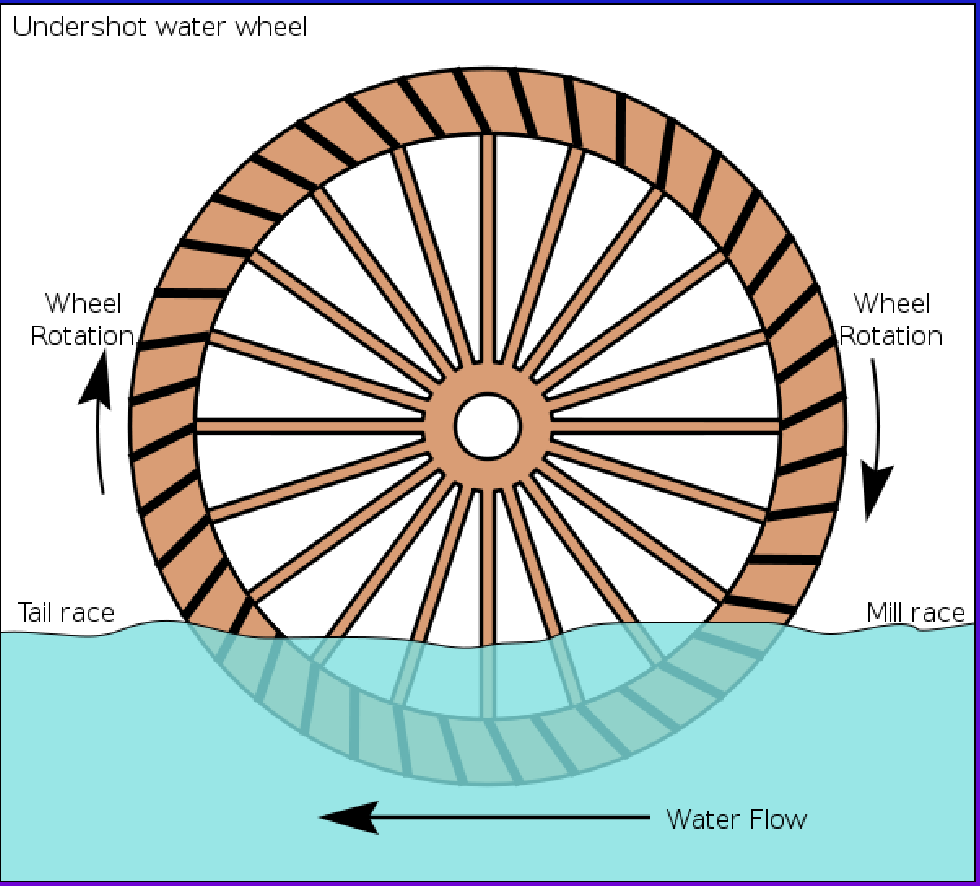
Used water from springs, rivers, tides

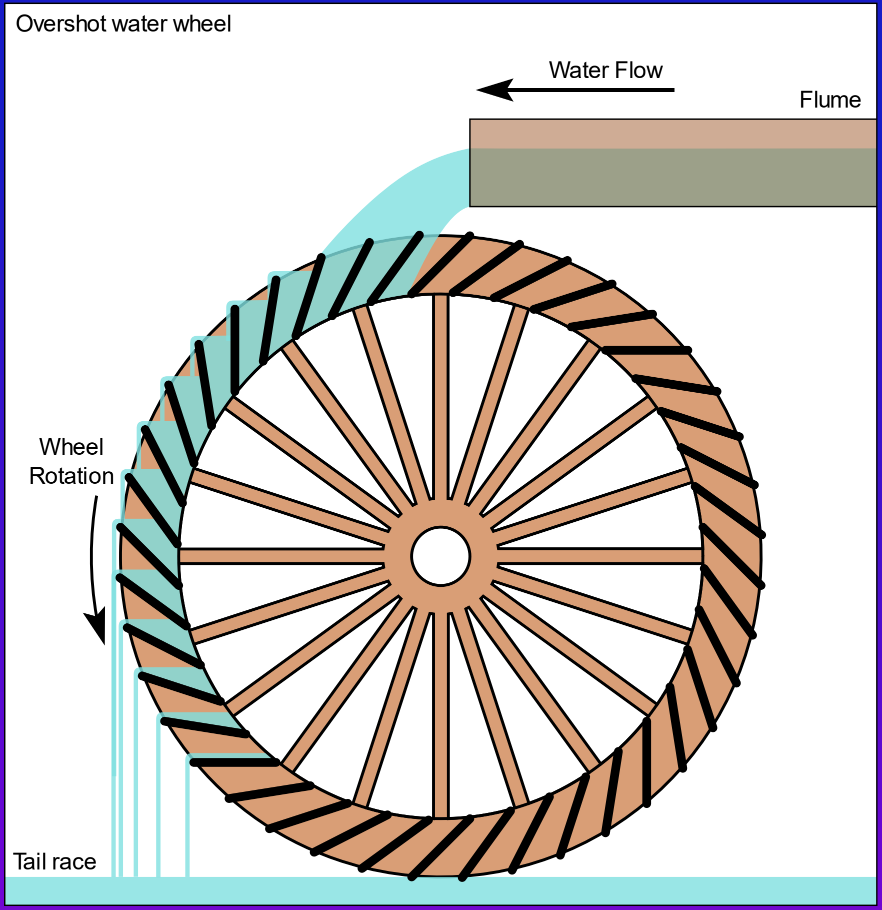
Oldest Watermill Using a Crank and a Connecting Rod
Roman, 3rd Cent. CE



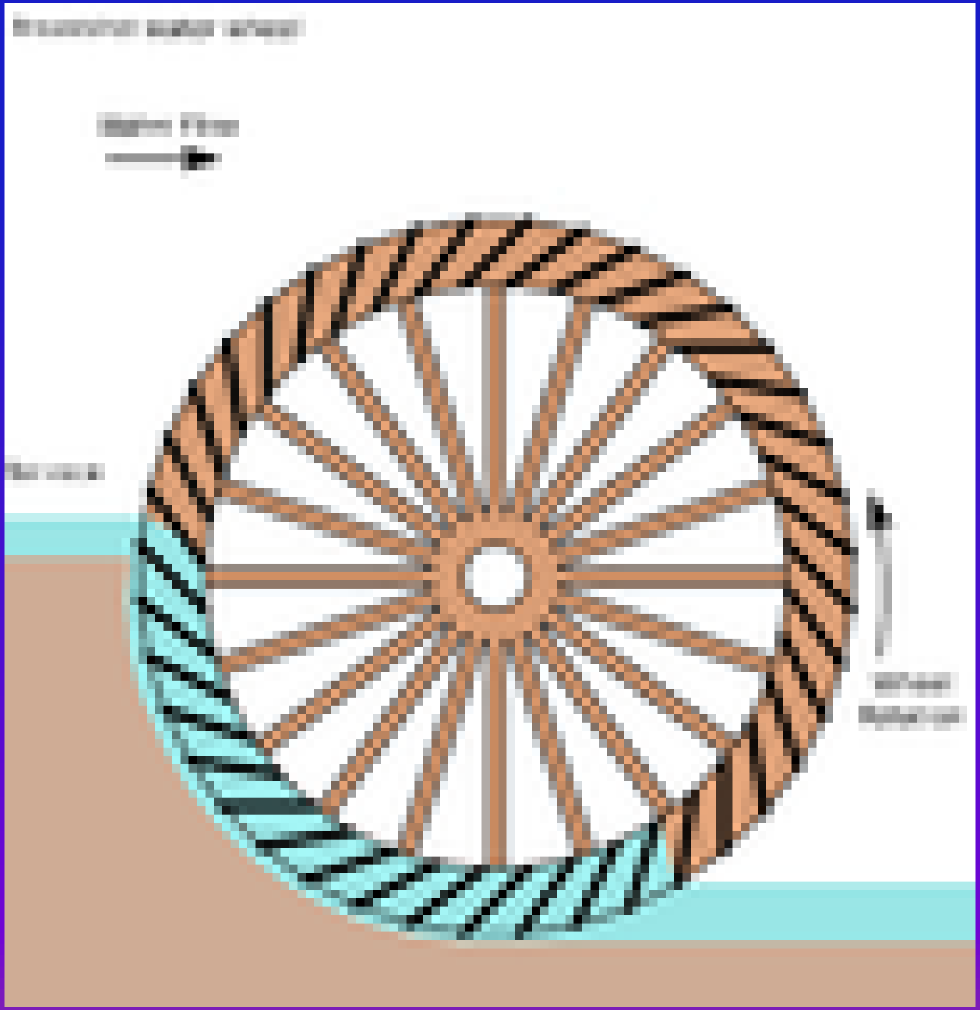
Roman water-powered grain mill.
It used a gear to transmit the movement from the water wheel

Undershot and Overshot Water Wheels for Milling 1st Cent. CE





Breast Shot Water Wheel for Milling
3rd Cent. CE

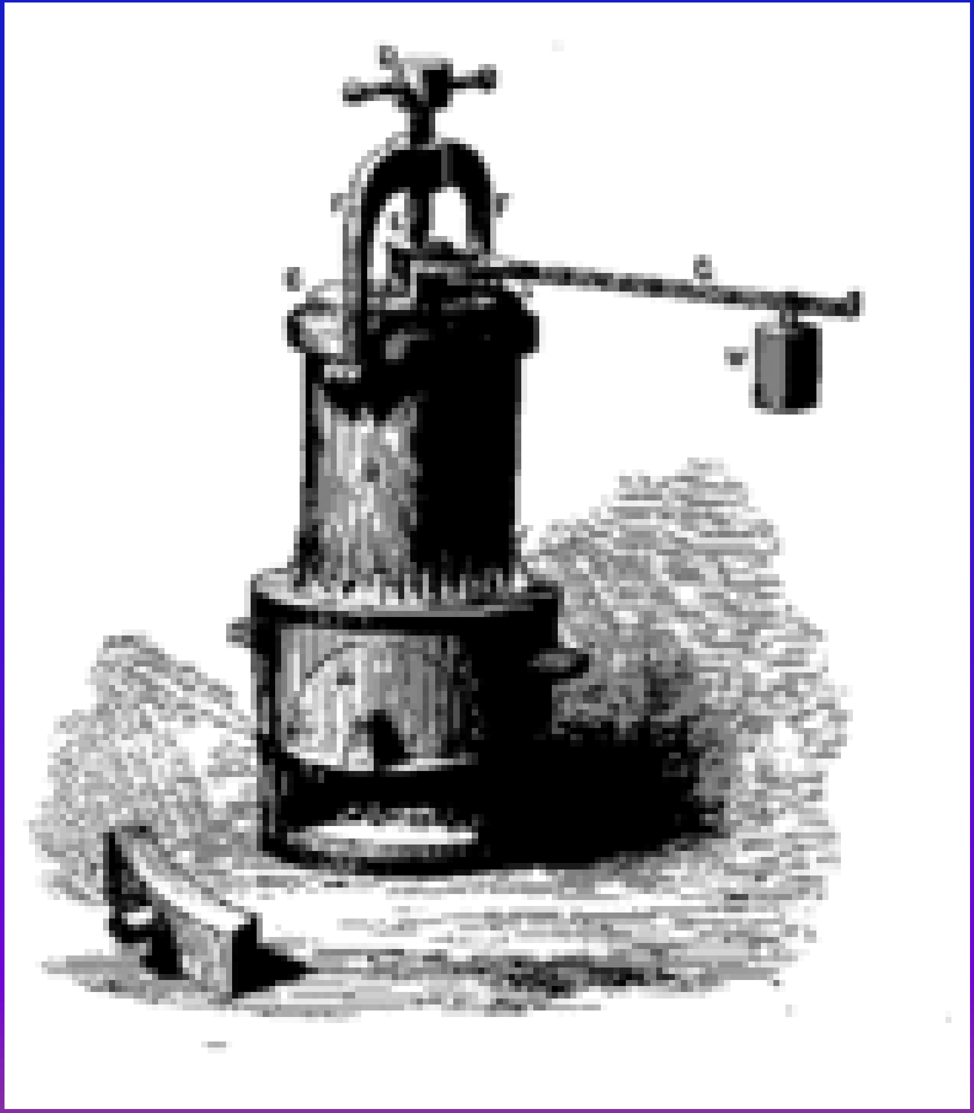


Water Mill in Belgium – 12th Cent. CE

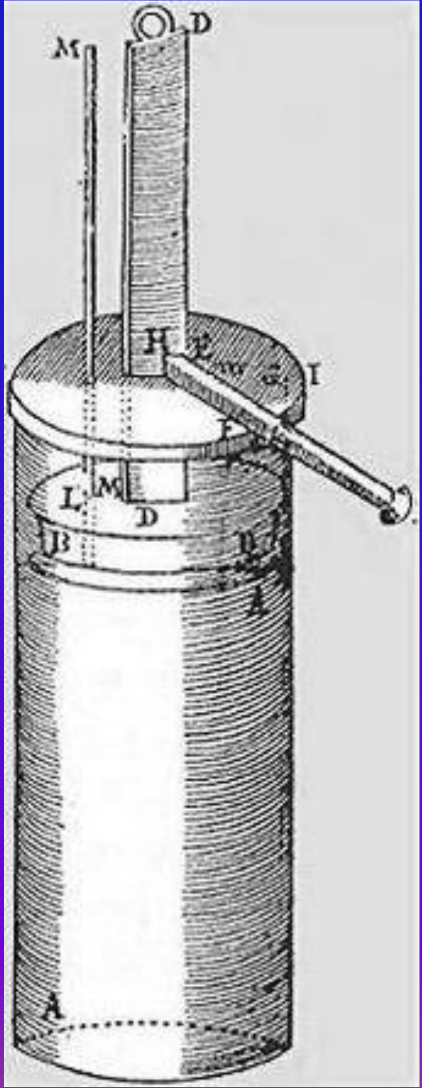
Breast Shot Watermill in England. Early 20th cent.

VAPOR POWER

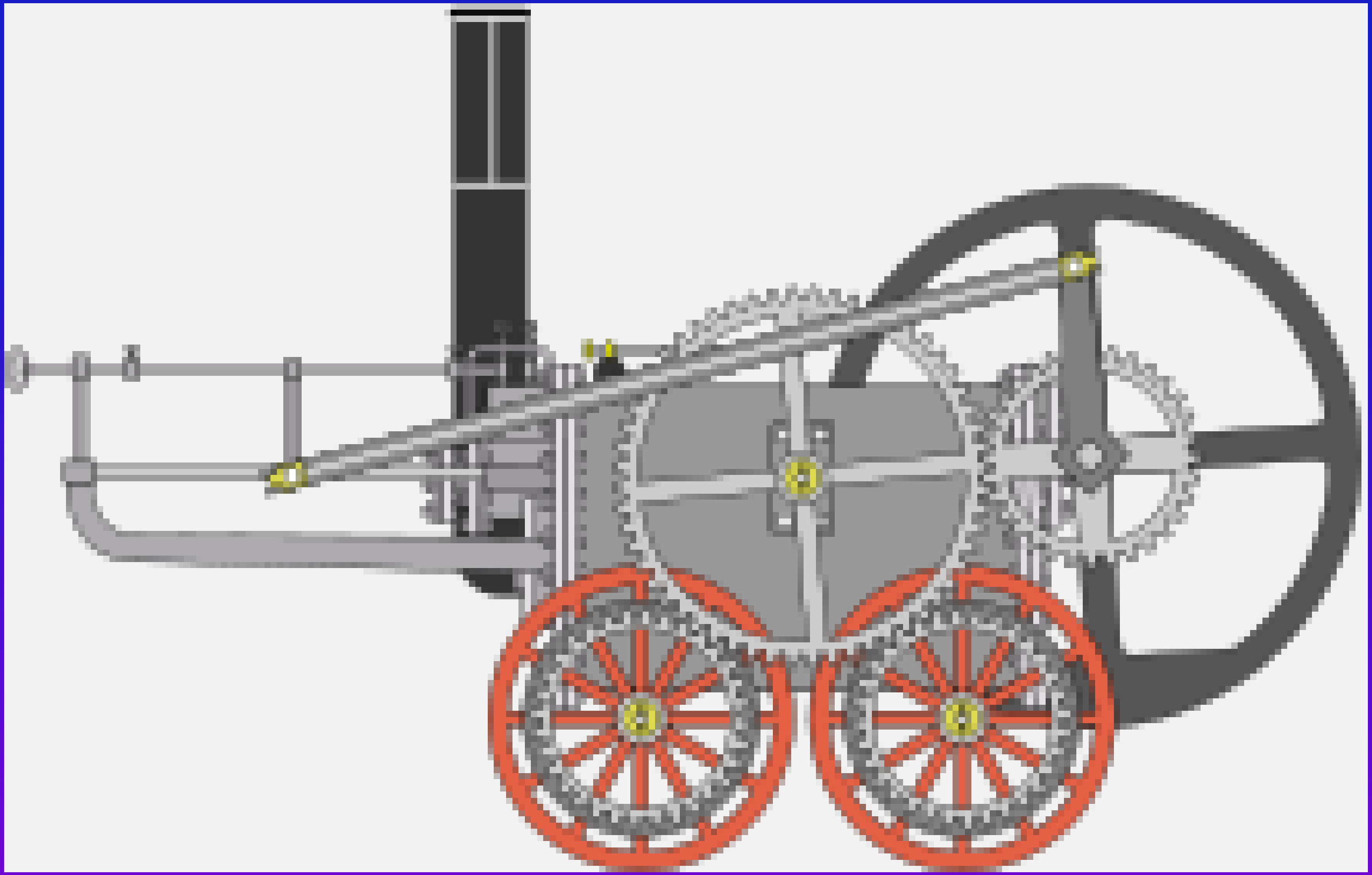
Denis Papin's "Steam Digester", London, 1679



