

Fuels, Energy and the Environment

By

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A Review of Various Energy Systems

Part 2



The Primary Sources of Energy

The bulk of the energy resources available can be viewed to be **solar in origin**. These may be of the **direct** type arising from the incidence of solar energy on earth. However, the energy available in the form of fossil fuels can be viewed as an **indirect** historical form of solar energy that may have taken millions of years to be processed to the form of common fuels. The indirect form of solar heating, apart from being responsible for the production of fossil fuels, is also responsible for making the following forms of energy available:

Indirectly Derived- Solar Energy

This can be considered to appear in:

Bio-energy resources

such as plants, wood and animal waste

- **Wind,**

from breezes to hurricanes

- **Waves, Sea Currents**

- **Hydro-Power**

Energy that is not solar in origin

This form of energy mainly includes the following:

- **Nuclear Energy:**

that is derived mainly from nuclear fission processes

- **Nuclear Fusion Energy:**

that may become at some time in the distant future potentially available.

- **Geothermal Energy:**

that is derived from hot regions of the earth's interior

- **Others:**

that are of lesser practical importance which may become available in limited and specific applications such as through the oxidation of certain metallic or non-metallic materials

The Non-Fossil Fuel Forms of Energy

Hydropower

Ocean Energy

Wind Energy

Solar Energy

Geothermal

Renewable Energy Systems

- **Wind energy using turbines**
- **Solar energy using heating and power generating devices**
- **Waves and Tidal Energy**
- **Bio-mass combustion**

Thermal Systems

(that produce primarily heat energy)

Some examples are:

- **Furnaces and boilers**
- **Heat exchangers and Regenerative systems**
- **Refrigeration, air conditioning and cryogenic systems**
- **Porous media heating and combustion**
- **Burners , spontaneous auto-ignition and combustion**

Distribution of solar power compared to Man's power consumption

Mode of energy flow	Power level
Solar radiation	$173,000 \times 10^{12}$ watts
Direct reflection	$52,000 \times 10^{12}$ watts
Direct conversion to heat	$81,000 \times 10^{12}$ watts
Evaporation	$40,000 \times 10^{12}$ watts
Man's power use	6×10^{12} watts

Some Typical Values of Energy and Power of Various Sources and Processes

Table (1)

Energy and power of various sources and processes

Process	Energy per day	Power- Watts
Sun's Energy	3.2×10^{31} J/day	3.7×10^{26}
Solar Energy to Earth	1.5×10^{22} J/day	1.7×10^{17}
Photosynthetic Energy	3.4×10^{18} J/day	4.0×10^{13}
Estimated Energy Consumption by Humans Globally	5.4×10^{17} J/day	6.0×10^{12}
Estimated Energy Consumption in North America	2.0×10^{17} J/day	2.3×10^{12}
Electrical Output of a Large Thermal Power Station	9.0×10^{13} J/day	1.0×10^9
Fusion Atomic Energy of one kg of Uranium 235	80 TJ	
Combustion Energy of a Barrel of Typical Oil	6.0 GJ	
Global Energy Use per Capita	0.2 GJ/day	2.0 kW
Estimated Food Energy consumption per capita	9.0 MJ/day	
Combustion Energy per Single Carbon Atom	0.7×10^{-18} J	

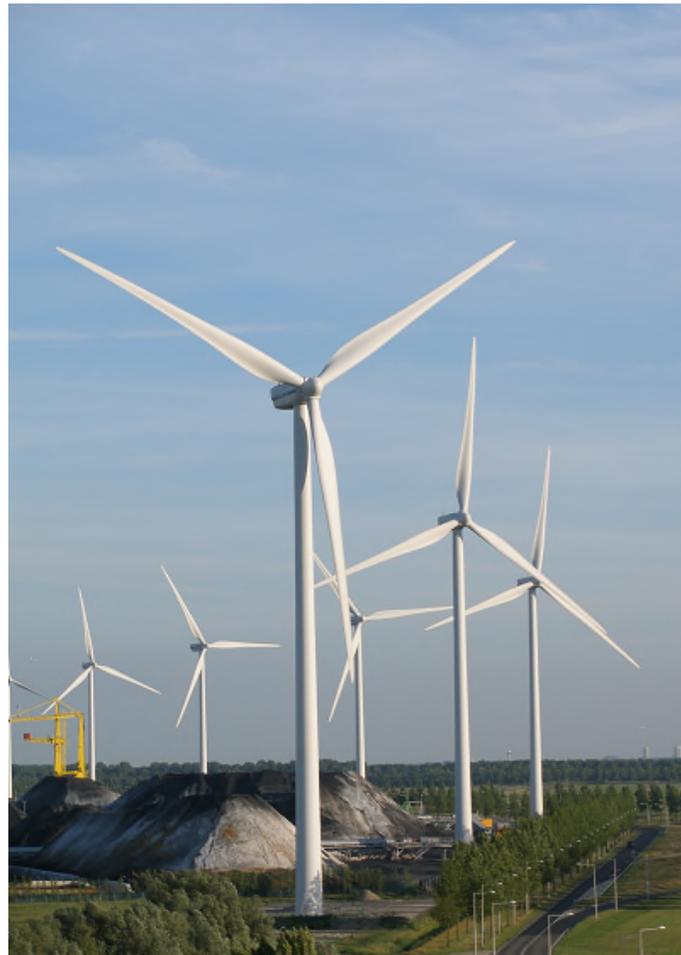
Examples of the relative specific energy on mass basis of the energy storage capacity of different systems

Energy Storage Medium	Specific Energy* MJ/kg
Gasoline	42-44
Diesel	42.5
Methanol	19.7
Ethanol	26.8
Hydrogen (liquid)	120.0
Hydrogen (gas)**	2.34
Methane	50.0
Lead-Acid Battery	0.19
Regen. Fuel Cell (H ₂ /Cl ₂)	0.44

