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Lecture 1:

Introduction to Energy Science

The Challenge

Sustainable energy- using energy in a way that meets the needs of the present without compromising the ability of future generations to meet their own needs. Can modern alternative energy sources provide the carbon-free energy we need?

History of energy technology

BC	**Water engineering**: Archimedes screw (Fig. 1), Aqueducts, Waterwheels
AD1000	**Waterwheels** common throughout western Europe but very inefficient
1644	**Mercury barometer** (Torricelli): led to better understanding of vacuum
1650	**Air pump** (von Guericke)
1690	**Papin steam engine** (Fig. 2a) steam used to push piston, retraction very slow
1712	**Newcomen steam engine** (Fig. 2b) cold water jet squirted into piston chamber
1769	**Watt steam engine** (Fig. 2c) steam condensed in separate chamber

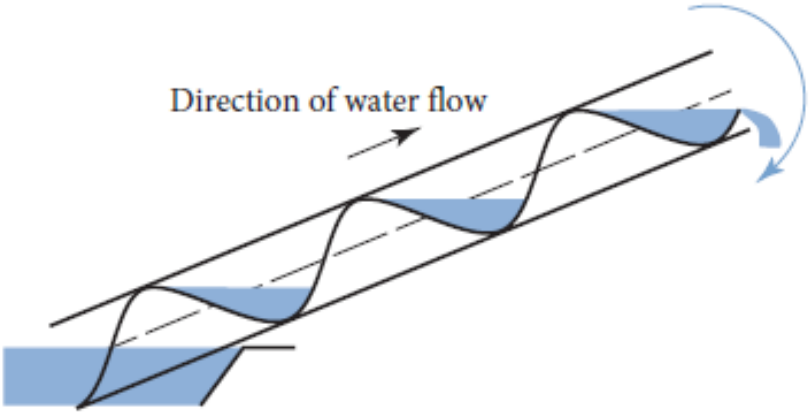


Fig. 1

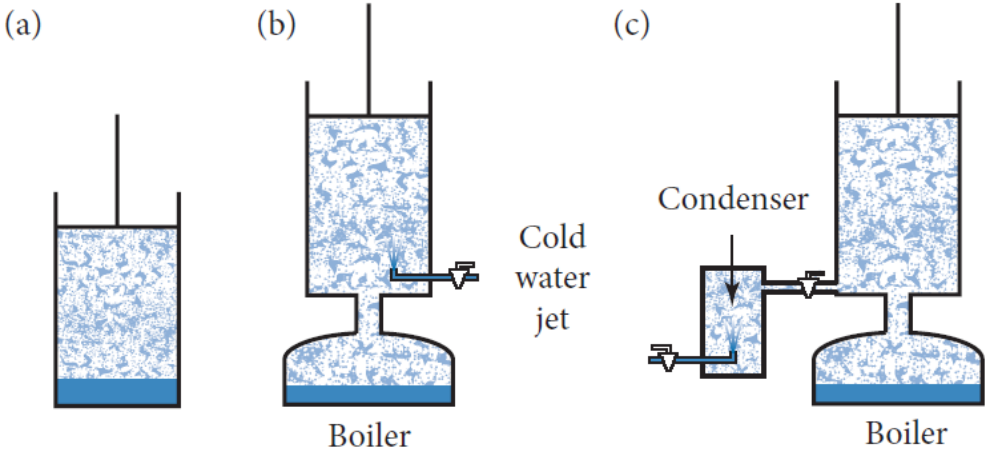


Fig. 2

History of energy technology (contd.)