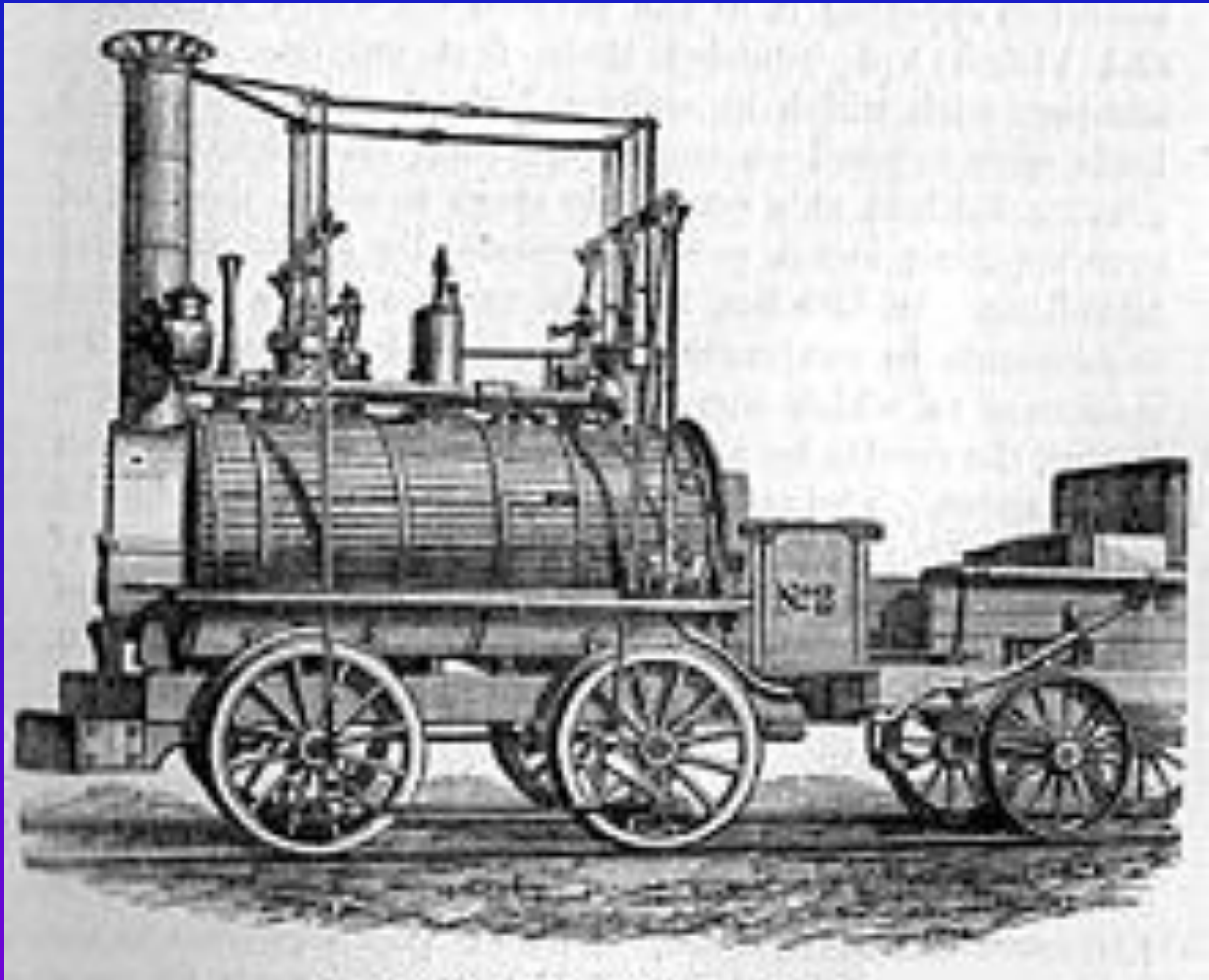
Denis Papin's First Piston Machine – Marburg, Germany, 1690



First Locomotive – Richard Trevithick, 1804



George Stephenson's First Locomotive 1816

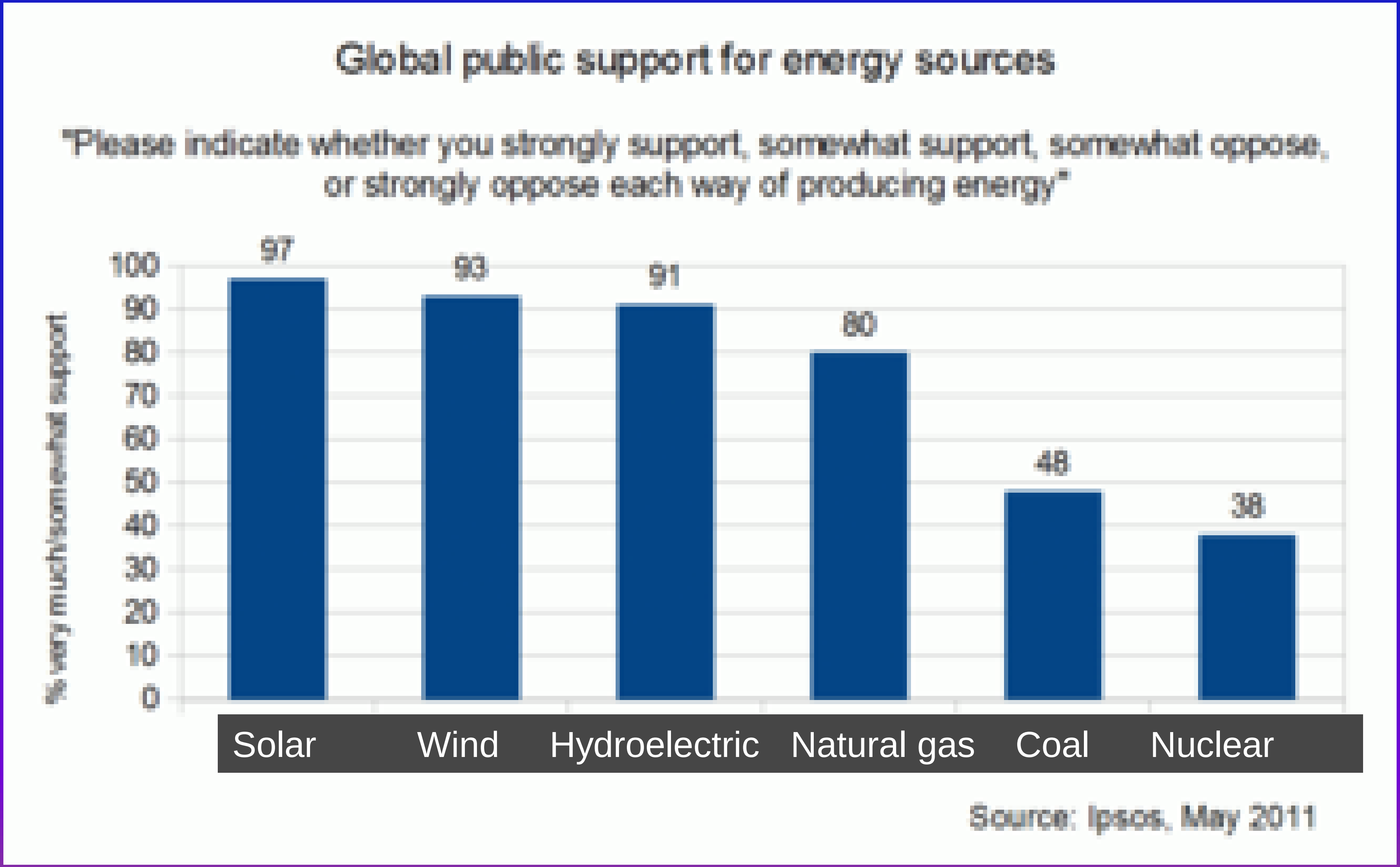


Old Killingworth Locomotive, still in use.

Steam Locomotive – France 1930

HYDROELECTRIC POWER

Global Public Support for Energy Sources - 2011



Hydroelectric Power

Low-cost, **non-polluting energy source**

Raising water level by building a dam on a river

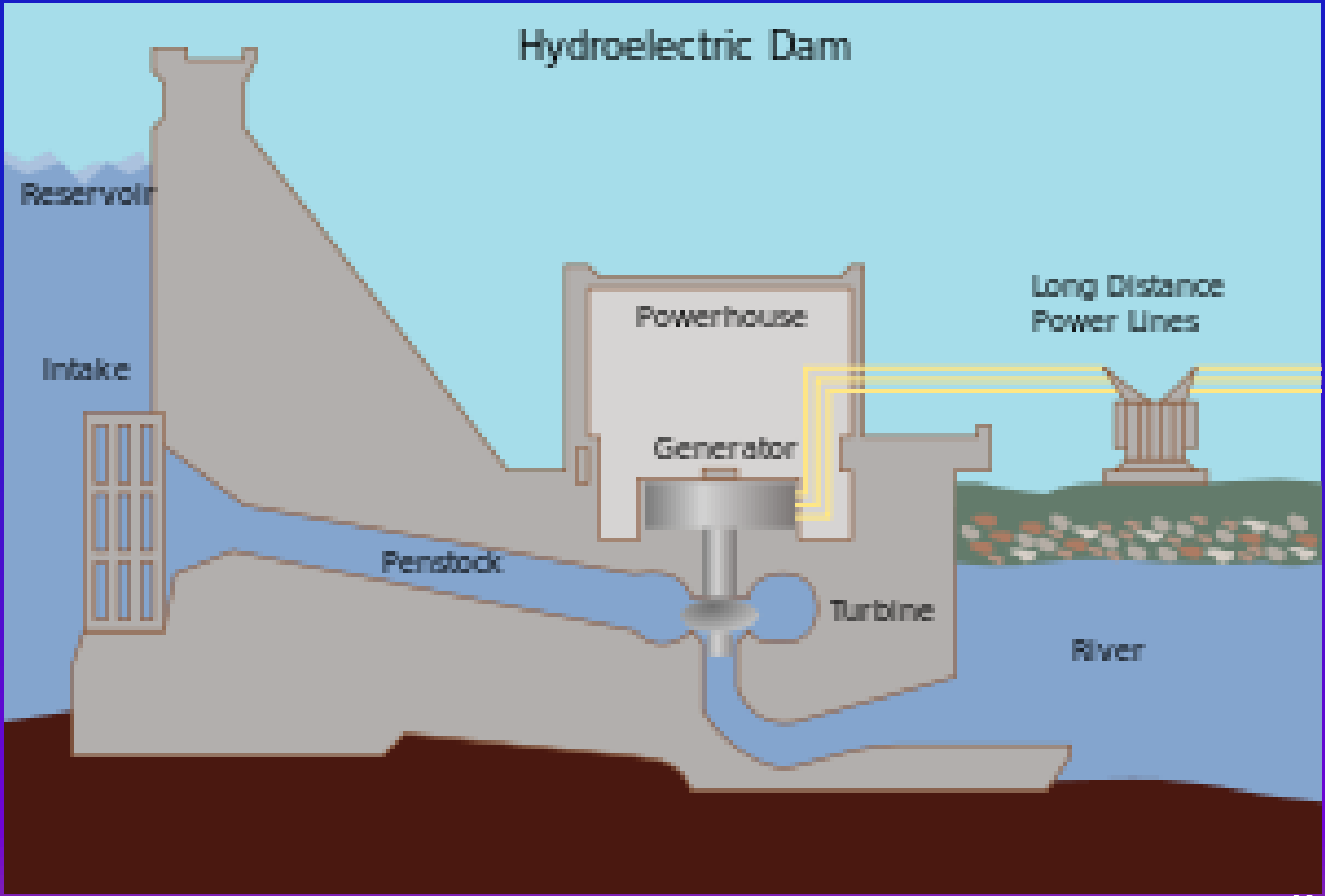
Water is forced to fall by **gravity** through

turbines that turn generators

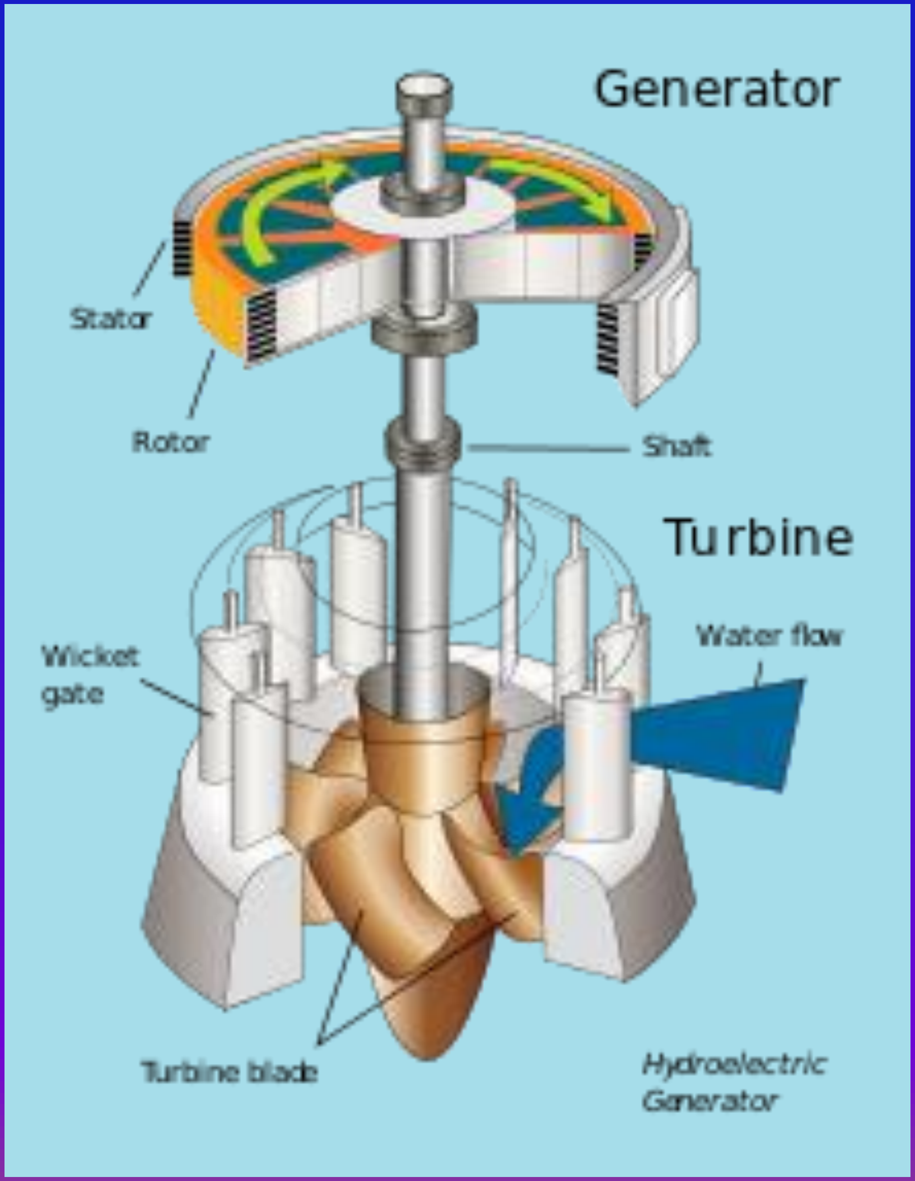
Generators create electricity

Hydroelectric Dams are the Most Widely used Form of Sustainable Energy

Hydroelectric Dam



Turbine and Generator



Water Dams

3000 BC – Jawa Dam, Jordan – 9 m high

2800 BC – Sadd-el-Kafara Dam, Egypt – destroyed

1700 BC – Great Dam of Marib, Yemen – 4 m high

15th-13th Cent. BC – Eflatun Pinar – Konya, (Hittites)

251 BC – **Du Jiang Yan – Oldest dam in China**

220 BC – Various dams in India

Roman dams - Lake Homs and Harbaka in Syria –

water-proof mortar

Middle Ages - **Amstel-dam, Rotte-dam**

Xia Dynasty in China
c. 2070 – c.1600 BC

First dynasty in the traditional Chinese history

Yu – First emperor of this dynasty

Stopped the Yellow river flood by building **canals**

for drainage and irrigation of fields

Vast agricultural progress

Early **medicine**

Roman Dam at Cornalvo, Spain
2000 years old

Hydropower - History

1770s French Bernard Forest de Bélidor wrote about hydraulic machines

19th century – **Electrical generator developed**

Industrial revolution demanded water and power

1878 – **First hydroelectric power in England**

1881 – **First waterpower in USA**

1886 – 45 hydroelectric power stations in the US and Canada

1889 – 200 stations in US

1920 – **40% of the power in USA was hydroelectric**

1936 – Hoover Dam

Hydropower in Modern Times

1936 – **Hoover Dam** - 1,345 MW

1942 – **Three Gorges Dam** (China) – 22,500 MW

1984 – **Itaipu** (Brazil & Paraguay) – 14,000 MW

US has over 2,000 hydroelectric power stations ⇨ 6.4% of its total electrical production