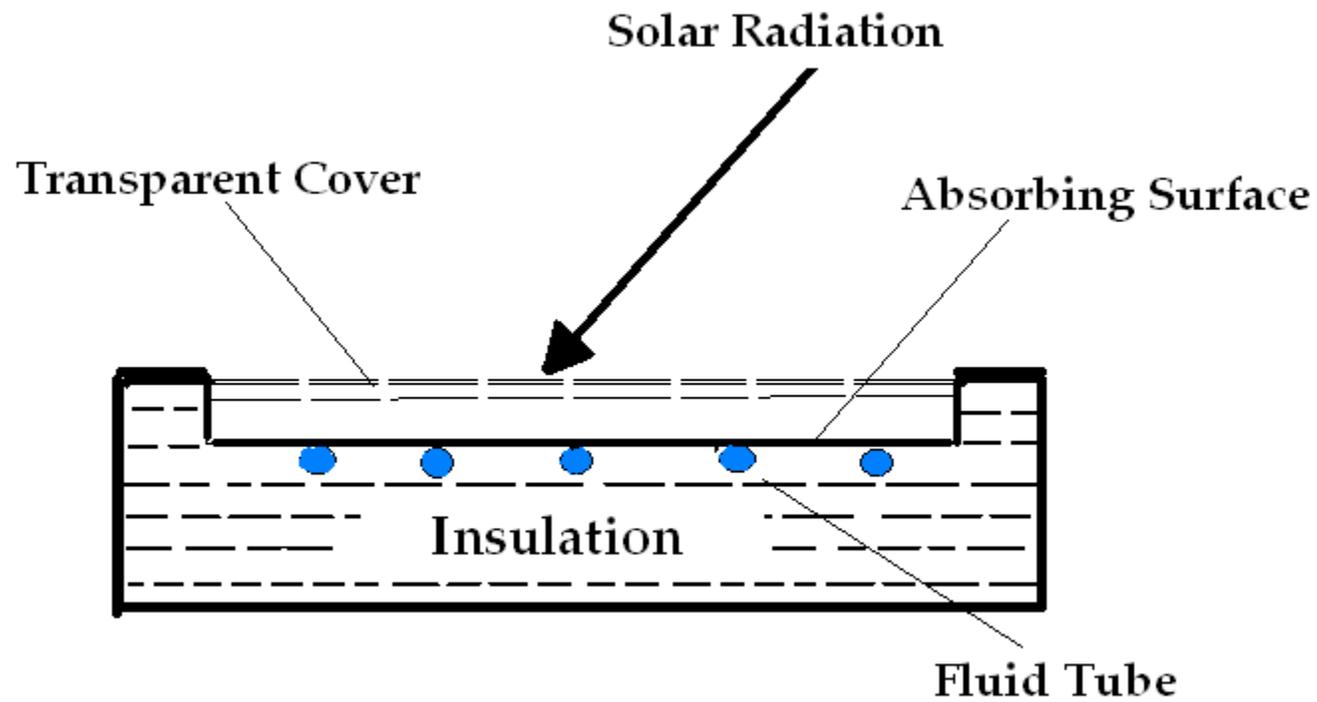
* Based on lower heating value of fuels

** Includes weight of magnesium-based hydride storage

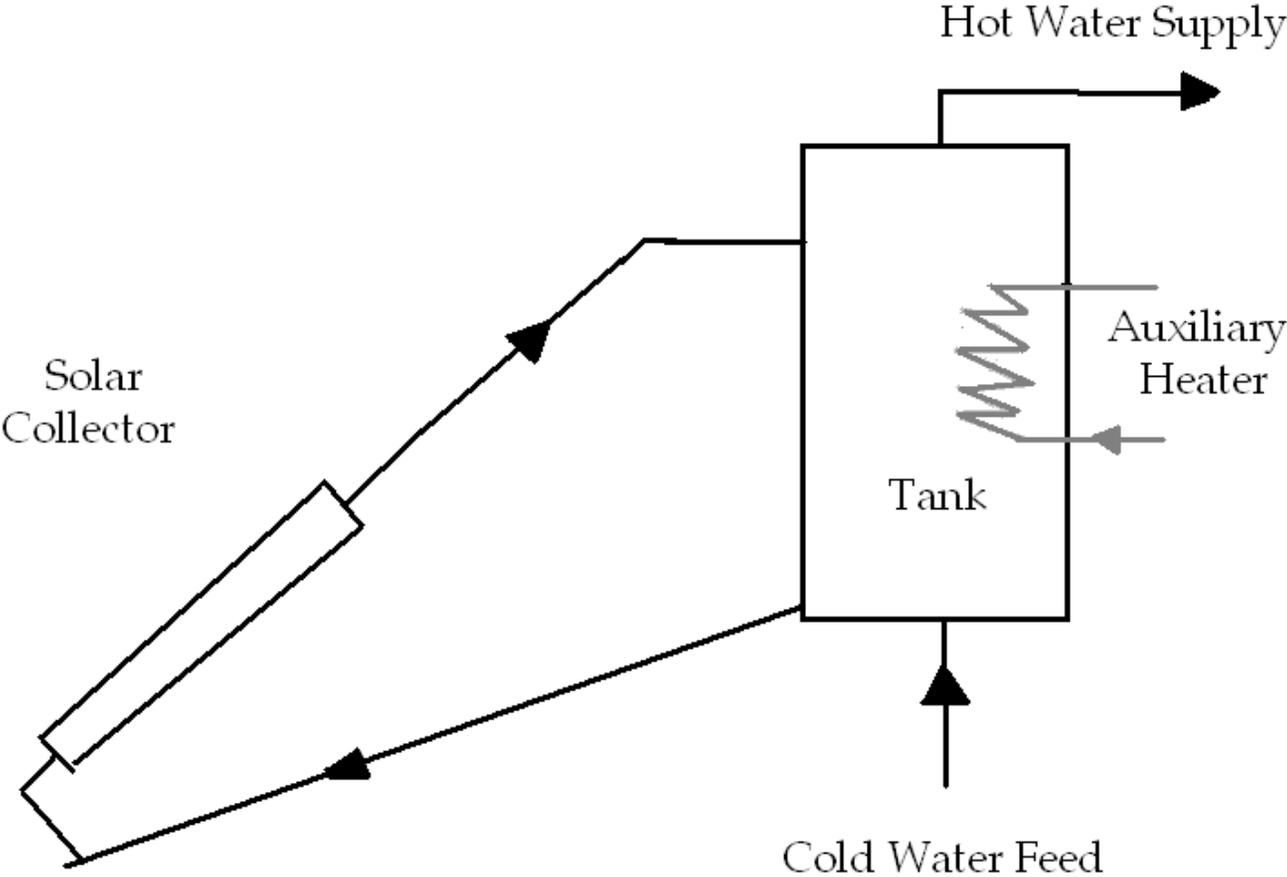
Wind Turbines for Generating Electrical Power