1799 **Volta electric battery**: electrochemical cell, copper and zinc electrodes in electrolyte of sulfuric acid

I824 **Carnot** proved maximum possible efficiency of heat engine depends only on hot and cold temperatures between which it operates, independent of working fluid

1832 **Fourneyron water turbine**, much more efficient than early designs

1884 **Parsons rotary steam engine**

1831 **Faraday's laws of electromagnetic induction** (Fig. 3) current generated in closed circuit by time-varying magnetic field and also in a loop of wire when moved through stationary magnetic field, leading to electric motors, dynamos

1860 **Swan electric light bulb**

1876 **Otto's 4-stroke internal combustion engine**

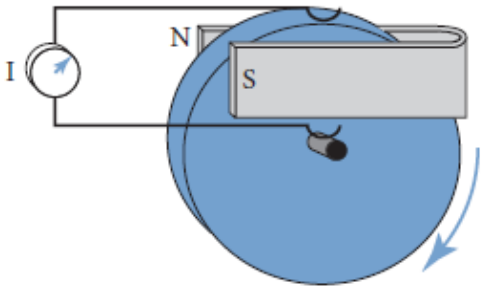


Fig. 3

History of energy technology (contd.)

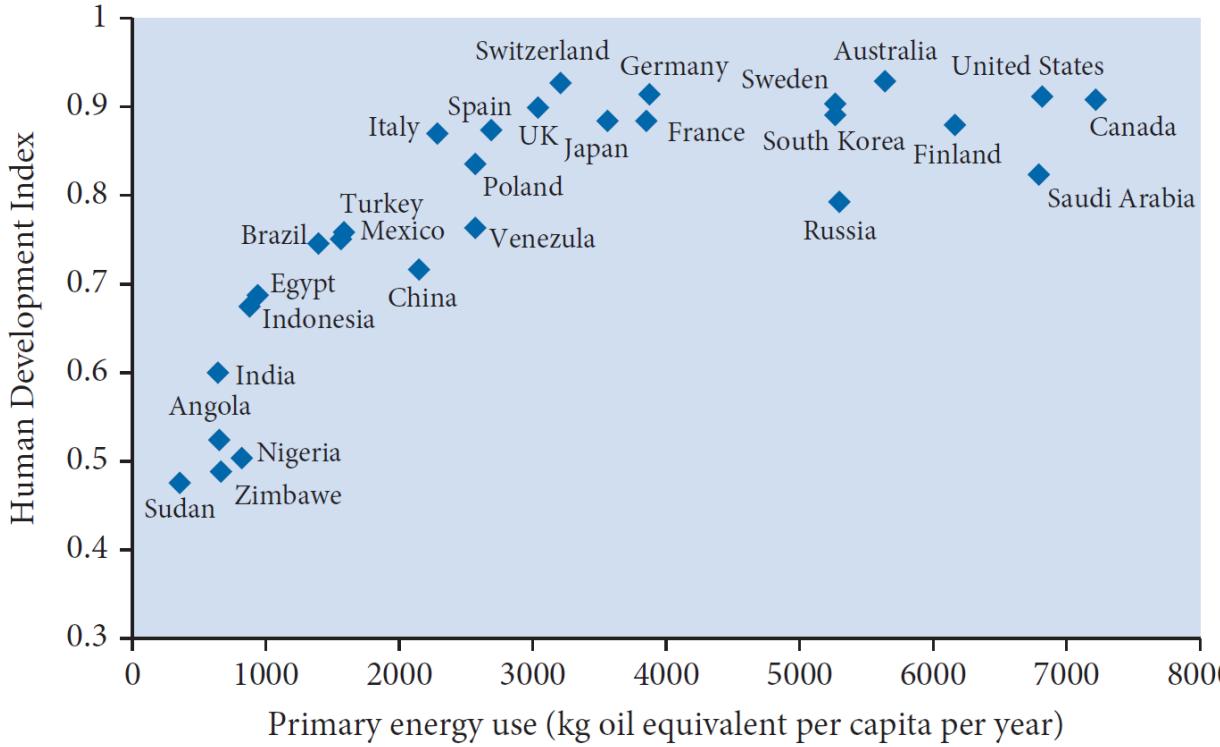
1879	**incandescent lamp** (Edison)
1880	first **electric power distribution system** (Edison)
1881	first **power station** (Holborn Viaduct, London), Edison
1886	first **modern car** (Benz)
1895	first **hydroelectric plant** (Niagara Falls), used Fourneyron turbines
1903	first **controlled powered flight** (Wright brothers)
1956	first **nuclear power station** (Calder Hall, UK)
1950s	development of **silicon photovoltaic cells**, around 6% efficient
1960s	development of **light emitting diodes (LEDs)**,very efficient
1970s	R&D of **alternative energy**, following oil price shocks, including **wind power**, **wave power**, **biomass**, **geothermal power**
1980	**rechargeable lithium-ion battery (Goodenough)**