Norway	98% of total Electrical Production			
Brazil	68%	“	“	“
Venezuela	67%	“	“	“
Canada	60%	“	“	“

2012 World (Civil) Electricity Generation by Fuels

Coal/Peat	40.4%
Natural Gas	22.5%
Hydro	**16.2%**
Nuclear fission	10.9%
Oil	5.0%
Renewable	5.0%

Hoover Dam – 176 ft. high - 1936

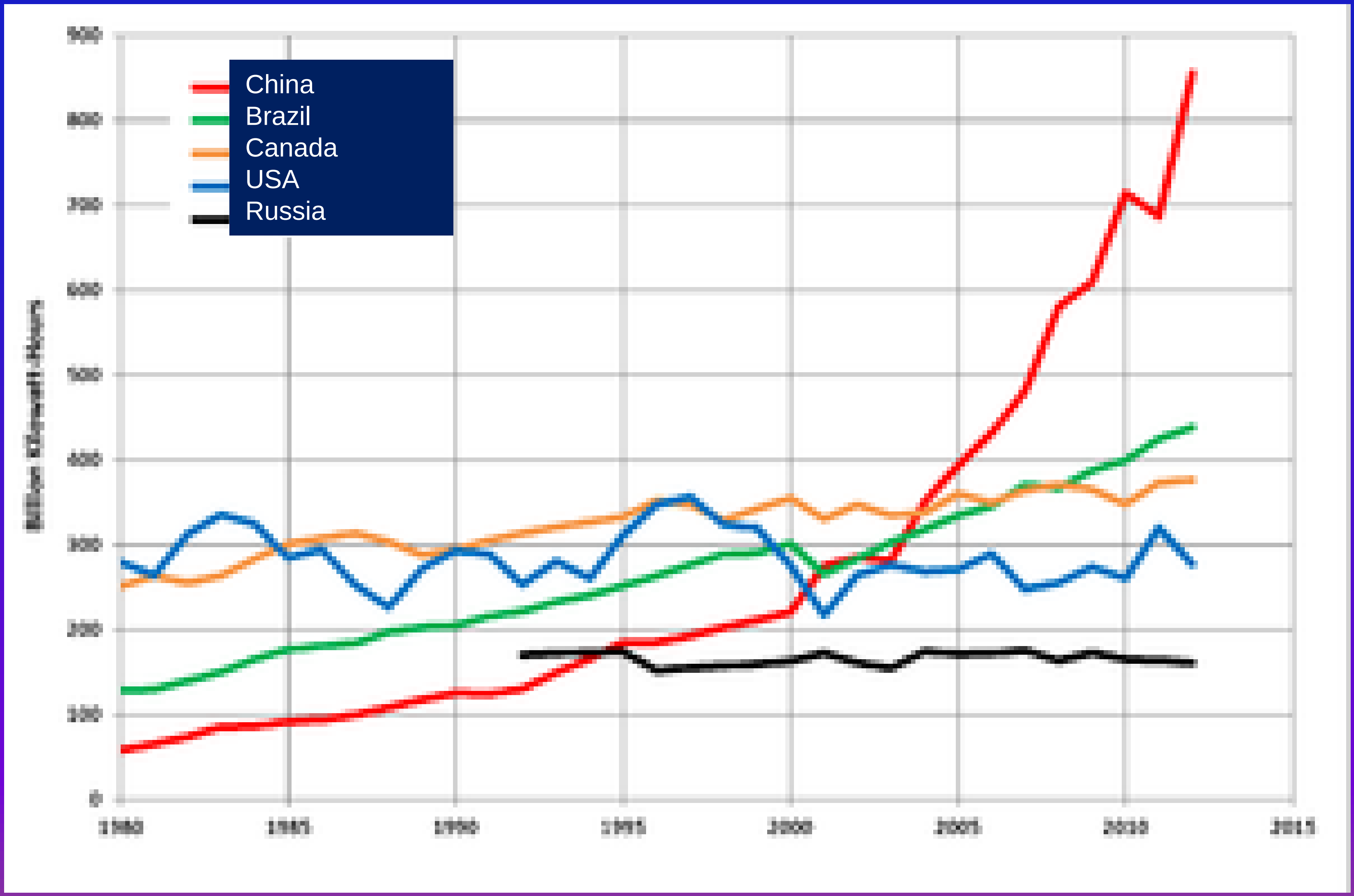
Itaipu Dam – 1984
Parana River, Brazil & Paraguay
94.7 TWh in 2008

1 TWh = 10^{12} watt/hour

Three Gorges Dam – 2003 - 2009
Central China, Yangtze River
The Largest Hydroelectric Power
98.1 TWh in 2014

Three Gorges Dam Turbine

The Top Five Hydroelectric Power Producing Countries



ENERGY RESOURCES

Fossil	Renewable	In Development
Coal	Solar	Nuclear
Oil	Wood	Geothermal
Gas	Hydraulic	Biomass
	Wind	Biogas

WIND POWER

WIND POWER

Definition: Use of air flow through wind turbines to mechanically power generators to produce electricity.

Wind farms consist of many wind turbines connected to the electric grid.

On shore and off shore farms.

Inexpensive source of renewable energy very much adopted by many countries.

China and India made progress.

Denmark generates 40% of its electricity from wind.

Wind Power - History

Known and used since sailing.

Netherlands, USA, and Australia used wind mills.

1887 - James Blyth - Glasgow - to power home lightning

1888 - Charles Bush - Cleveland OH - 17m in diam.

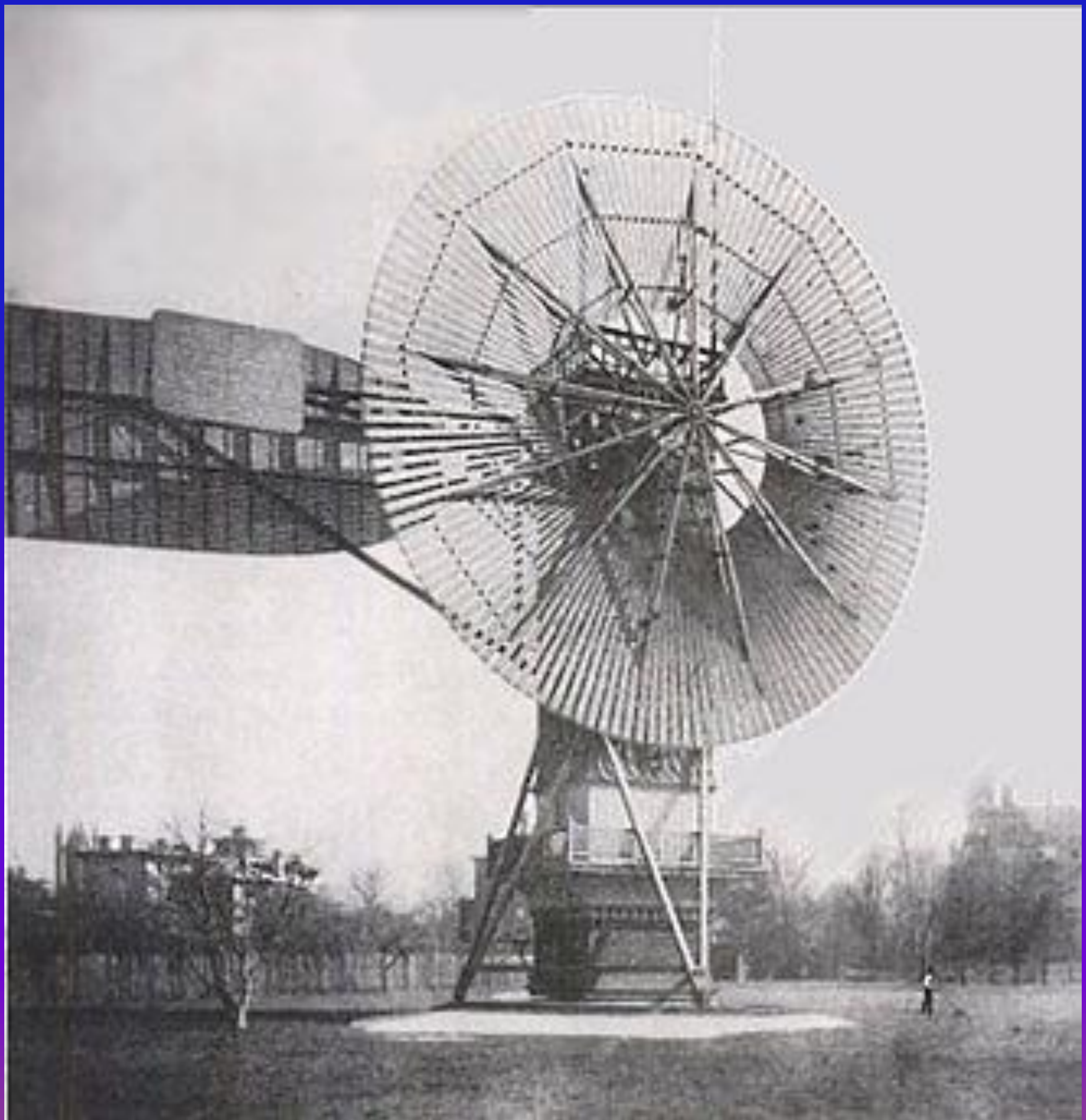
19th Cent. - Introduction of electric power.

A Mycenaean Boat

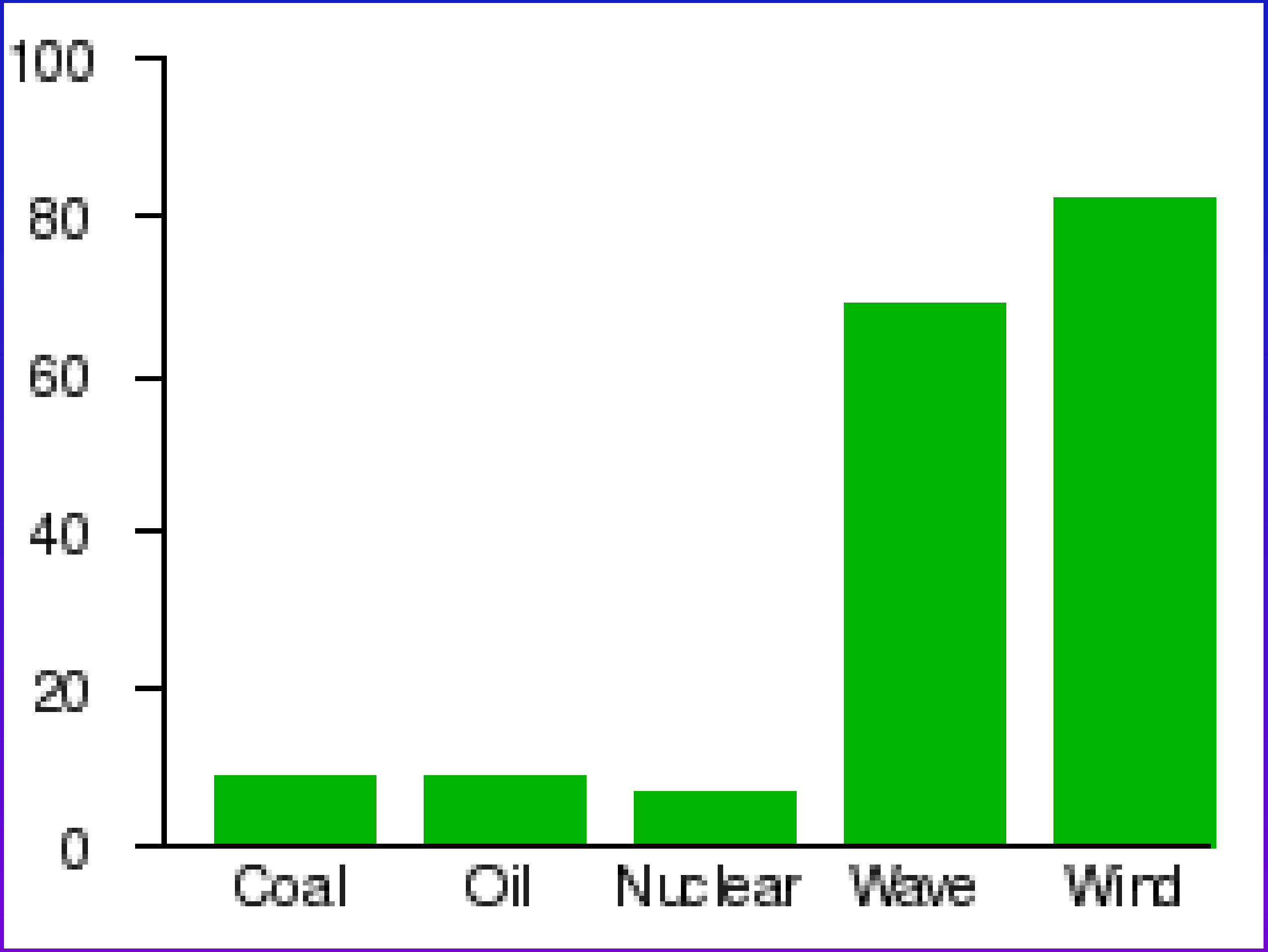
Spanish galleon – 16th century

Royal Yachting Association

Charles Brush Windmill - 1888



Which Should Be Increased in Scotland?



California Wind Turbines at Altamont Wind Farm (6000 Turbines)

Wind Turbine in Texas

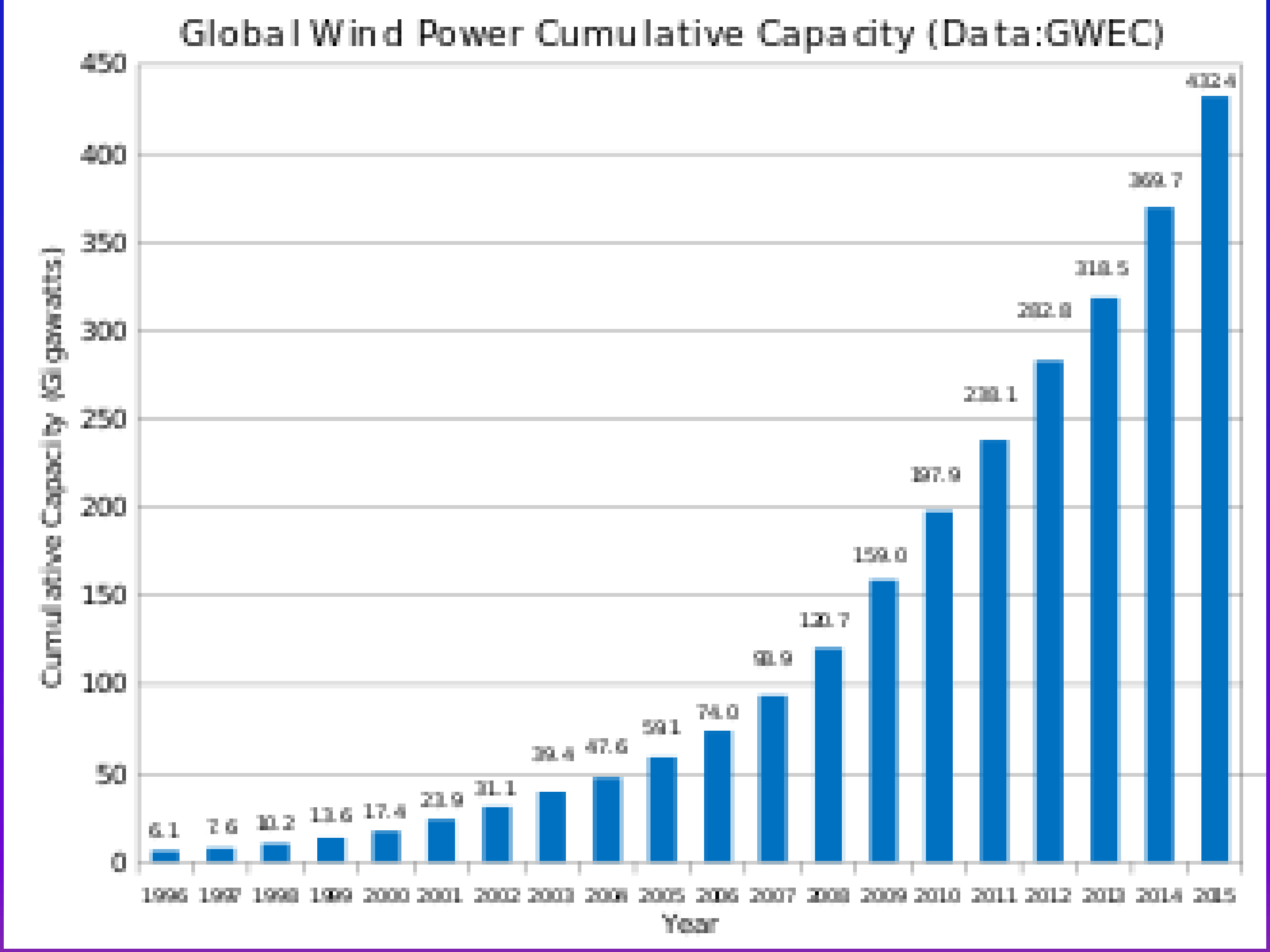
U.S. Landowners Typically Receive $3,000–$5,000 Annual Rental Income