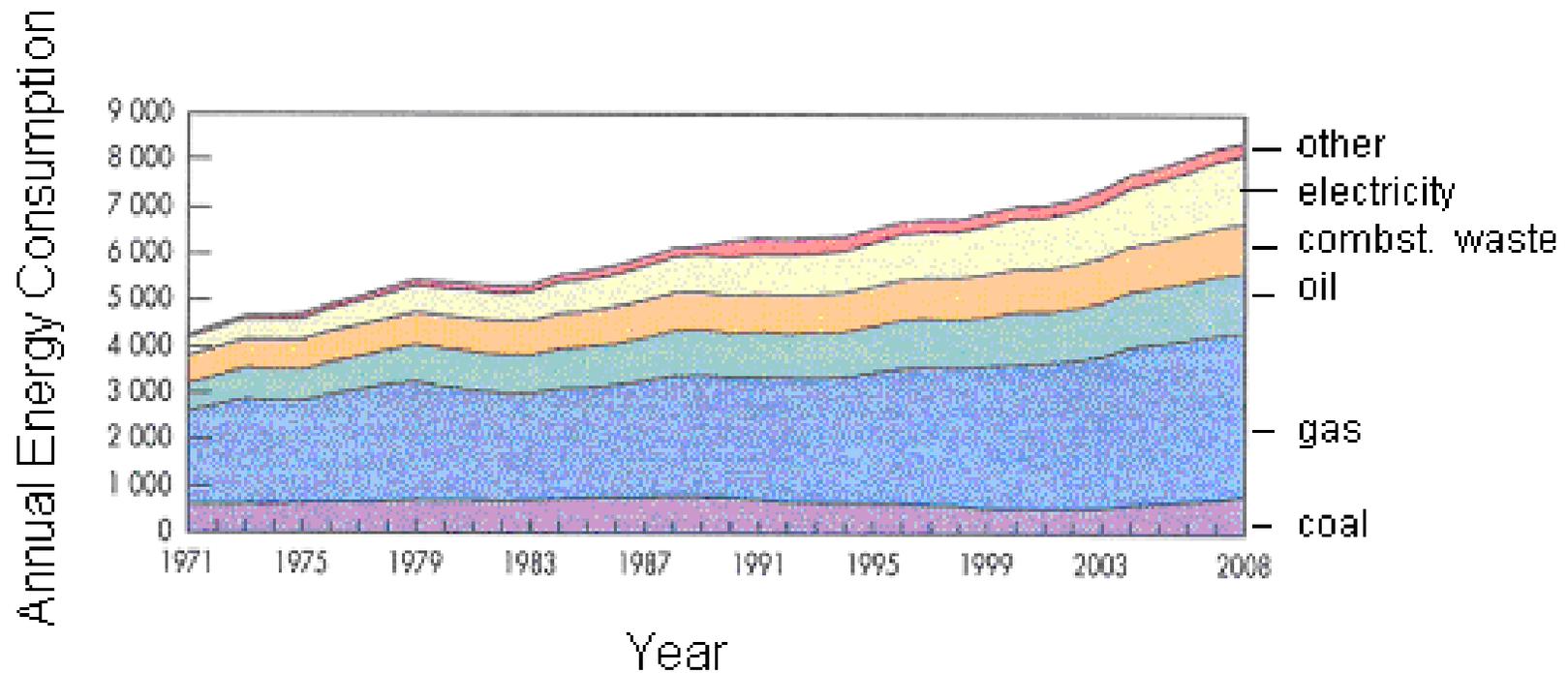
Schematic of a simple solar collector



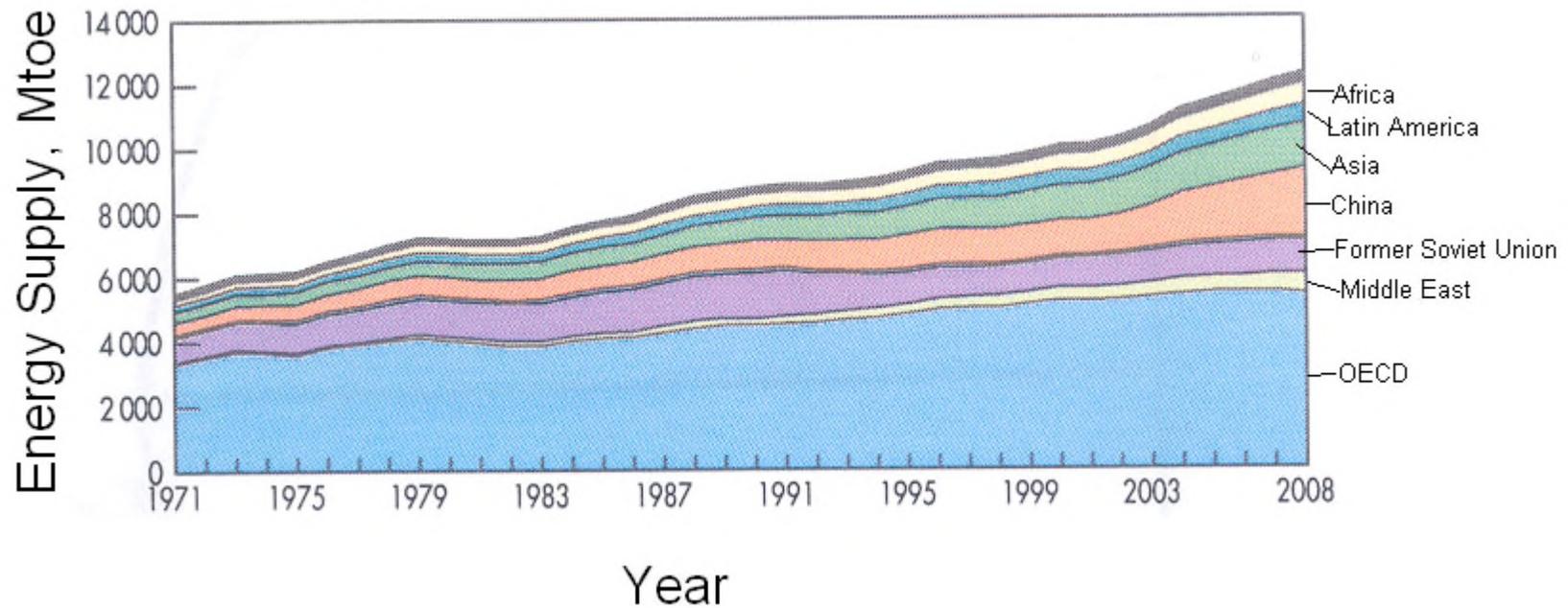
Natural convection solar collector circuit with an auxiliary heater



Annual Energy Consumption Over Recent Years

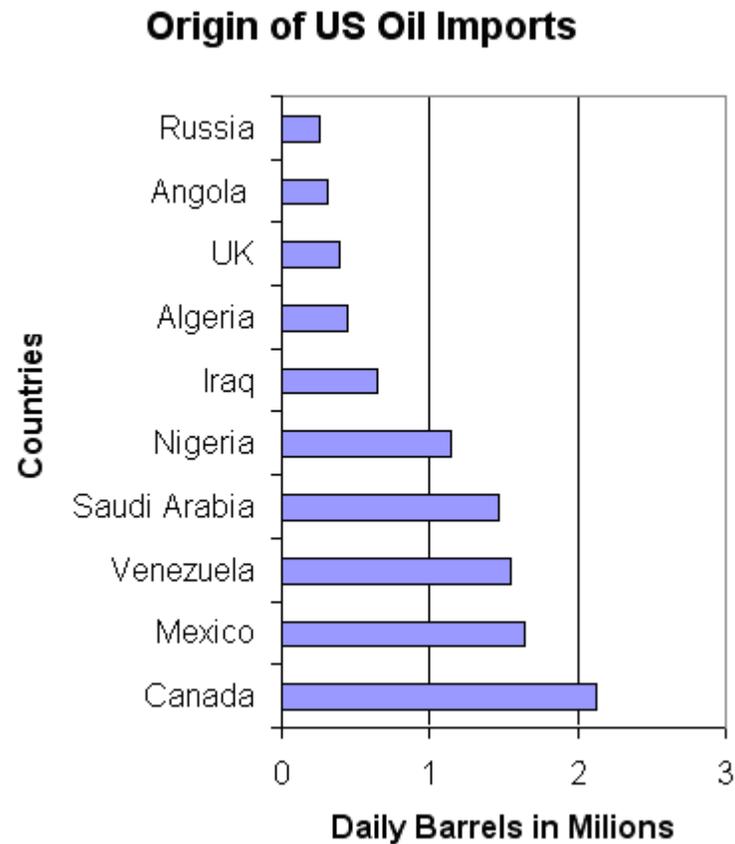


Changes in the world annual consumption of coal, oil, natural gas, and electricity measured in 103 ton oil equivalent over the period of 1977 to 2008