Power scales

Device	Power (kW)
Treadwheel (AD 0)	0.2
Tour de France cyclist (uphill)	0.5
Strong horse	0.7
Newcomen steam engine (1712)	4
Fourneyron water turbine (1832)	30
Parsons' steam turbine (1900)	10^3
Smith–Putnam wind turbine (1942)	1.3×10^3
Boeing 747 gas turbine (1969)	6×10^4
Sizewell B nuclear power station (1992)	1.2×10^6
Drax coal power station (1986)	3.9×10^6

Human Development Index (HDI) and Primary Energy Consumption

The **Human Development Index** (HDI) is a measure of the standard of living. There is a strong correlation for low values of the HDI of a country with the **energy use per capita**. There is a large spread in energy consumption per capita between different highly developed countries.

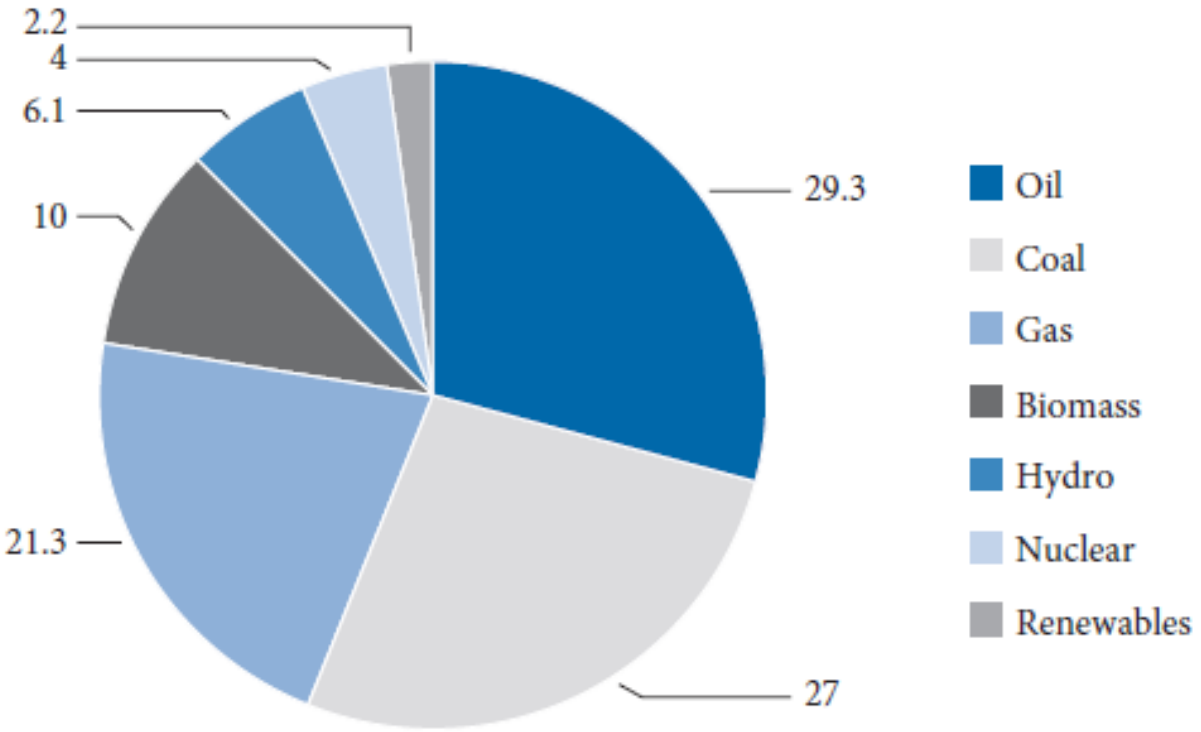


Energy intensity and global energy trend

- **Energy intensity** (amount of energy per unit of GDP) is expected to decrease globally over the next 20 years and energy efficiency is expected to improve.