Float-wind Turbine “Windfloat”, Operating at Rated Capacity (2 MW) - Portugal

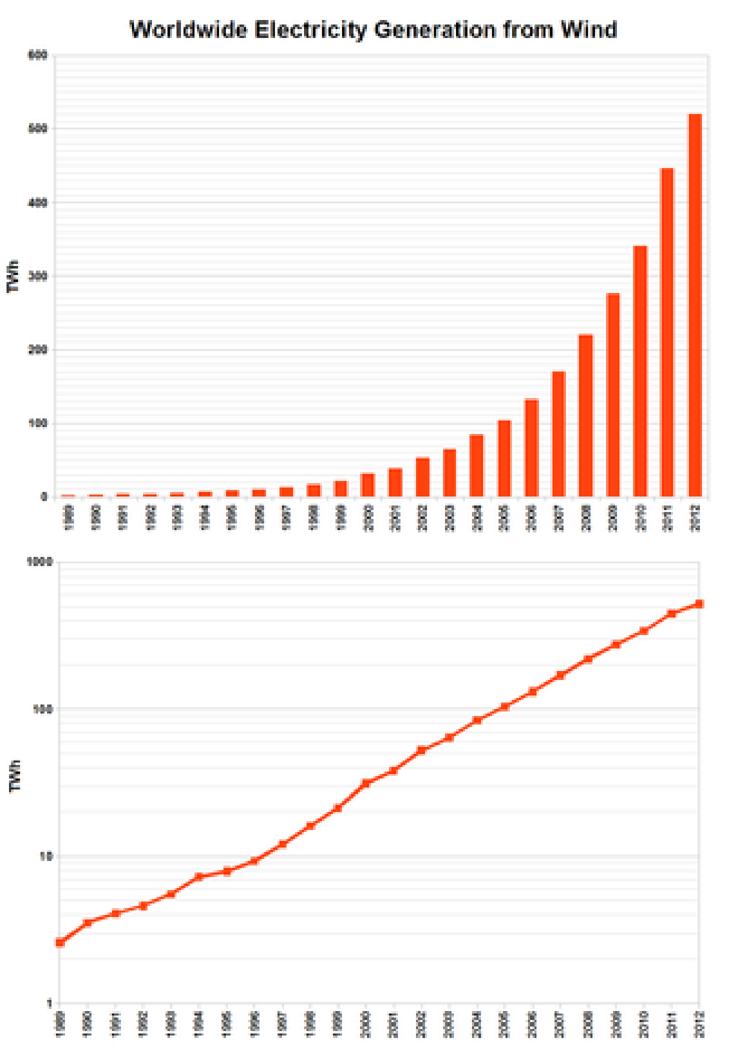
Vertical Axis Wind Turbine – Bristol, UK

5 M HIGH AND 3 M ACROSS

Wind Power – Global Growth of Installed Capacity – 1999 - 2015



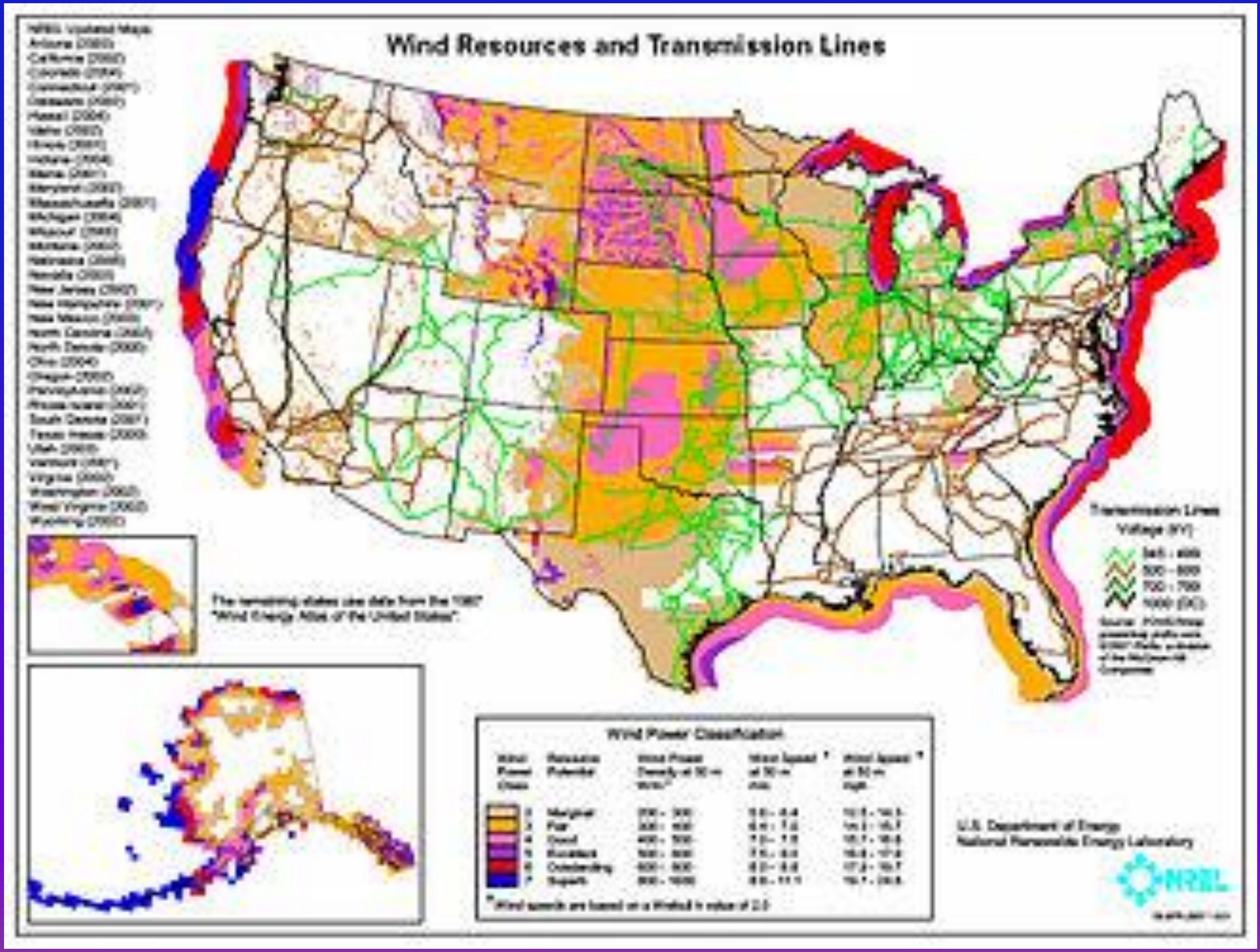
Worldwide Electricity Generation from Wind (up to 2012)



Top Windpower Electricity Producing Countries (in TWh)

Country	Production
USA	141
China	118
Spain	49
Germany	46
India	30
United Kingdom	19
France	15
Italy	13

Wind Resources and Transmission Lines in USA



ENERGY RESOURCES

Fossil	Renewable	In Development
Coal	Solar	**Nuclear**
Oil	Wood	Geothermal
Gas	Hydraulic	Biomass
	Wind	Biogas

ENERGY DEVELOPMENT

NUCLEAR ENERGY

NUCLEAR ENERGY

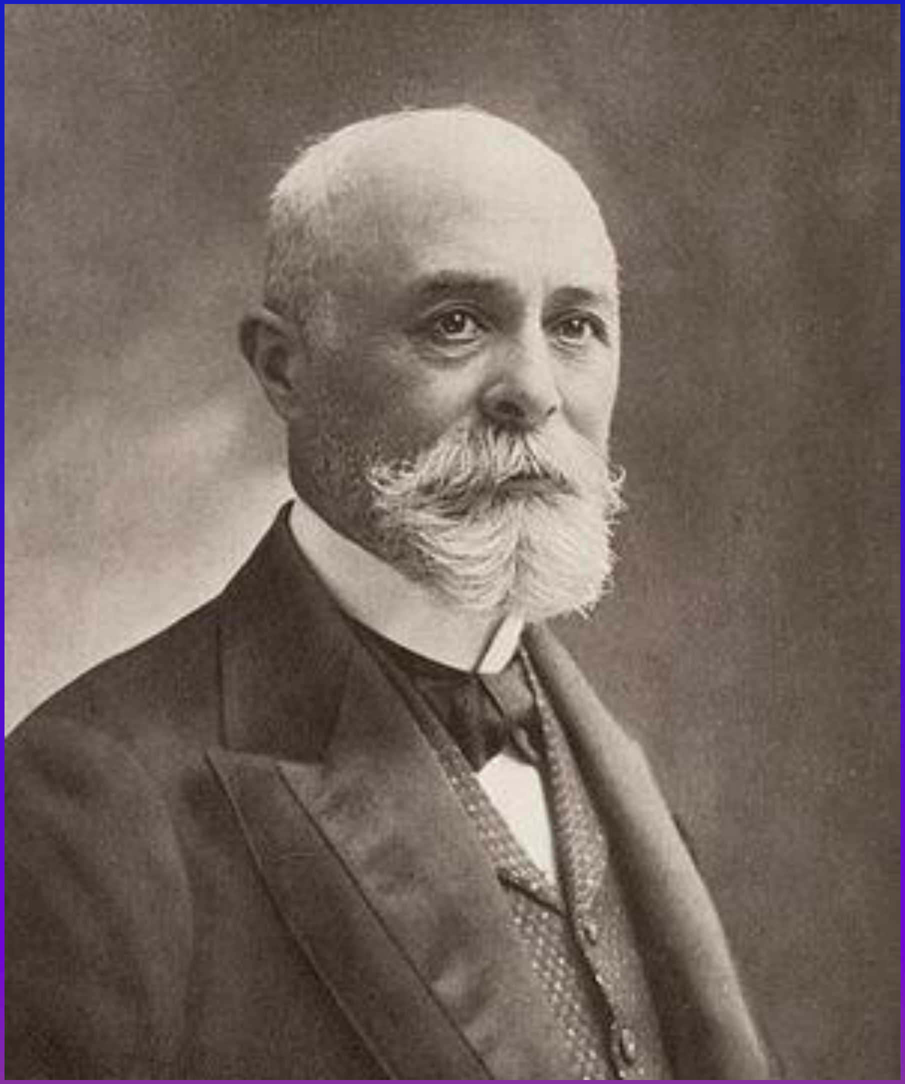
Greeks and Indians introduced the philosophical

concept of the atom

(*a-tom* = that cannot be divided)

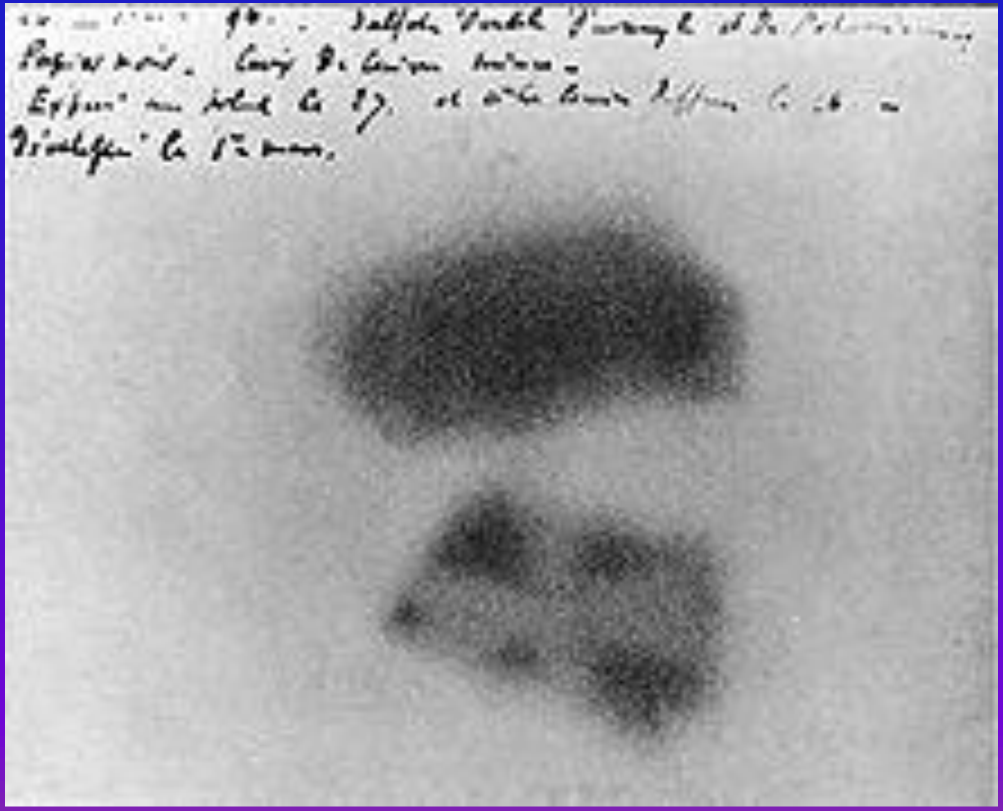
19th cent. - The **atom** is the smallest constituent of the matter

Henri Antoine Becquerel (1852-1908)
French Physicist



Discovery of Radioactivity by Antoine Henri Becquerel (1896)

Spontaneous radioactivity is a famous example of **serendipity**. *"Chance favors the prepared mind"*



Becquerel in his Lab

NUCLEAR ENERGY
Electrons

1897 – Sir John Joseph Thomson (English physicist):

Cathode rays are made by electrons. “The plum pudding“ model

Electrons = identical to particles given off by photoelectric and radioactive materials

Electrons carry the negative electric charge of the atom

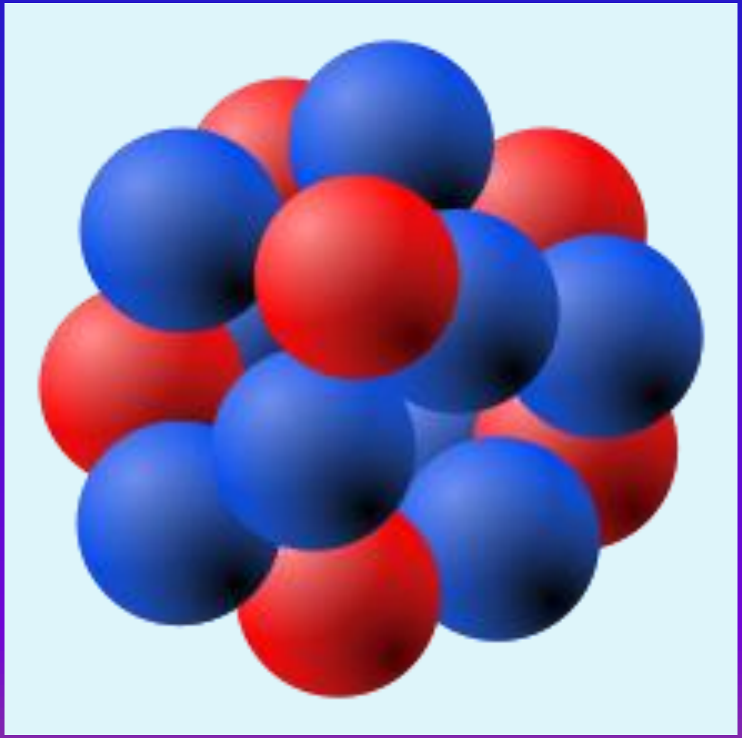
Electrons carry the electric current in metal wires

Atomic Nucleus

1911 – Ernest Rutherford described the **nucleus**

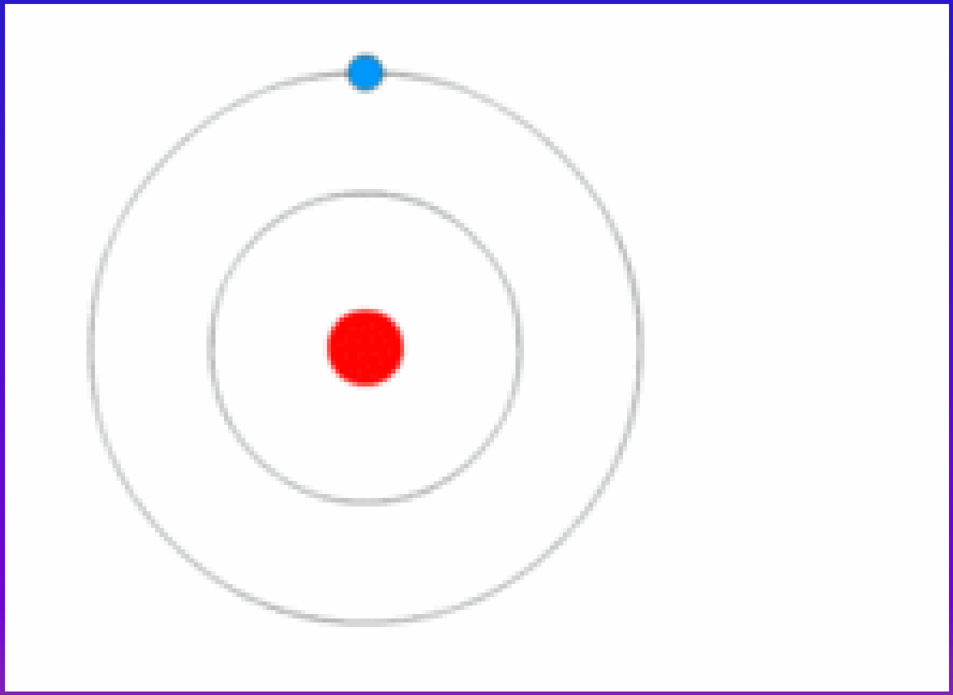
1932 – **Protons** and **neutrons** were described