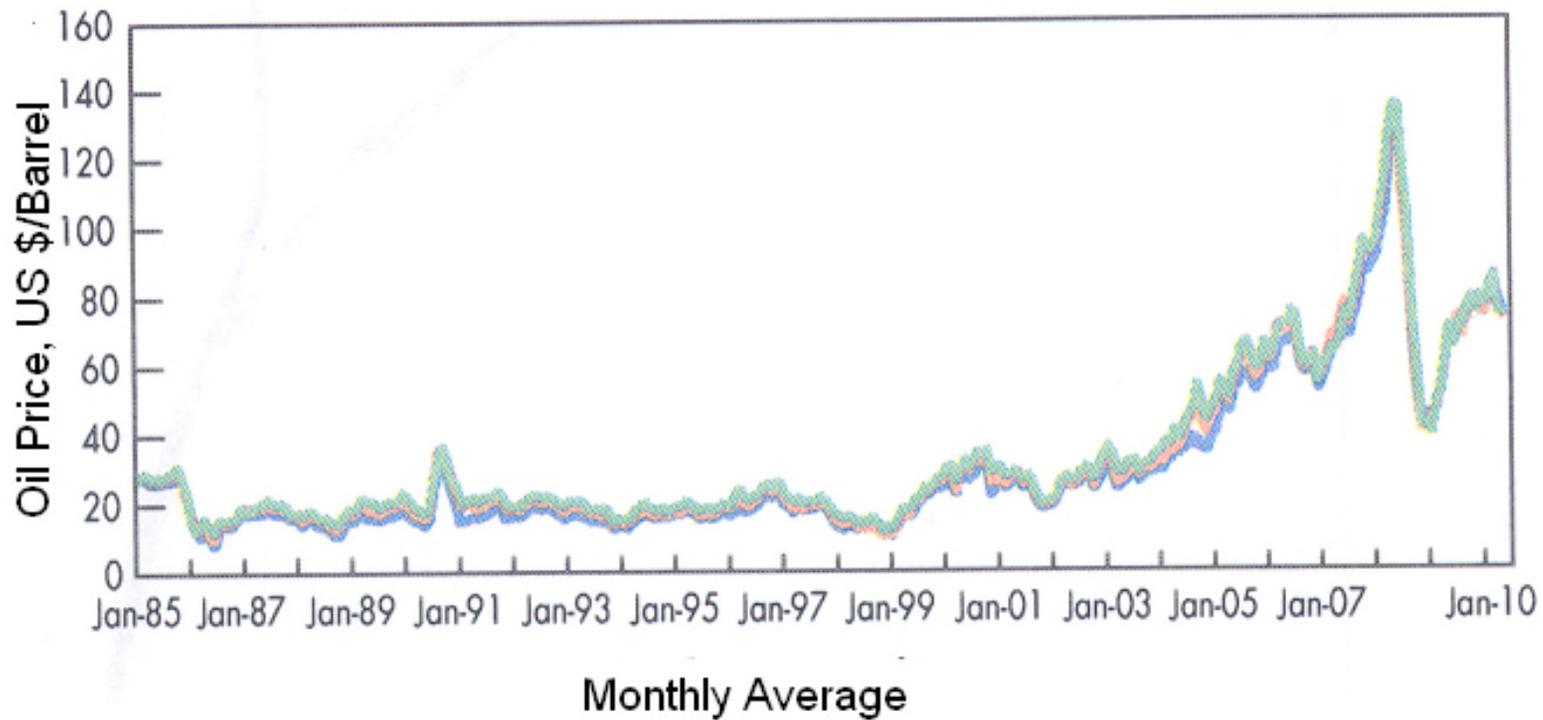


The origin and size of oil imports of the United States in Millions of Barrels per day in recent years showing Canada to be the top supplier.

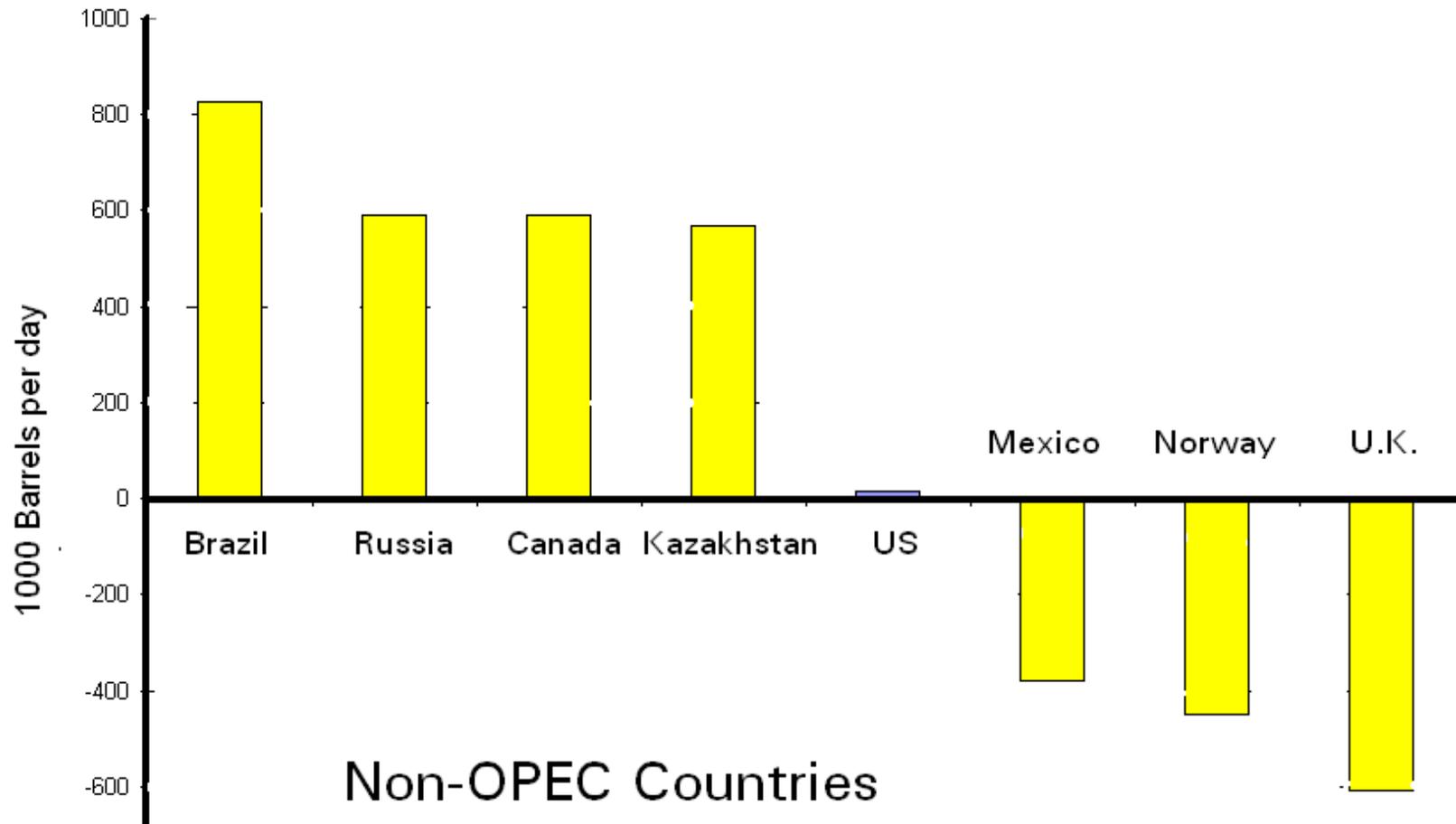
Source: Information US Government Administration