- As an agricultural society becomes industrialized and more developed its energy intensity increases, but as more service sector jobs grow and technology develops the energy intensity falls as more high value commodities that require less energy are manufactured.
- **Global energy demand is predicted to increase by about third by 2035**, with electricity generation by two thirds.

  But still 17% (1.2 billion) of global population without electricity

Primary energy demand



Percentage of primary energy demand by source in 2014
Total 14365 Mtoe = 601 EJ = 19.1 TWy

- Primary energy demand is predicted to remain approximately constant in OECD countries over the period up to 2035 at ~230 EJ, while growing significantly in non-OECD countries. Traditional biomass is estimated as 10% throughout this period.

Electricity generation by fuel

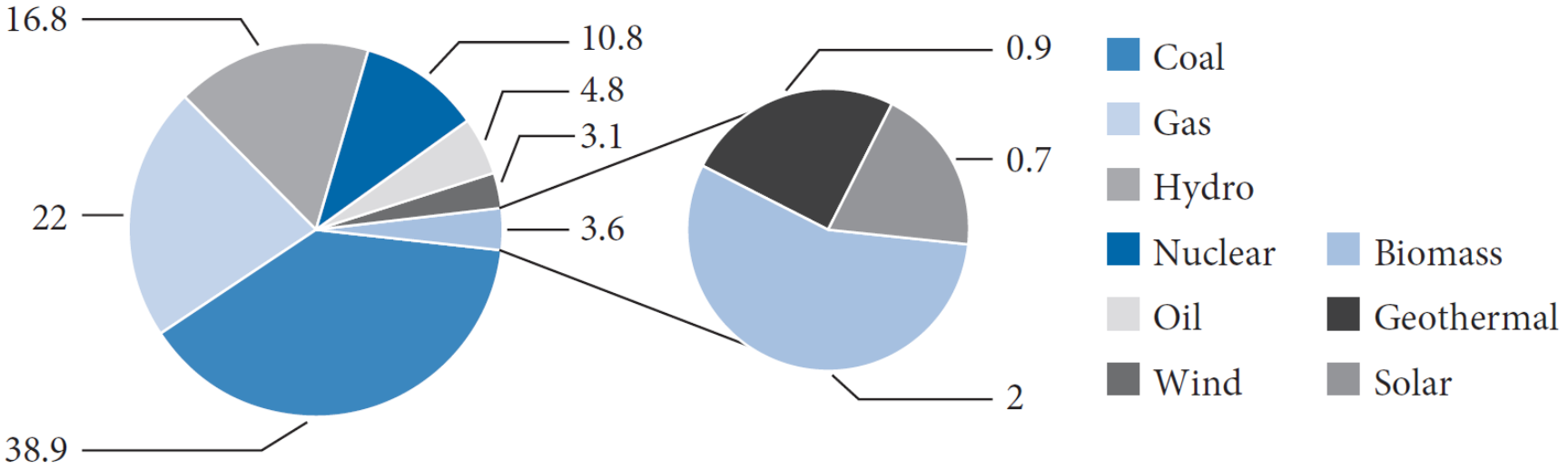


Fig. 1.8 Electricity generation (%) by fuel in 2014 (total 22 400 TWh = 2.56 TWy = 80.6 EJ) (TSP).