Nucleus = largest part of the atom



The Electrons

1913 - Niels Bohr – Electrons move on orbits around the nucleus. “Quantum leaps” btw. orbits



Nuclear Energy - History

1932 – Ernest Rutherford: immense amounts of energy released by **protons hitting lithium atoms** in an accelerator

1932 – James Chadwick discovered the **neutron**

1934 – Frédéric and Irène Joliot-Curie discovered **induced radioactivity, which emits rays: alpha, beta, gamma**

URANIUM (U)

Uranium Ore (Pithchblende)

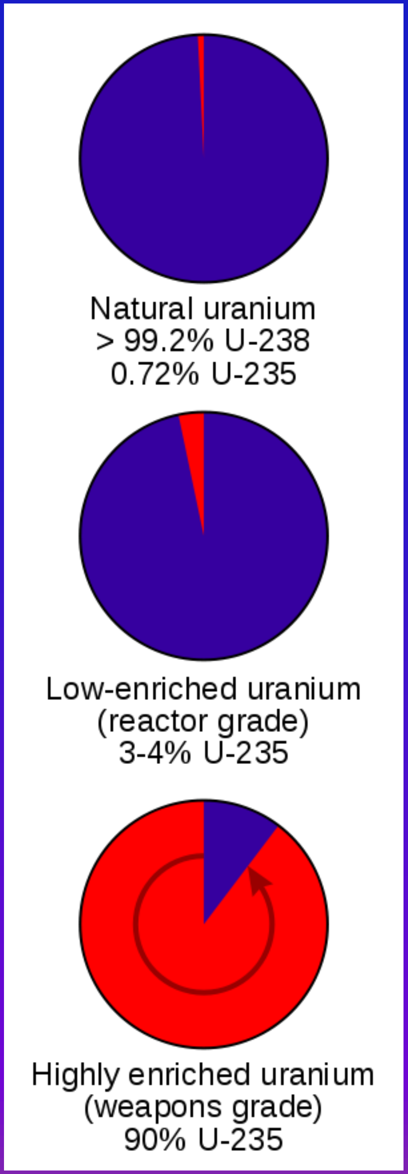
E

Enrichment of Uranium U-235

Natural Uranium
0.72% U-235

Low-enriched Uranium
(reactor grade)
3-4% U-235

Highly enriched Uranium
(Weapons grade)
90% U-235



PLUTONIUM (Pu)

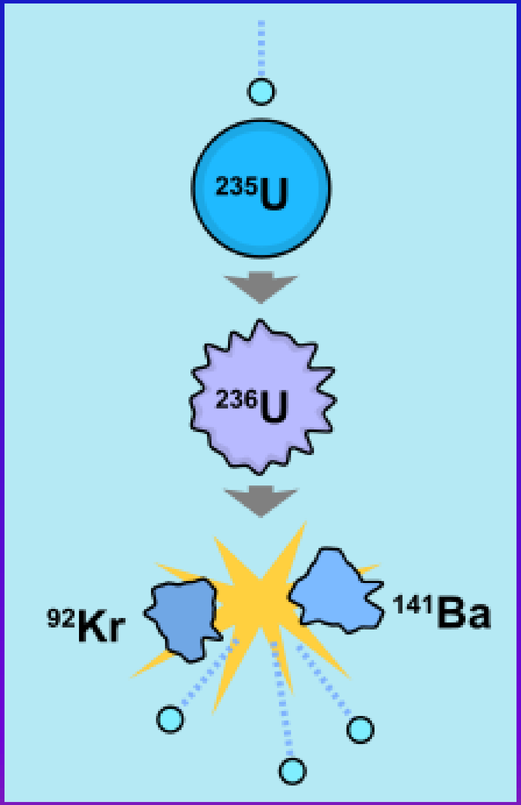
1940 – Produced and isolated by deuterium bombardment of uranium in the Berkeley Radiation Laboratory of the University of California, Berkeley

1945 – "Trinity" - first implosion at Alamogordo, NM

1945 – "Fat Man" atomic bomb dropped at Nagasaki

High-Energy Physics (1)

Nuclear Fission: 1938 - Otto Hahn directed neutrons onto uranium ⇨ **radiobarium, radiokrypton,** and **3 neutrons**



Nuclear Fission
Otto Hahn's Experimental Apparatus

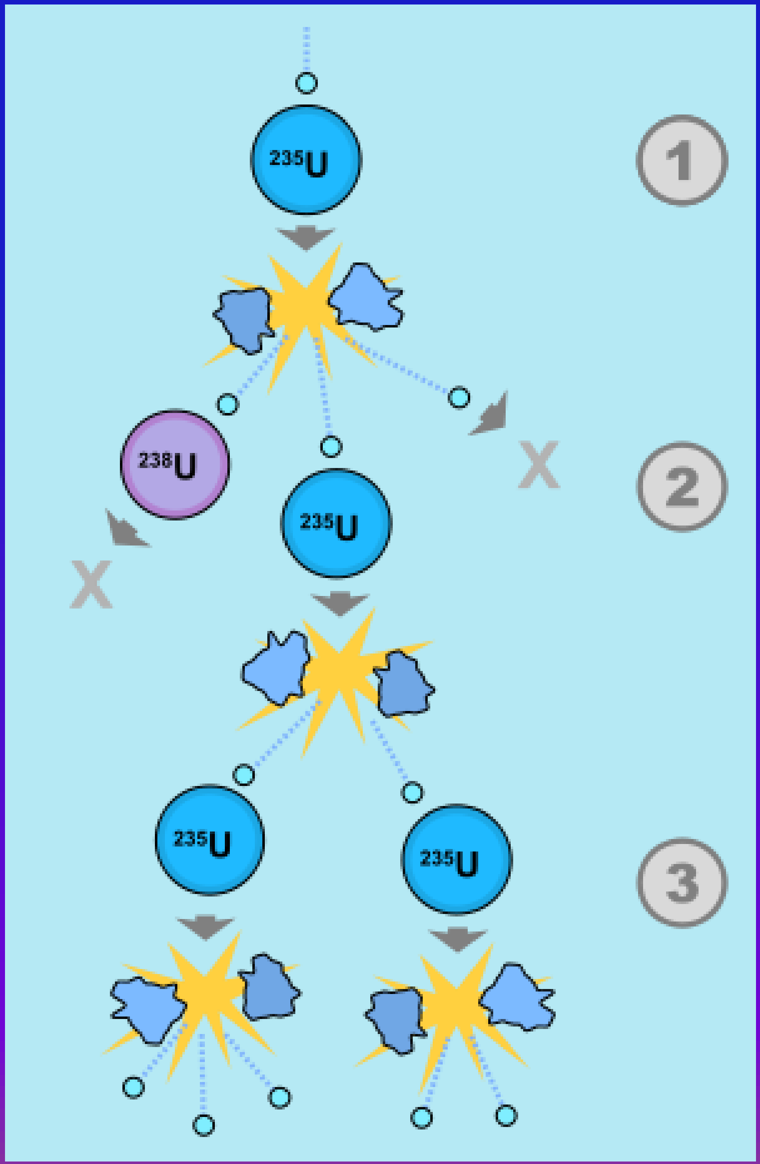
High-Energy Physics (2)

1930s – Enrico Fermi – Used neutrons to increase the effectiveness of **induced radioactivity**

Leo Szilard – **Self-sustaining nuclear chain reaction**

Dec. 2, 1942 – Fermi and Szilard – **First man-made nuclear reaction "Chicago Pile-1"** – University of Chicago

Chain Reaction



December 2, 1942, when Scientists Observed the First Man-made Nuclear Reactor, the *"Chicago Pile-1"* at University of Chicago

NUCLEAR ENERGY

Definition: Energy released from nuclear reactions generating heat

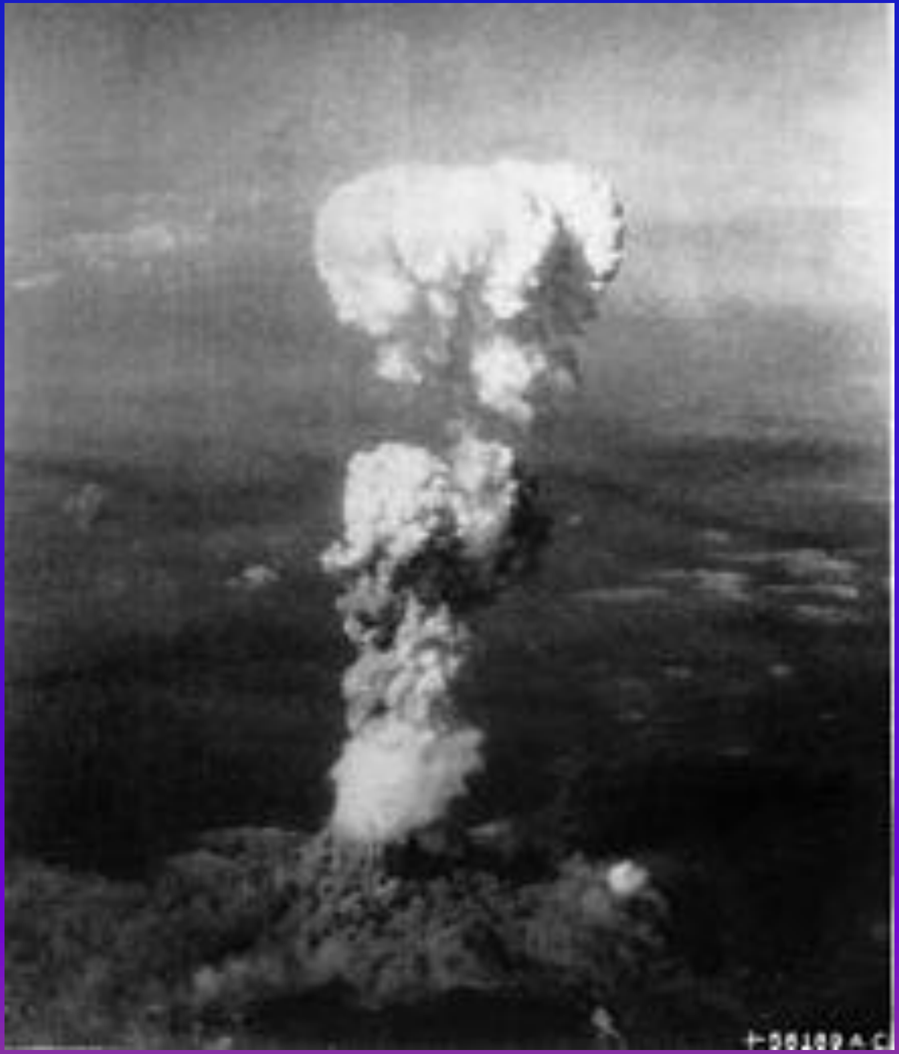
Nuclear reactions: nuclear **fission**, **decay**, **fusion**

Nuclear power plant heat ➪ steam turbines ➪ electricity

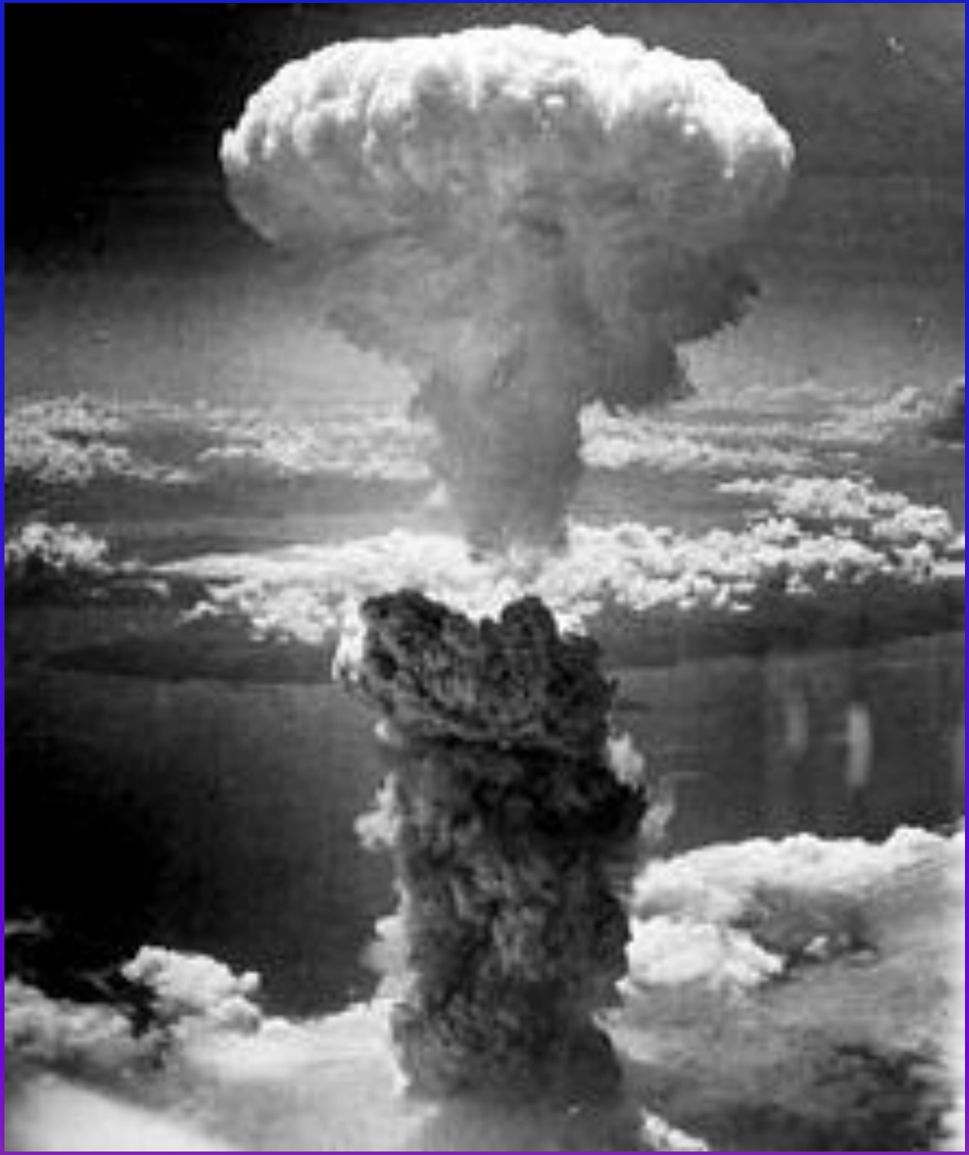
Fission - electric power plants

Since 1970, fission-electricity prevented release of 64 Bil. Tonnes of CO_2

Hiroshima after Dropping the Uranium-based Atomic Bomb (1945)



Plutonium Implosion Atomic Bomb Nagasaki, Japan, 1945



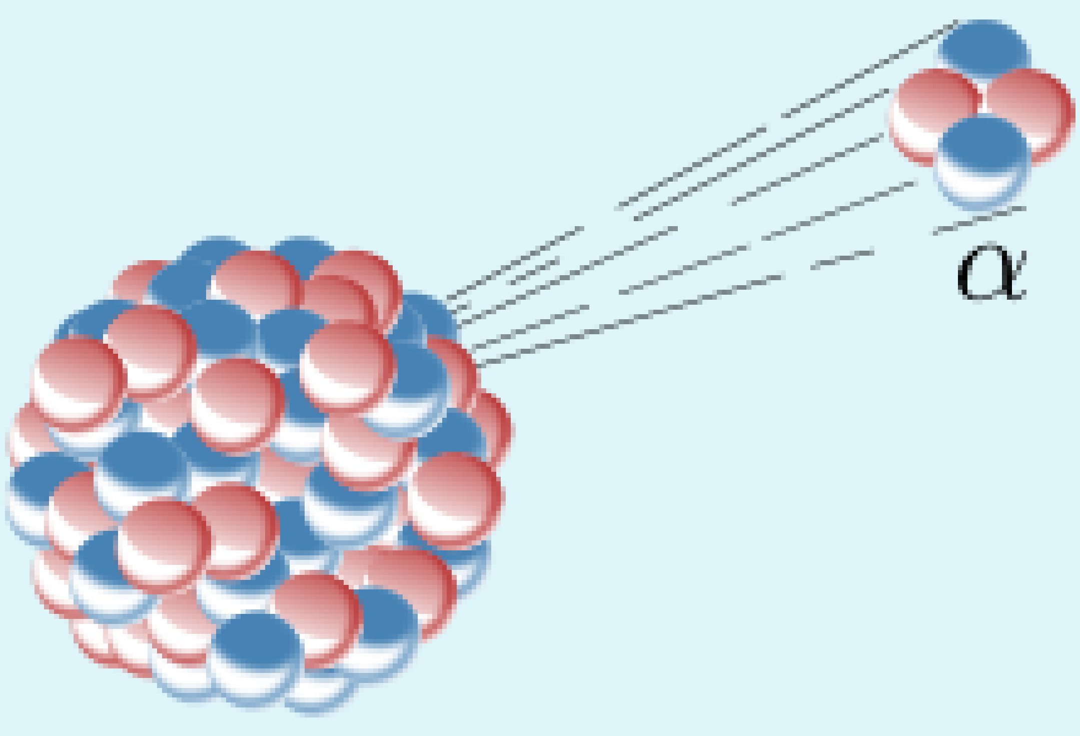
First Light Bulbs Lit with Electricity from a Nuclear Reactor (Chicago, 1951)