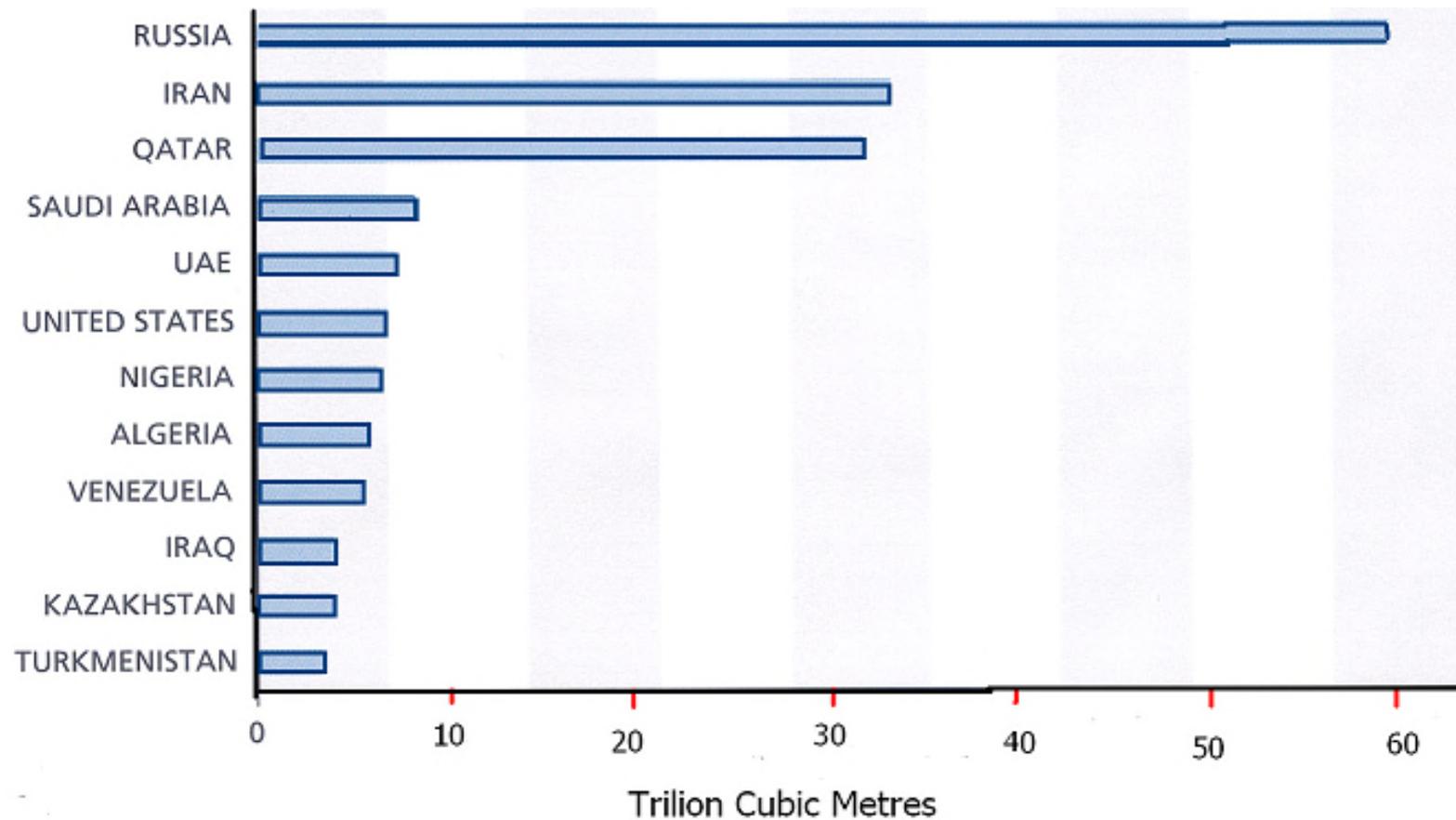
The wide fluctuation in the average price of oil over recent years



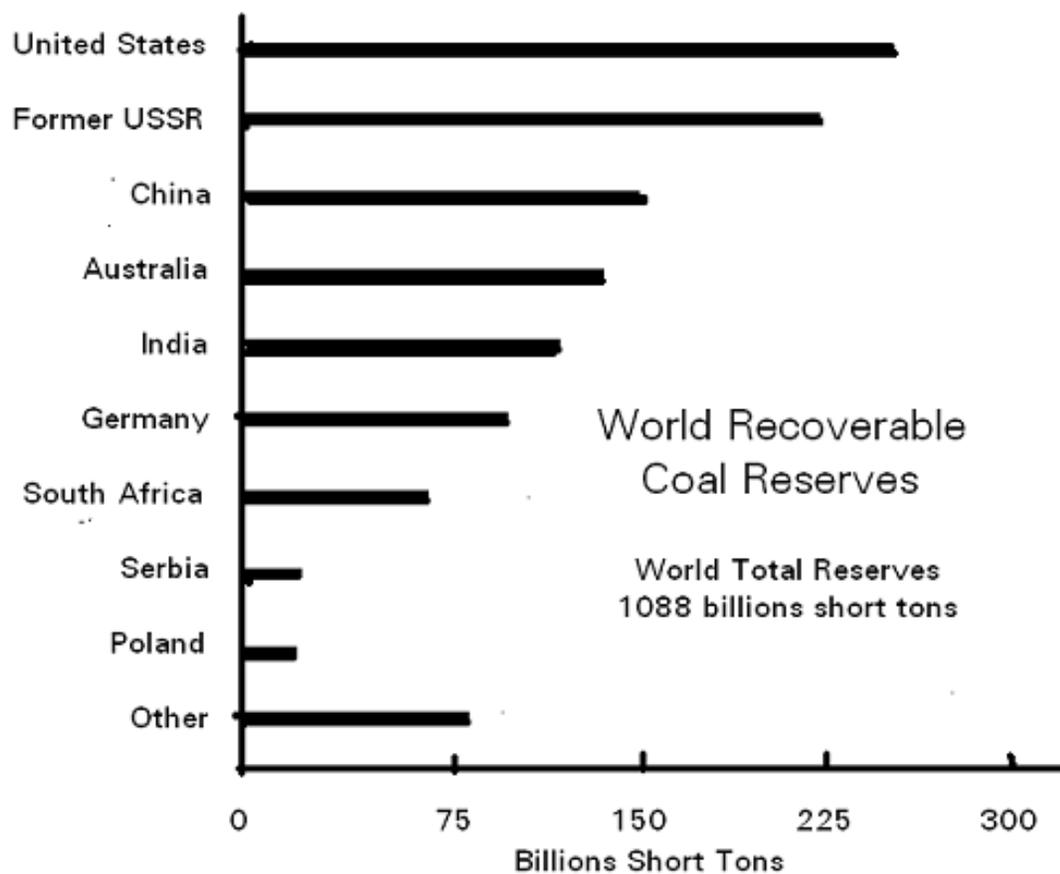
The distribution of conventional natural gas reserves with Russia, Iran and Qatar appearing to be the holders of the majority of world reserves at present.