- Final energy demand, which is primary energy less the energy lost in conversion to forms utilized by end users, such as electricity and refined fuels, is currently about 2/3 of primary energy consumption, i.e. ~400 EJ

Primary energy trends

- By 2035, the GDP is expected to more than double, with China and India together providing almost half and the OECD countries about a quarter of the growth.
- The global population is expected to increase by ~1.5 billion, with Africa accounting for around half the increase, and most of the rest in non-OECD countries.

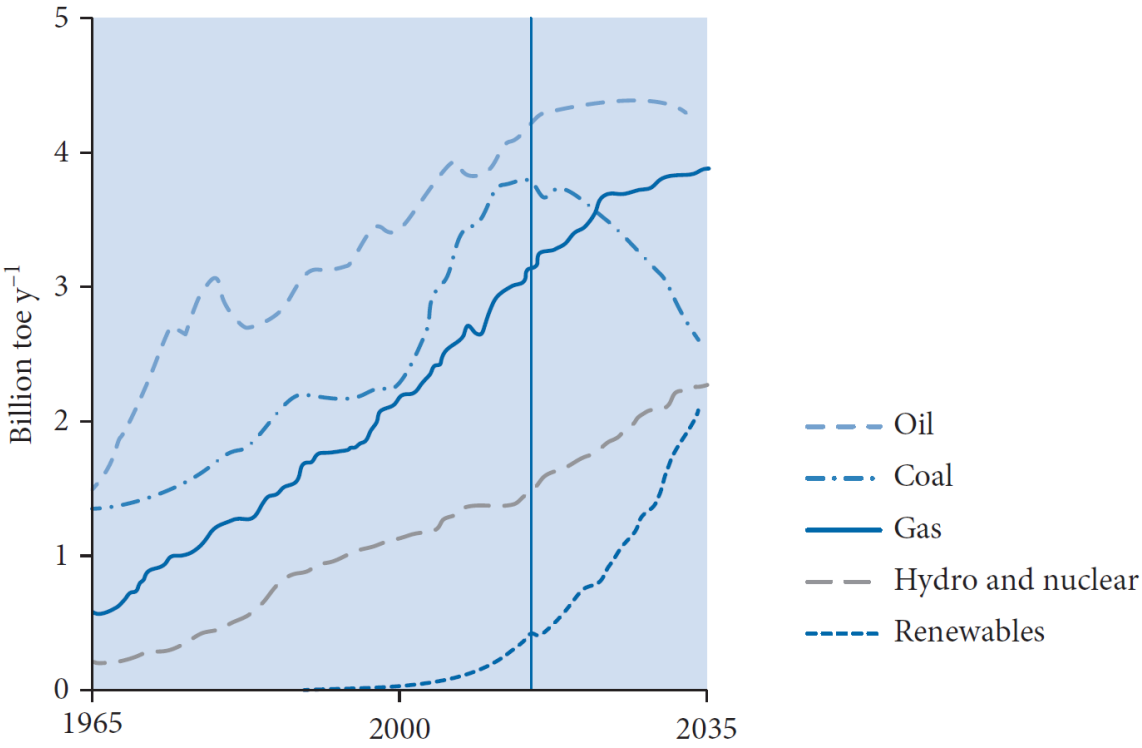


Fig. 1.7 Primary energy (excl. biomass) and possible projection to 2035 (BP2016).

Primary energy trends

- China’s economy has been growing rapidly over the last decade. Its combustion of coal has increased significantly, but its energy demand is expected to slow down over the next two decades.
- The pollution and high carbon intensity of coal is causing coal to be displaced by gas and renewables.

- Shale oil is making the US self-sufficient in oil, but Asia is increasingly reliant on oil imports. Shale gas is expected to grow, as is nuclear and hydro generation (mainly in Asia).
- The largest growth is expected in renewables throughout the world.