High-Energy Physics (3)
Fusion

The only man-made device to achieve nuclear fusion is the **hydrogen bomb** (called “Ivy Mike”) in 1952

High-Energy Physics (4)
Decay

The nucleus emits an alpha particle and transforms (decays) in an atom with a smaller mass



Nuclear Energy – History of its Applications

1940s - Manhattan Project - Enriched uranium ⇨ **First nuclear weapons -** Hiroshima and Nagasaki

Dec. 20, 1951 - **First electricity generated** – Arco, ID

June 27, 1954 - **First world nuclear power plant** for electricity in USSR

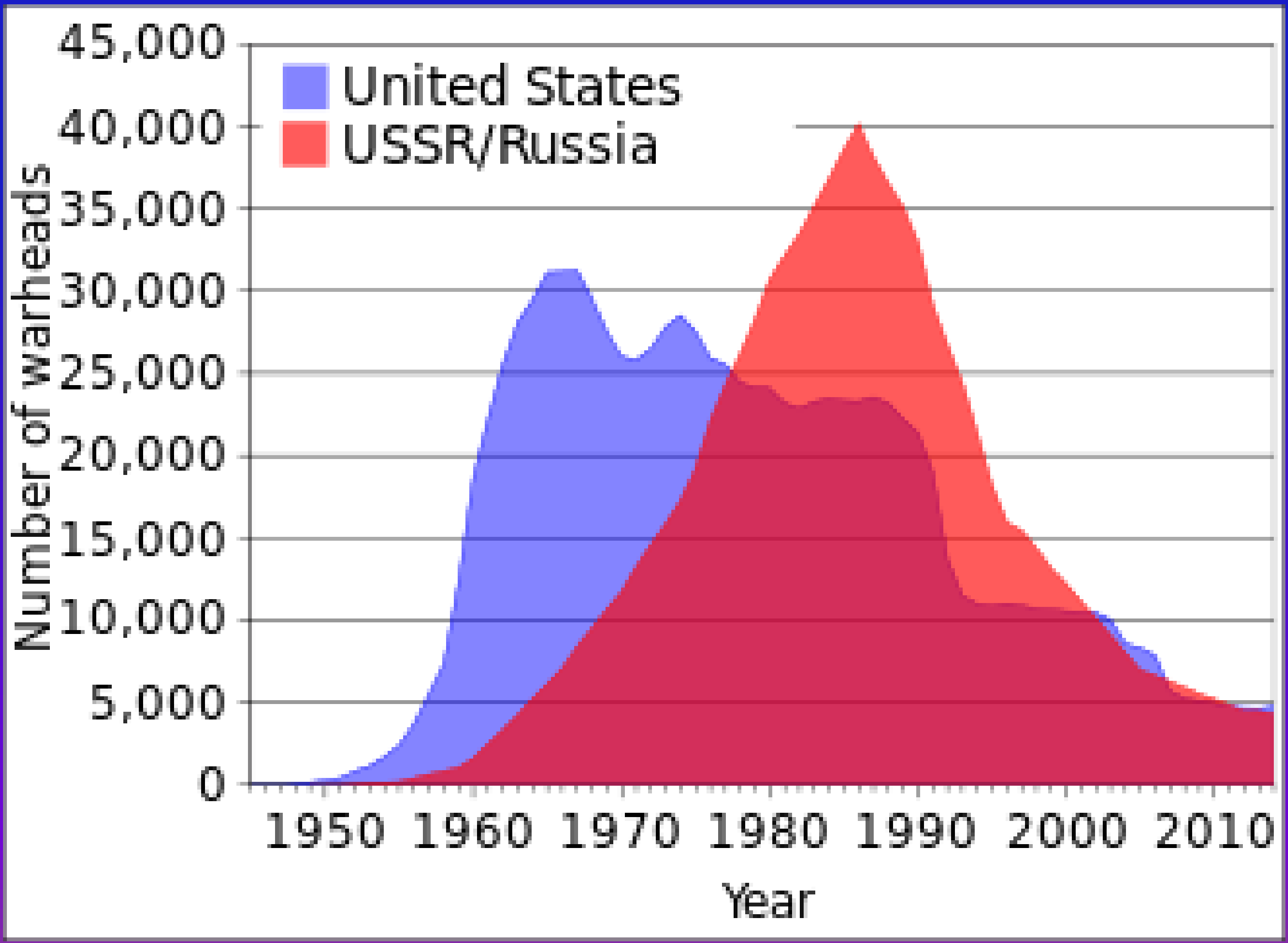
1955 - UN Intl. Atomic Energy Agency (IAEA)

Aug. 27, 1956 - **First commercial nuclear power station** - Calder Hall, UK

US – 75 nuclear submarines; Russia – 61 nuclear submarines

Main applications: **Electricity, Weapons, Satellites**

USA and Russia Nuclear Weapons Stockpile



US Nuclear Power Ships (1964):
USS Bainbridge, USS Long Beach, USS Enterprise

Nuclear Energy (NP)
Its Changing Status in the World

Installed nuclear capacity: 1960 – 1 GW

1970 – 100 GW

1980 – 300 GW

After 1970 – 2/3 of nuclear plants cancelled

1973 - Oil crisis - France and Japan ⇉ **more NP**

Mid-1970s - anti-nuclear protests. **Opposition to NP**

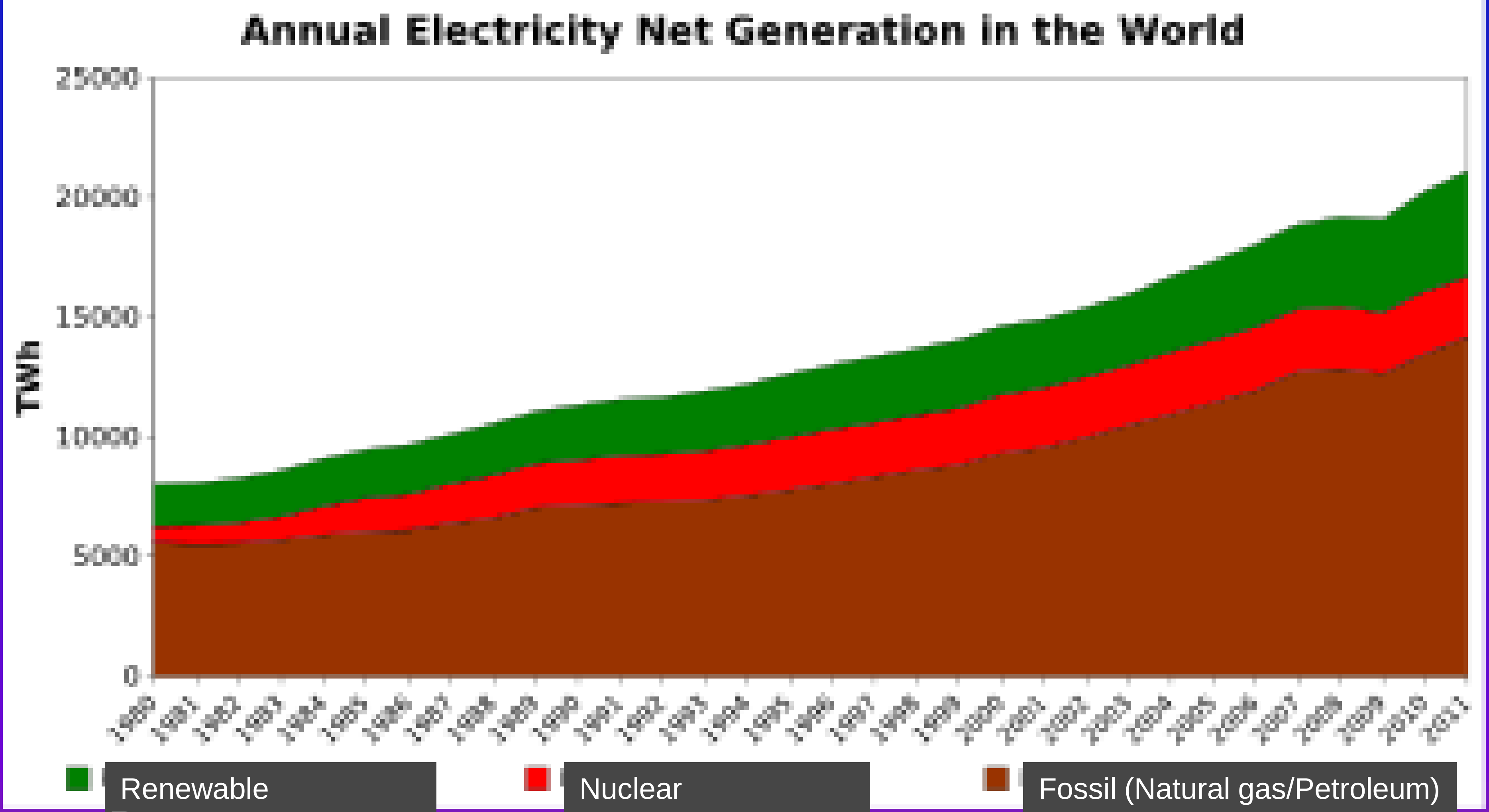
2001 - **"Nuclear renaissance"** b/o oil prices ↑ and greenhouse emissions ↑

2012 World (Civil) Electricity Generation by Fuels

Coal/Peat	40.4%
Natural Gas	22.5%
Hydro	16.2%
Nuclear fission	**10.9%**
Oil	5.0%
Renewable	5.0%

August 27, 1956. Calder Hall, UK The World's First Commercial Nuclear Power Station Connected to the National Power Grid

Annual Electricity Net Generation Growth in the World (1980 – 2011)



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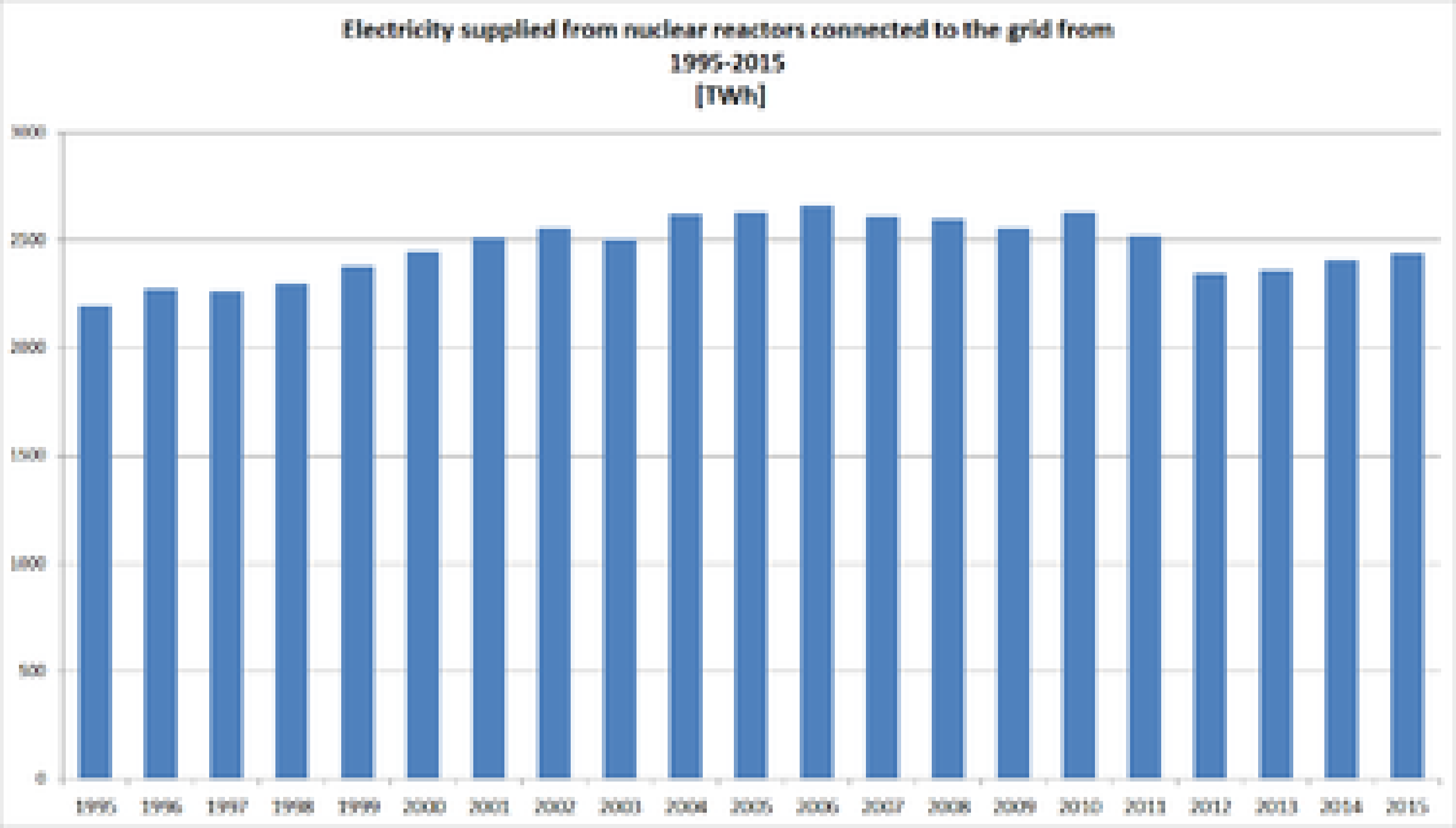
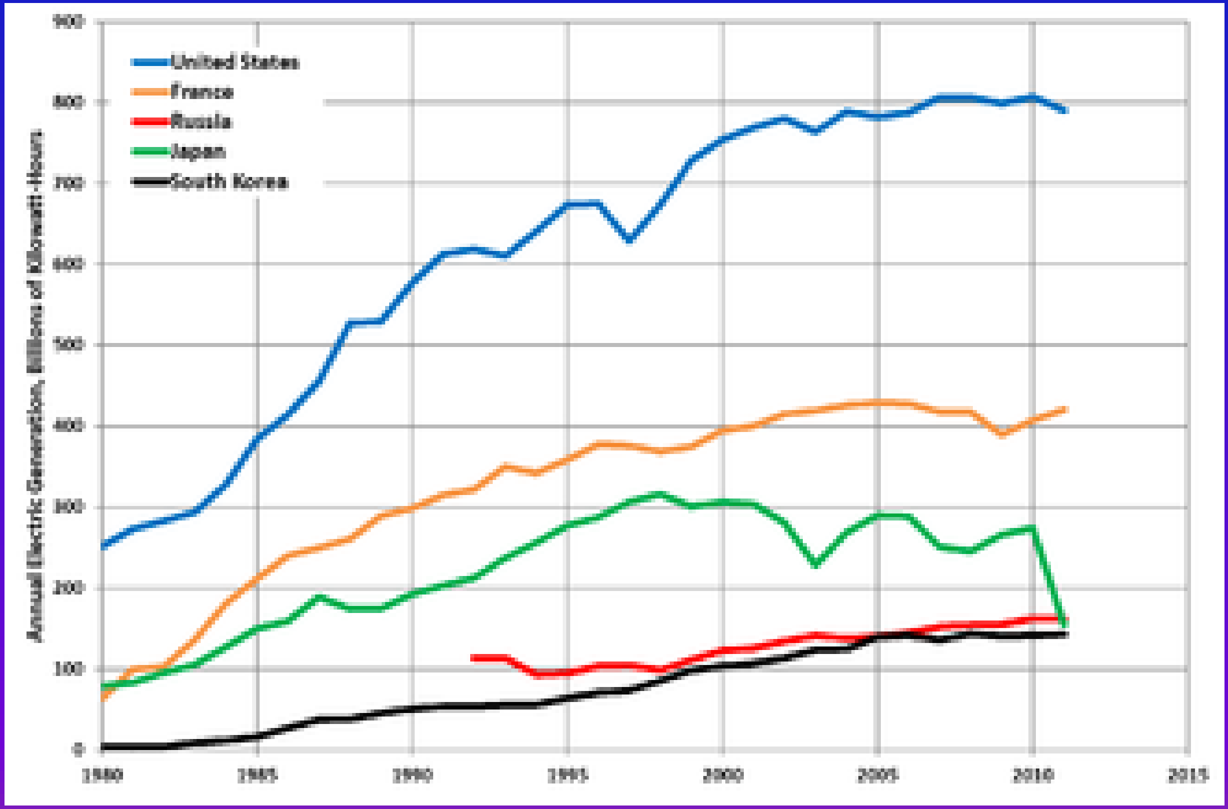
Electricity (TWh) Supplied from Nuclear Reactors 1995-2015



Electricity Generation Trends in the Top Five Fission-Energy Producing Countries 1980 – 2012 Annual Electricity Generated (Bil. kWh)

USA (19%)*
France (80%)*
Japan
Russia
S. Korea

* % of total electricity



Applications of Nuclear Energy

Consumer products: Household appliances

Food & Agriculture: Approved to preserve food and to eradicate pest insects

Industrial uses: Auto and aircraft, mining, oil exploration, construction

Medicine & Scientific Research: Nuclear medicine imaging; radioactive tracers

Space Exploration: Essential

Oil and Gas Exploration

Water desalination

Smoke Detector uses NE

Radura Logo Shows that Food has been Treated with Ionizing Radiation

Nuclear Energy - Economics

Uranium resources reportedly available for "160,000 years"

Costs (2012)**:** Natural gas $64/MWh

Nuclear power $96/MWh

Solar power $130/MWh

Risks and Concerns: Nuclear accidents

Terrorist attacks

Increasing cost of oil

Nuclear fission = 2.5% of global energy consumption

"New renewables" = 2.0% of global energy consumption

Nuclear Energy Accidents

1979 - **Three Mile Island,** NJ – Solid decay products were contained.