Estimated Major Conventional Natural Gas Reserves by Countries



Estimated World Reserves of Coal

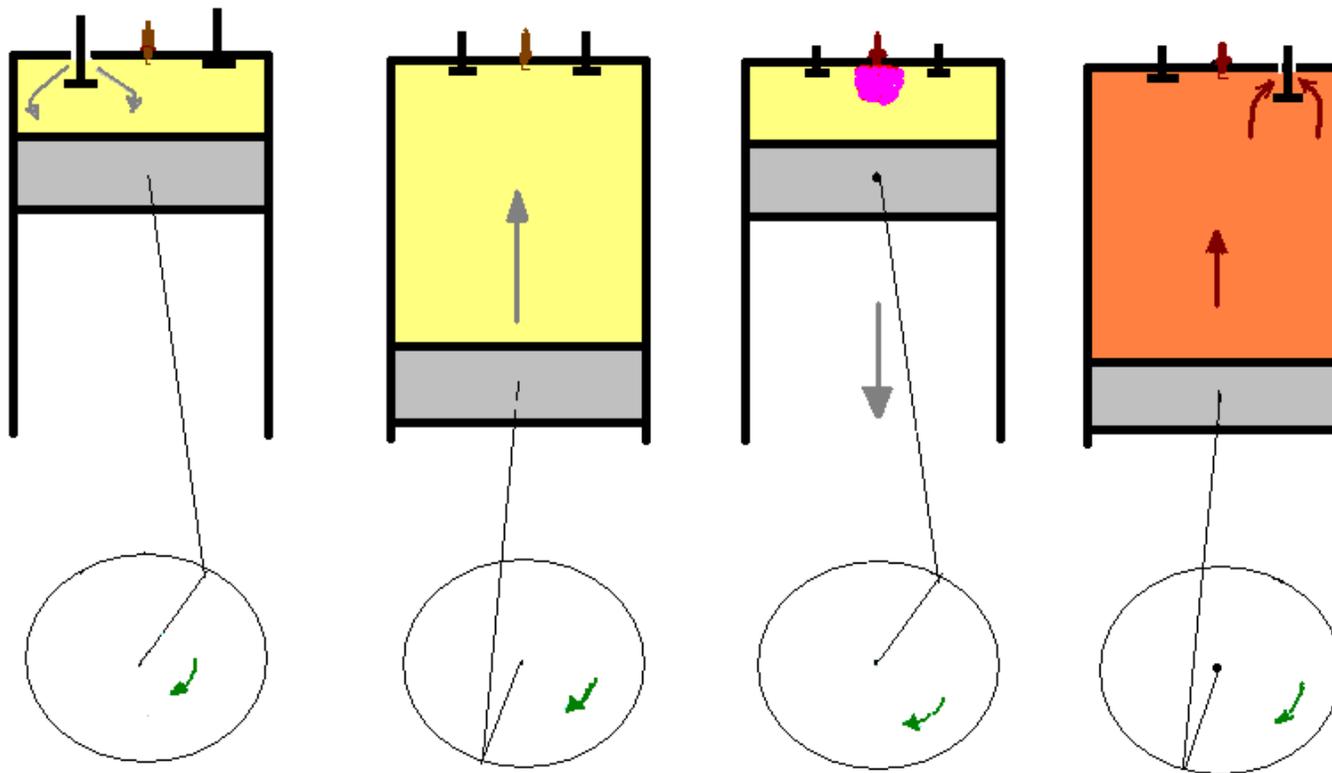


Some Examples of Fuel Consuming Energy Systems

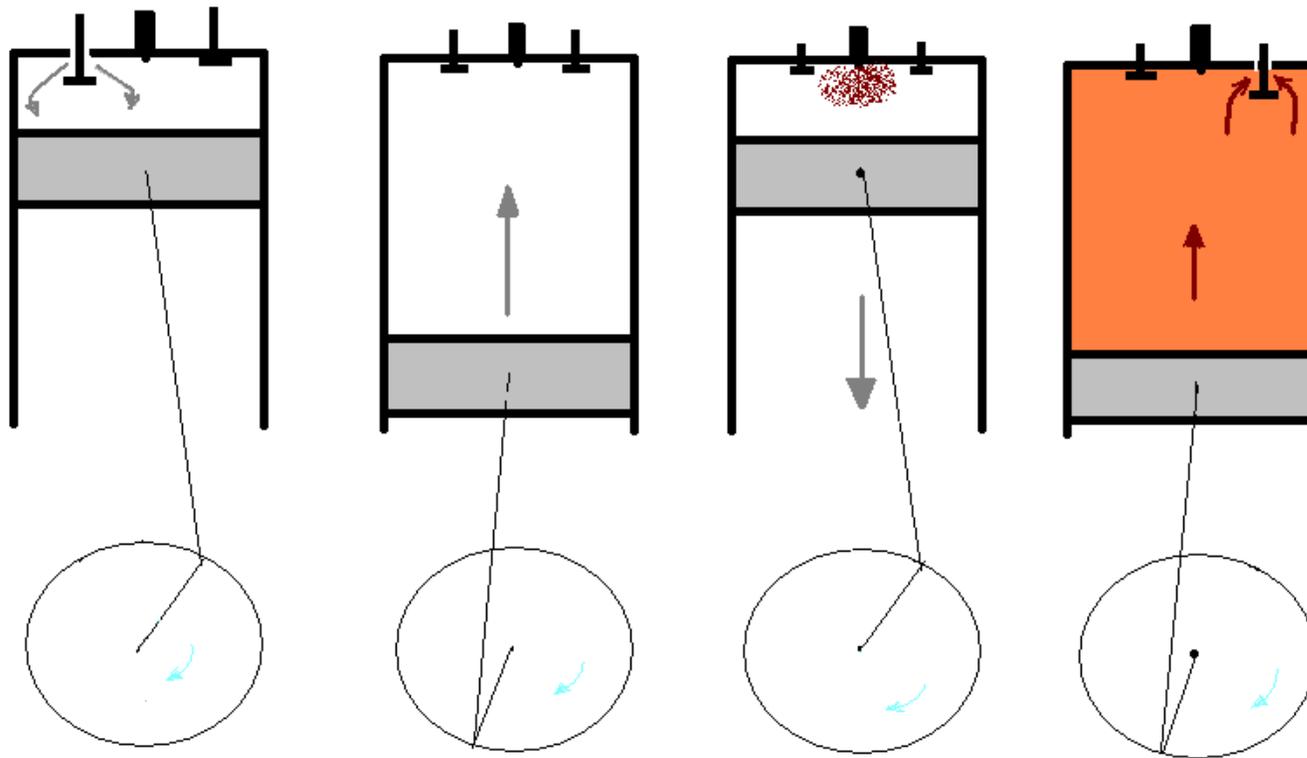
Mainly power systems consuming fuels via combustion both steady and unsteady types, e.g.

- Spark ignition engines
- Diesel engines
- Gas-diesel engines (dual fuel)
- Gas turbines
- Vapor power type of heat engines
- Fuel cells
- Stirling engines
- Homogeneous charge compression ignition engines, (HCCI)

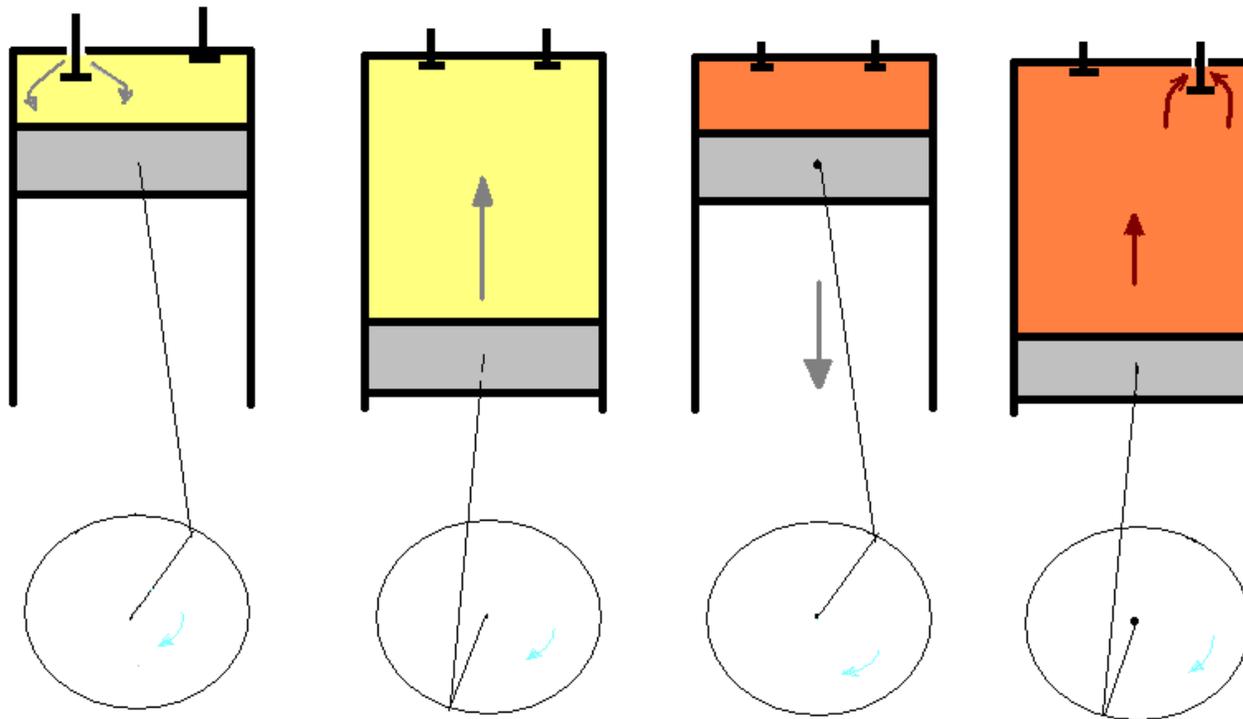
Spark ignition engine operating on premixed fuel-air