Fuel distribution

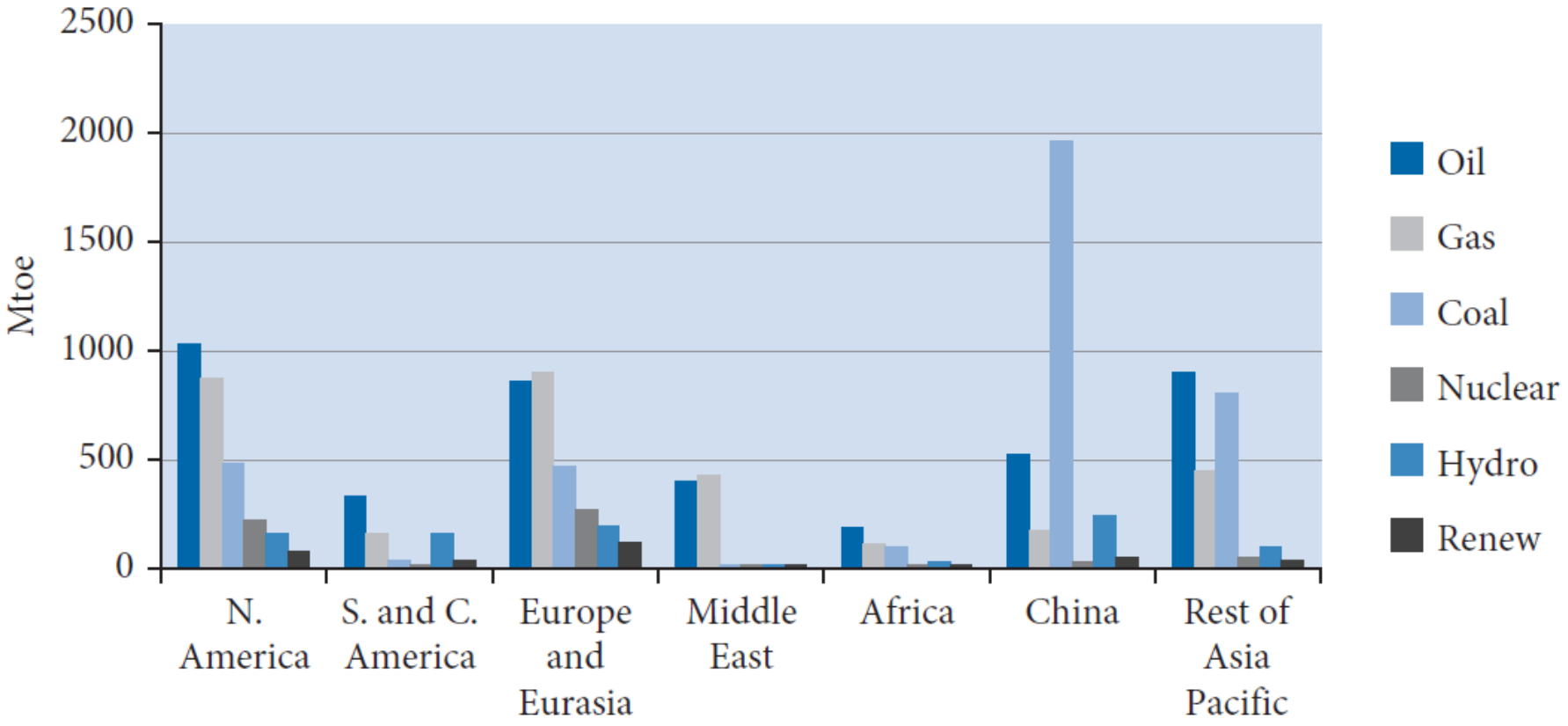


Fig. 1.9 The distribution of energy fuel by region in 2014 (BP).

Global trend of CO_2 emissions

Global emissions of CO_2 from fossil fuels have **stayed constant** at 32 $GtCO_2$ per year since 2013, indicating a decoupling of emissions and economic growth.

This is coming about through **fuel switching** to sources with lower carbon dioxide emissions per unit of energy (gas is about half that of coal), the **increase in renewables**, particularly in wind and solar PV, and **energy savings**.

Continuing such CO_2 emissions would put the world at risk of significant climate change owing to the associated global warming.