One cancer death / 2 Million people.

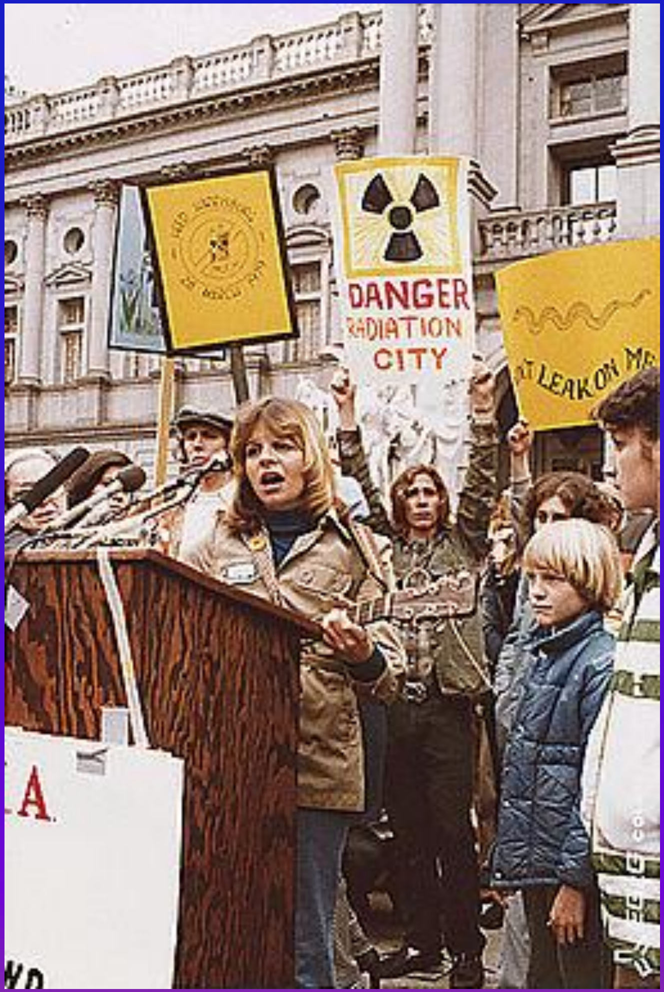
1986 – **Chernobyl,** Ukraine – Solid decay products released 2%-3% increase in cancer deaths.

2011- **Fukushima, Daiichi,** Japan nuclear accident.

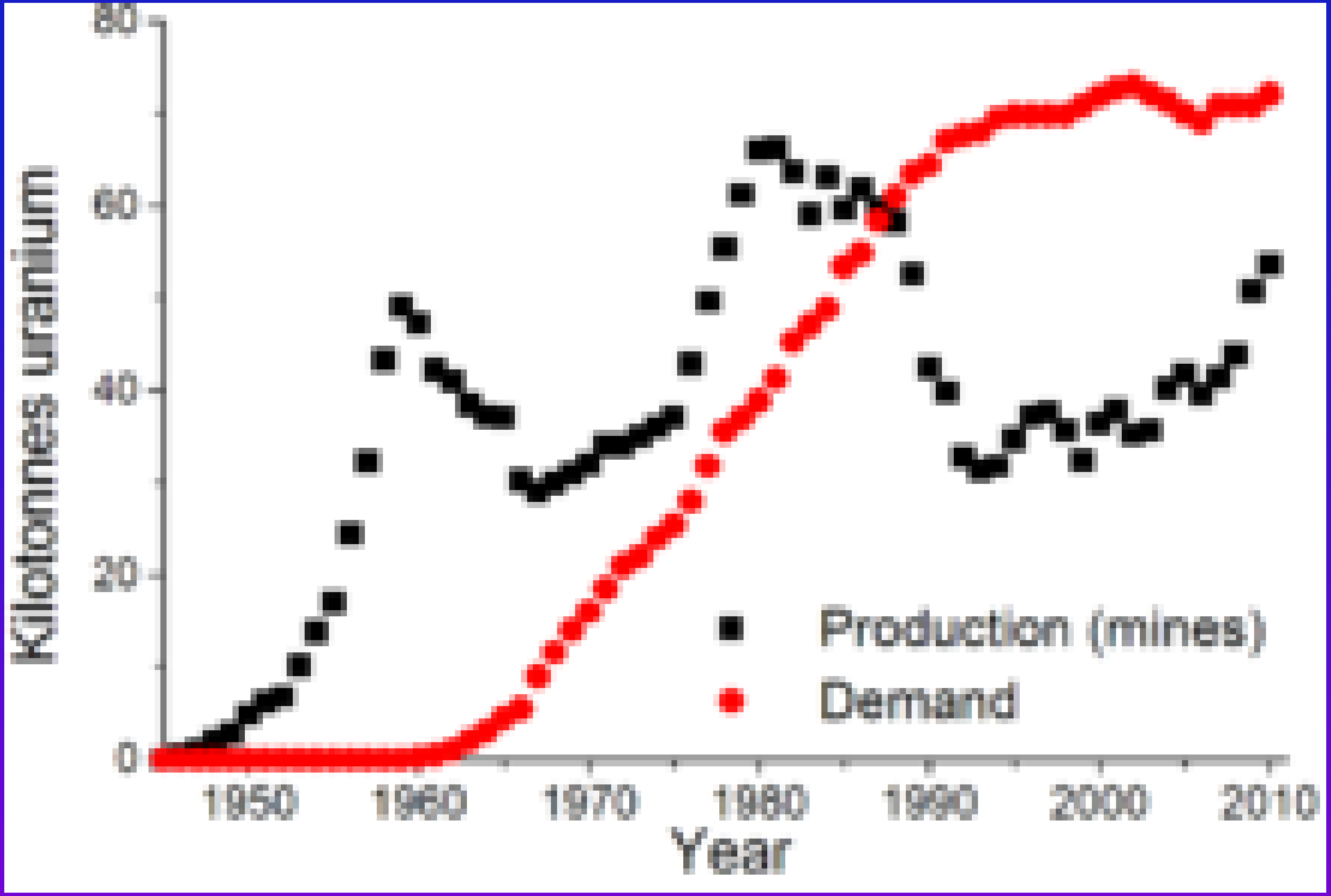
No reported disease or deaths related directly to the accident.

Anti-Nuclear Protest in Bonn, Germany, following the Three Mile Island Accident October 14, 1979.

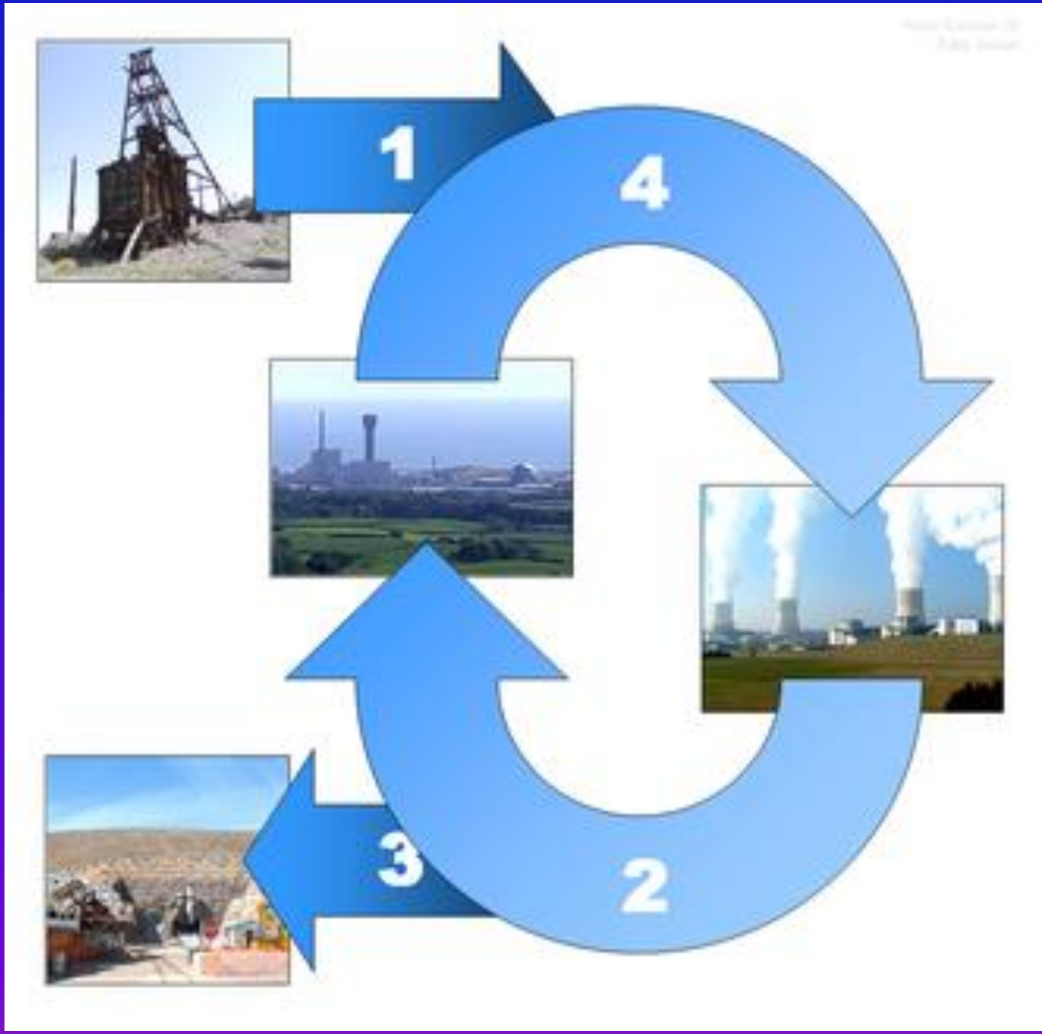
Anti-nuclear Protest in Harrisburg, PA, following the Three Mile Island Accident, 1979



World Uranium Production and Demand



The Nuclear Fuel Cycle



Ionizing Radiation Hazard Symbol

Nuclear Energy Debate

1970-1980 - Debate about Use of NE for electricity

In favor: It is a sustainable cheap energy

Reduces CO_2 emissions and air pollution

Energy security - Oil resources will run out

Promising for space propulsion

Against: Threats related to mining uranium ⇨ diseases

Threats about processing, transport, storage – radioactive waste

Accidents, sabotage

Terrorism

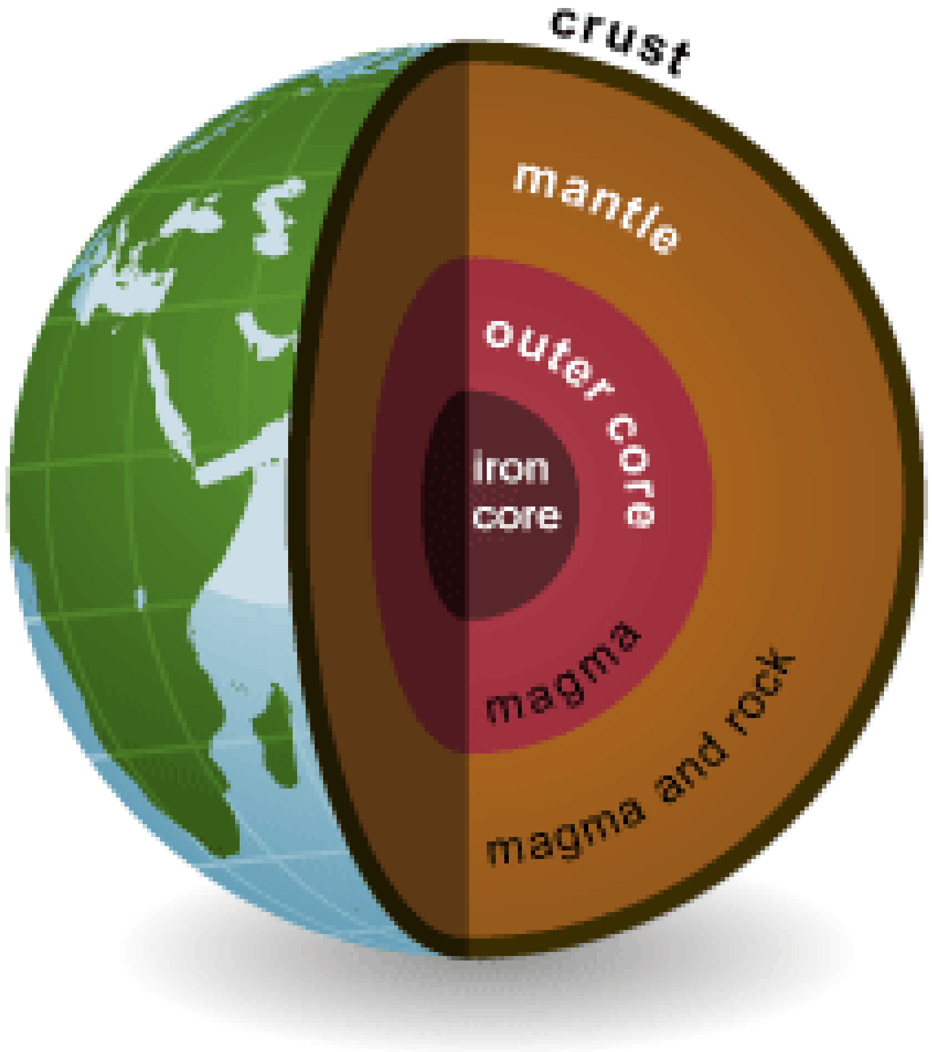
Risk of nuclear weapons proliferation

Nuclear vs. Renewable Energy

1. **Solar, wind, and hydropower are the safest and cleanest**
2. **Energy from carbon dioxide sources is on the way out b/o air pollution**, green house gas levels, and global warming
3. Nuclear power develops slowly because of public reservations and opposition
4. Nuclear power is economical
5. Nuclear power introduced in several European countries in 20-50% of applications
6. Could account for 80+% of the world energy in 40 years at a cost of 1% of global GDP annually.

GEOTHERMAL ENERGY

The earth's interior



GEOTHERMAL ENERGY

Definition: Energy generated and stored in the Earth

Earth's internal heat = thermal energy from

- Earth's formation
- Radioactive decay

Temperature at core-mantle = 7,200°F

Hot springs ➩ Heating since ancient times

2013 – Worldwide electrical energy = 11,700 MW

Cost-effective, reliable, sustainable, clean

Geothermal Energy - History

300 BC - Oldest source - Quin Dynasty - China

50 CE - Romans built a bath at Bath, England (*Aquae Sullis* = "Waters of Sul" a Celtic god)

14th Cent. - Chaudes-Aigues, South France, still working

1827 - Larderello, Italy - extracting boric acid

1892 - Boise, ID – District heating system

1904 - First geothermal generator at Larderello – 4 light bulbs

1943 - Iceland – Heating homes

1960 - First geothermal electric power plant - The Geysers, CA

1973 - Geothermal technology popular in Sweden

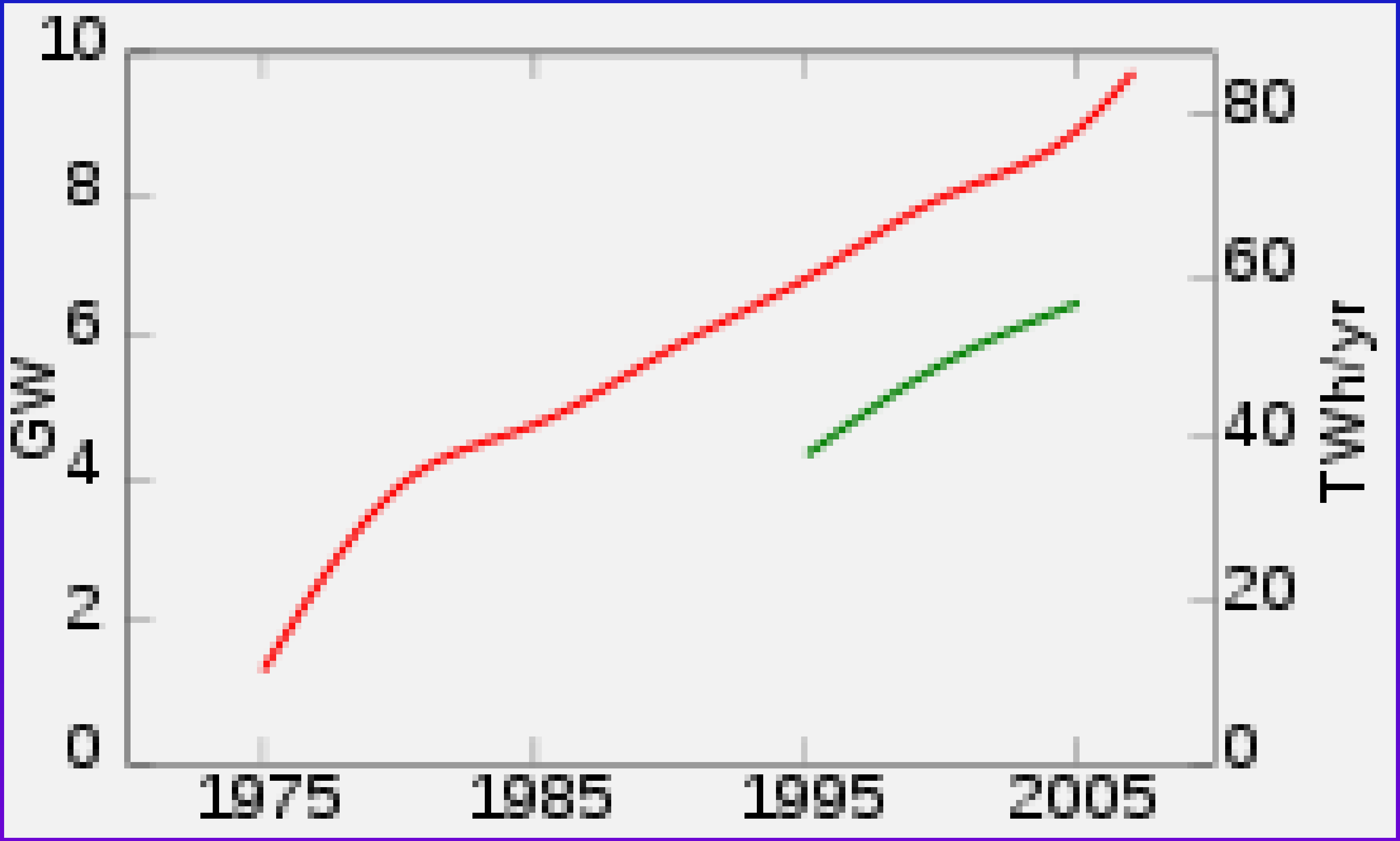
The Oldest Known Pool Fed by a Hot Spring, Built in the 3rd Century BC China

Nesjavellir Geothermal Power Station Iceland

Installed Geothermal Electric Capacity 2010

Country	Capacity MW	% of national Electricity Production
United States	3,086	0.3
Philippines	1,904	**27.0**
Indonesia	1,197	3.7
Mexico	958	3.0
Italy	843	1.5
New Zealand	628	**10.0**
Iceland	575	**30.0**
Japan	536	0.1

Global Geothermal Electric Capacity
Installed vs. Realized Capacity



Our Future Sources of Energy
LA Times 2016

Controlled Thermal Resources

THE POWER PLANT planned by Controlled Thermal Resources and Alger Alternative Energy would be able to generate nearly six times the electricity as similar facilities in the area.