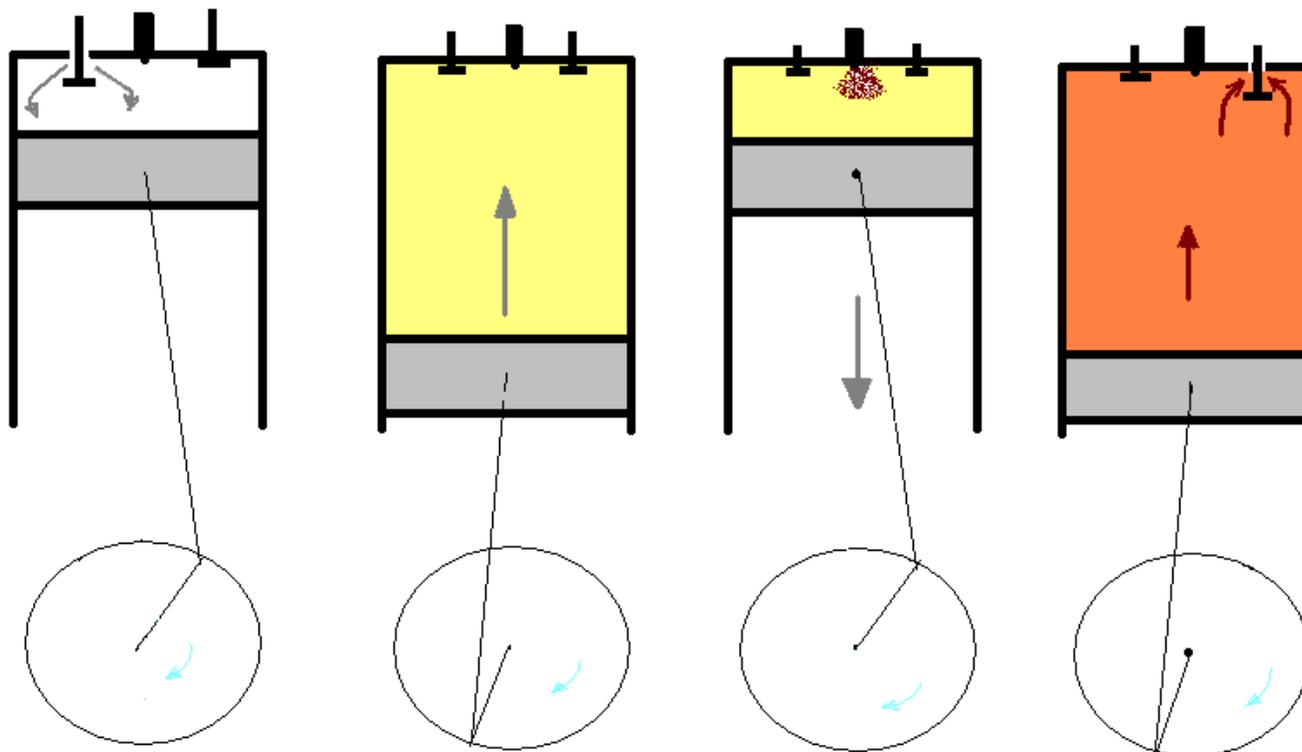
Compression ignition diesel engine using liquid fuel injection



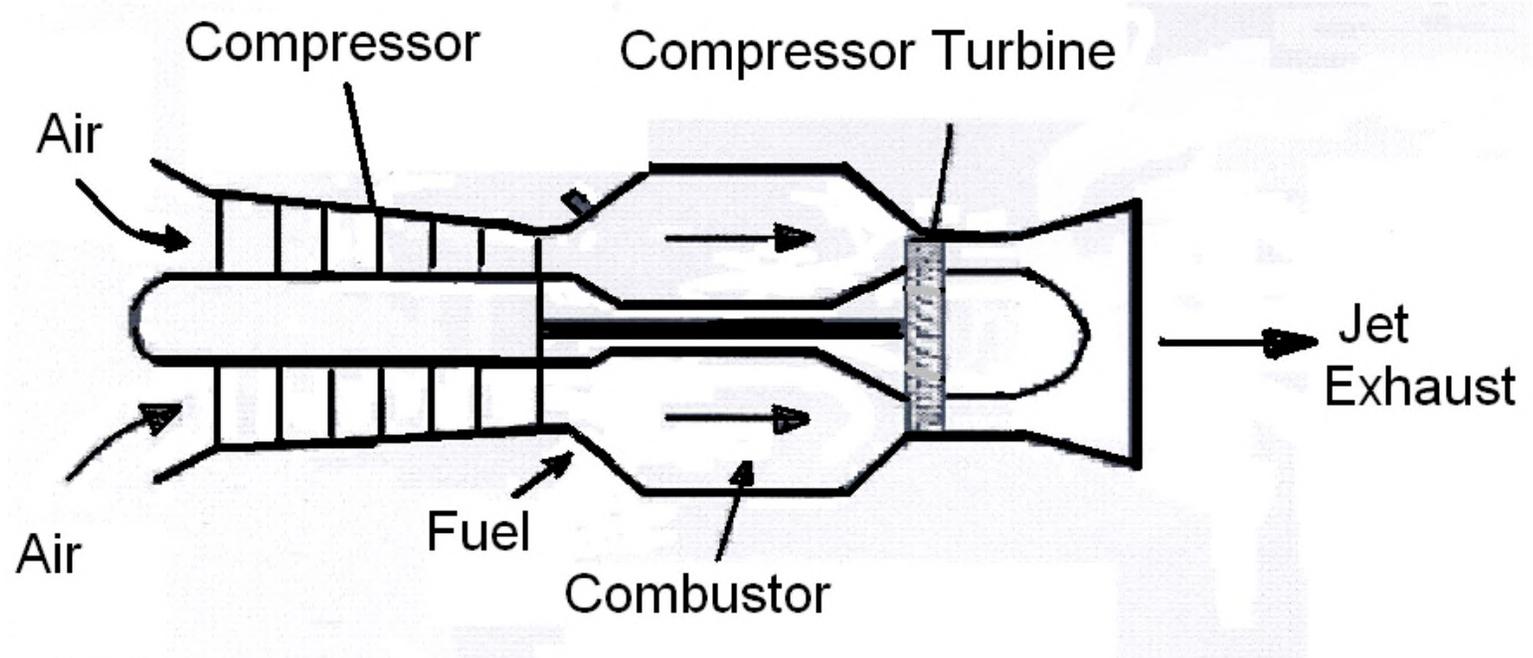
Homogeneous charge compression engine, HCCI