Looking to tap the desert's energy

2 firms plan Imperial Valley geothermal plant

By Ivan Penn

GEOTHERMAL HEAT PUMP

GEOTHERMAL HEAT PUMP

A geosolar system. **“Ground Source Heat pump” (GSHP)**

Using the heat from solar energy which is

absorbed into the Earth’s surface

Upper 20 ft. of Earth’s crust has constant temp. 50-60°F

Caves are warm in winter and cool in summer. A pump system may cool the house in summer and warm it in winter

Cost vs. energy savings

Annual growth of 10%

Ground Source Heat Pump - History

1853 - Lord Kelvin developed the Heat pump

1940 - R. Webber built the first GSHP

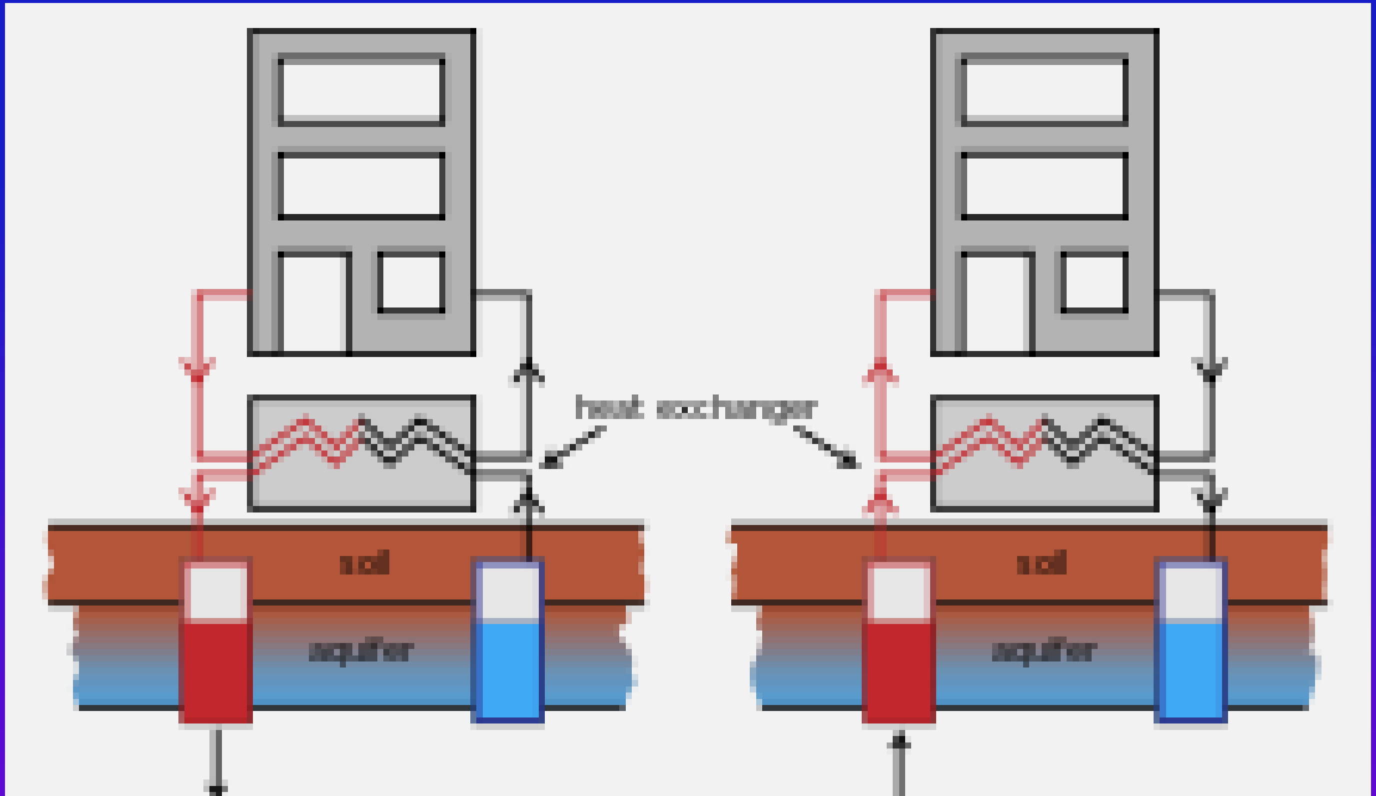
1948 – First commercial project installed - Portland, OR

1970 – GSHP popular in Sweden

2004 >1 million units worldwide

Great potential

Heat and Cold Pump



Heat storage
Summer cooling

Heat storage
Winter heating

Ground Source Heat Pump - Economics

High cost – Low operational cost

What's the cost of electricity and fuels?

Government incentives may reduce cost

2011-1012 State of Maryland incentives ⇨ cost of $26,700 for a home unit; $1.90/ Watt used

Cost varies widely

May be economical and reliable

BIOMASS ENERGY

BIOMASS ENERGY

Definition: organic matter derived from living organisms

Sources:

1st-generation biofuels = Sugarcane and corn stocks ⇨ bioethanol ⇨ electricity

2nd-generation biofuels = Burning wood (oldest biomass) and municipal waste = lignocellulose mass

Huge mass available for energy

Major disadvantage – air pollution

Biomass Energy - Economics

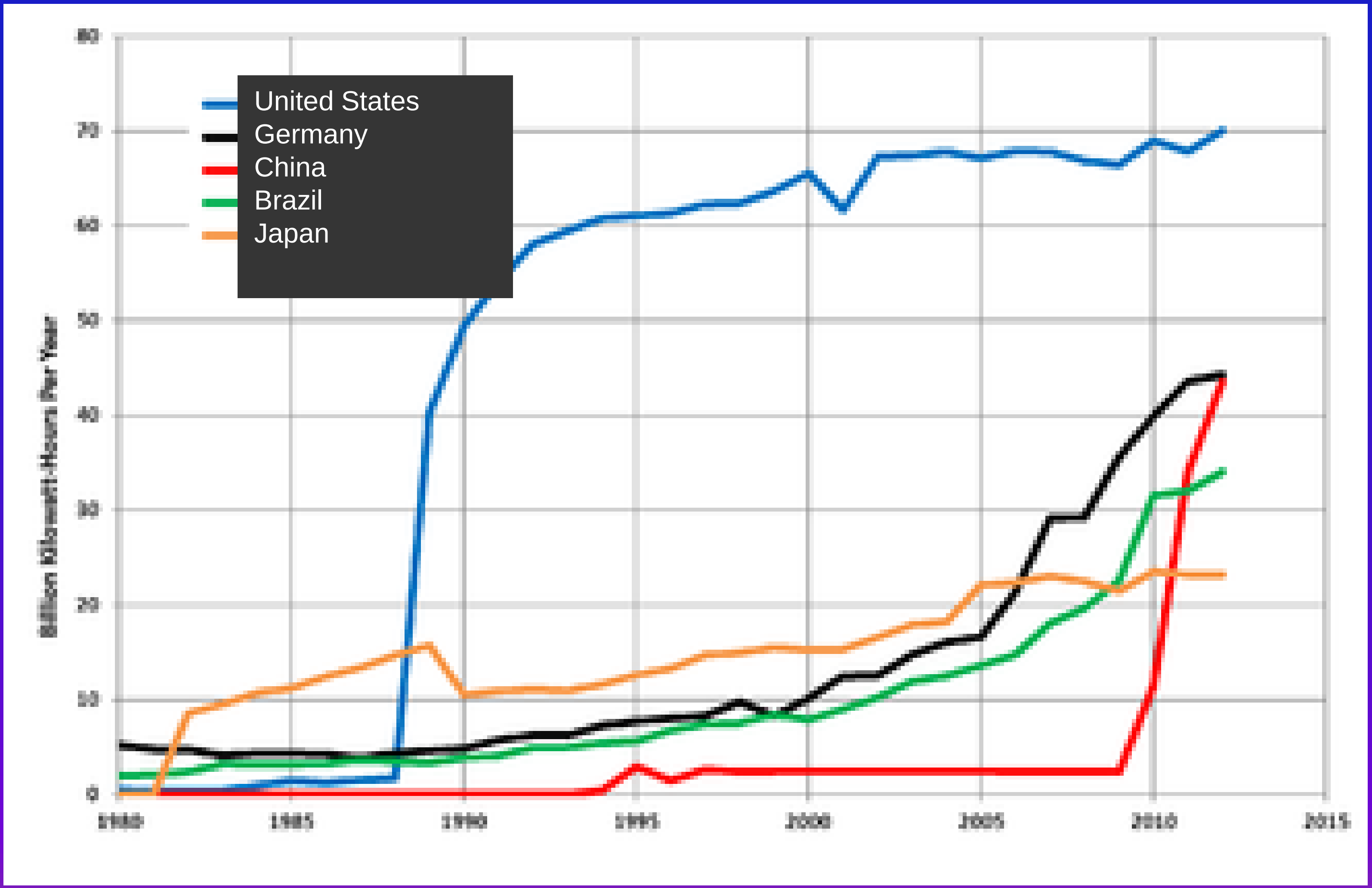
World resource: Annual production = 100 Bil. Tonnes of carbon = **1.4 times the Terawatt hours required**

Problems: Air pollution

Cost of transportation

Environmental concerns

Biomass-Producing Electricity in Billion kW/h



Biomass – An Ingenious Machine for Stump Removal

BIOGAS ENERGY

BIOGAS ENERGY

Definition: Mixture of gases produced by the breakdown of organic matter in absence of oxygen (anaerobic)

Anaerobic digestion – fermentation of biodegradable materials

Raw materials: Agricultural waste, manure, municipal, sewage, plant, green, and food **waste**

Biogas is: Methane 40-75%

Carbon dioxide 23-50%

Nitrogen 0-10%

Biogas – Uses and Production

Uses: Fuel, Heat, Energy. Compressed into liquid may replace 17% of vehicle fuel (UK)

Production: "Anaerobic digester" – Microorganisms digest the waste ⇨ biogas. The digestate is agricultural fertilizer

Renewable resource ⇨ Continuous production-and-use cycle

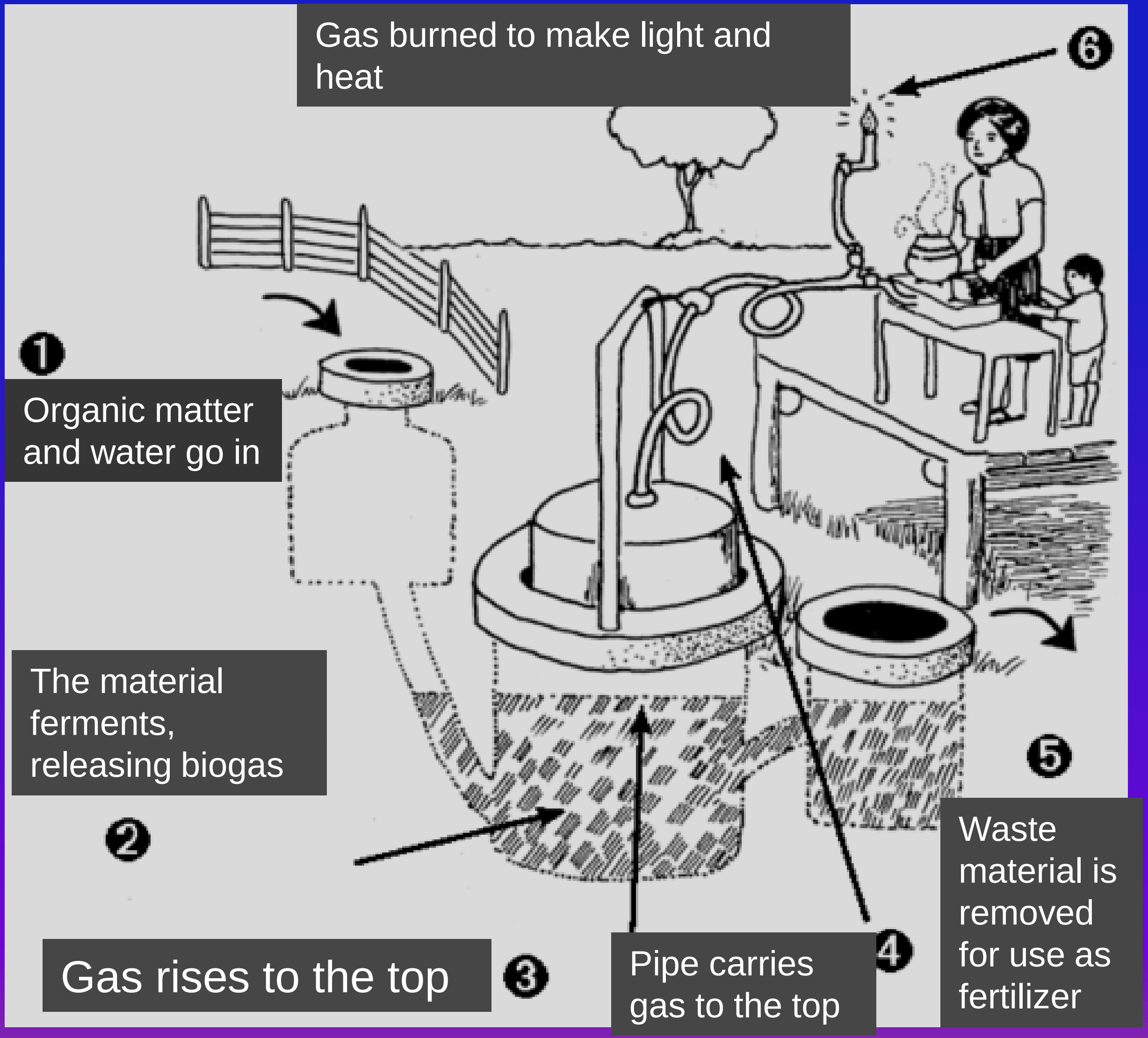
Manure ⇨ high levels of methane

Millions of cattle in US ⇨ 100 Bil. kWh electricity for millions of homes

One cow ⇨ manure/d ⇨ electricity for one 100W light bulb (!)

Explosive. The odor is due to added substance

Basic Design of a Biogas Plant



Biogas Bus and Biogas Train in Sweden

END OF LECTURE #8

End of this Course
What Did We Accomplish?

We have reviewed the Natural **Resources and the interactions of the Humans with them**:

Air, Water, Food, Metals, Minerals, and Energies

1. **Their Place on Earth ➪**
2. **Their History ➪**
3. **Their Economy ➪**
4. **Their Social Molding of Humankind ➪**
5. **Their Political Impact on the Society**

We Also Learned About our Patterns of Action

1. We find a resource
2. We exploit the resource to the maximum ⇨
   Toxic effects? Environmental hazards? Diseases?
3. We cannot replenish the resource
4. We search for other resources
5. We have been late in using available, renewable, non-toxic resources
6. What do we do for future generations?

Some Thoughts

Nature has many resources

It is for us to observe and discover

Man is a good observer

Progress has been slow

Progress has been marred by greed, disregard,
and incompetence

We must educate our children and our youth

They are the future on our planet

THANK YOU