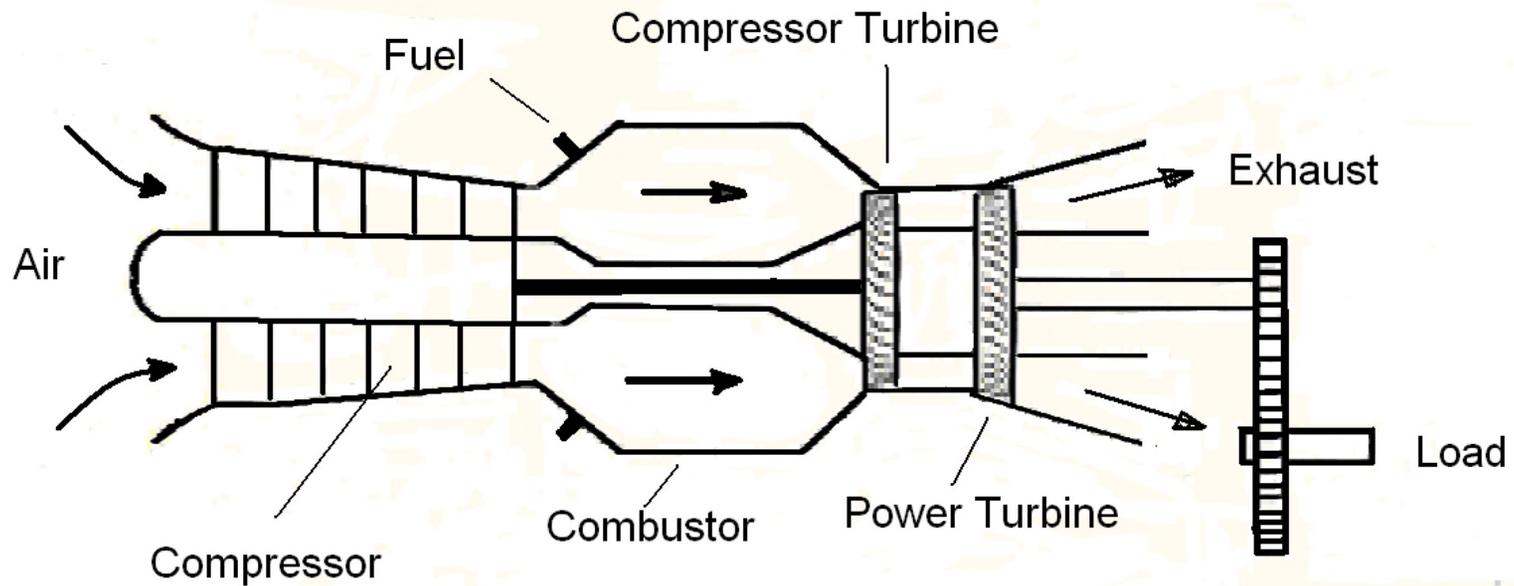
Compression ignition engine of the dual fuel type with pilot fuel ignition



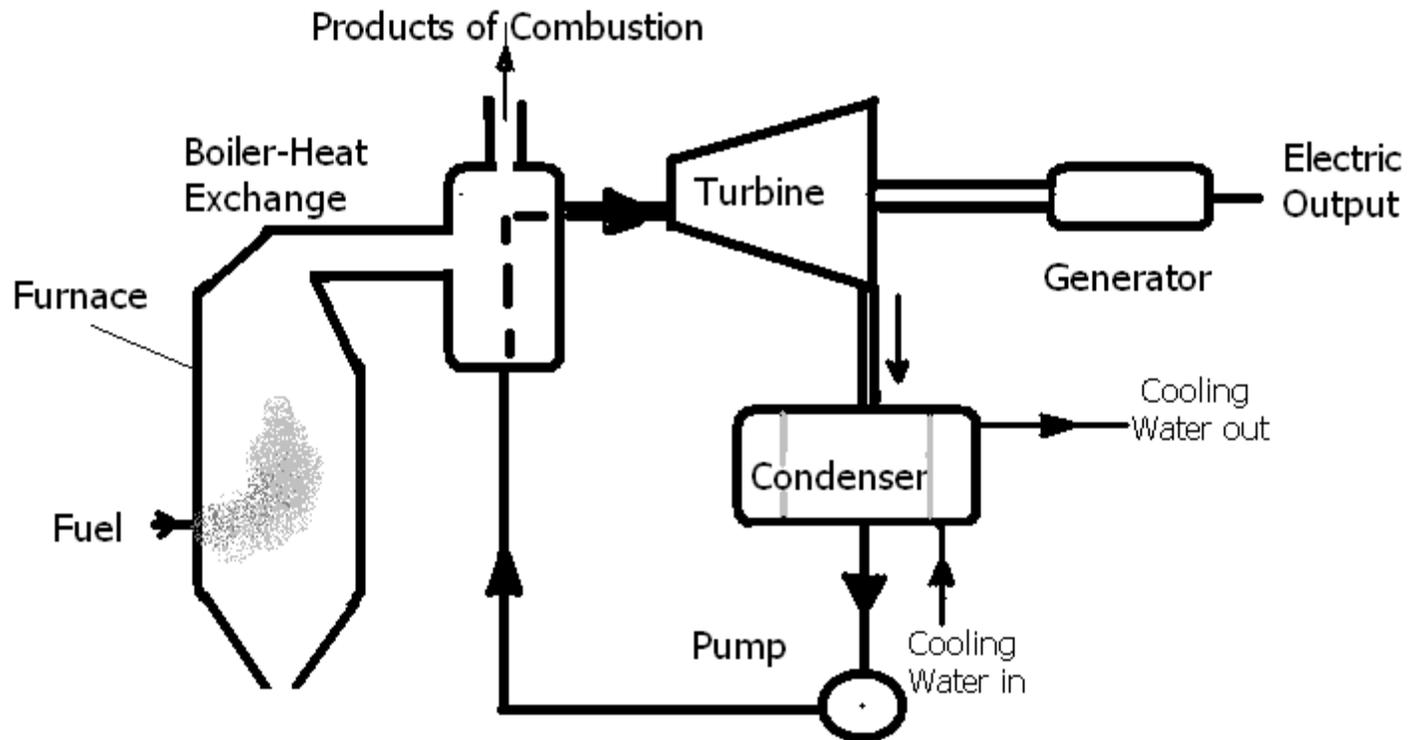
Schematic of an aviation jet engine gas turbine



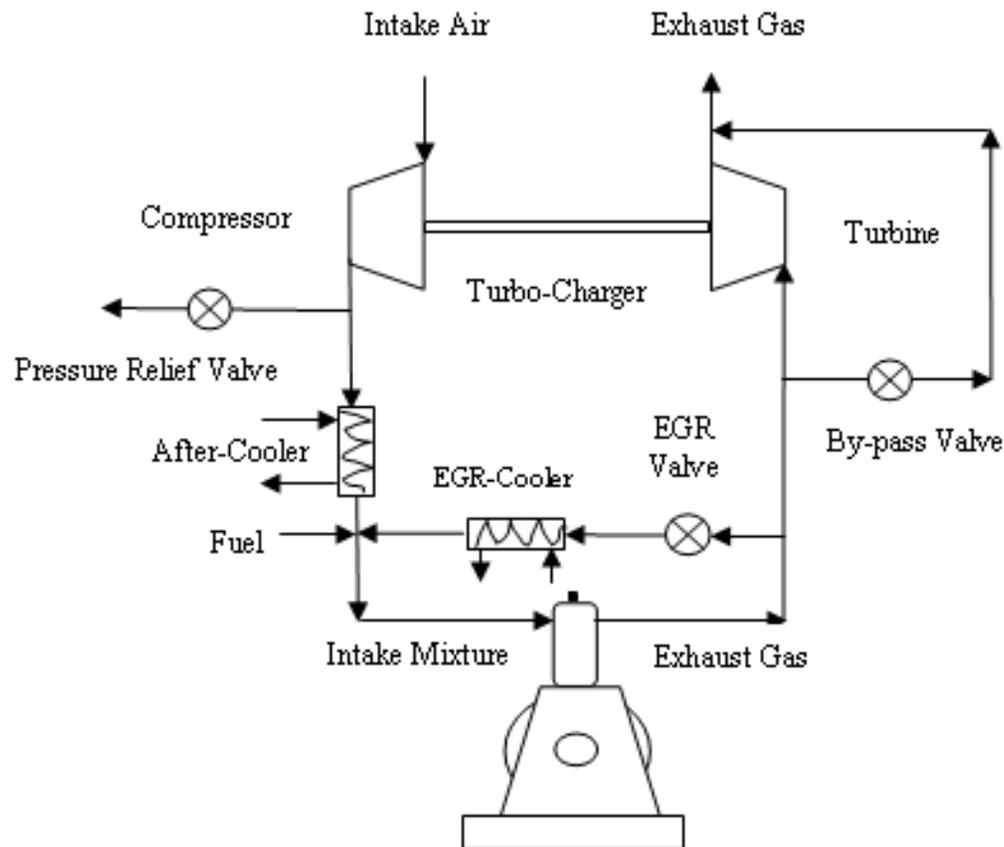
Schematic diagram of an industrial type gas turbine



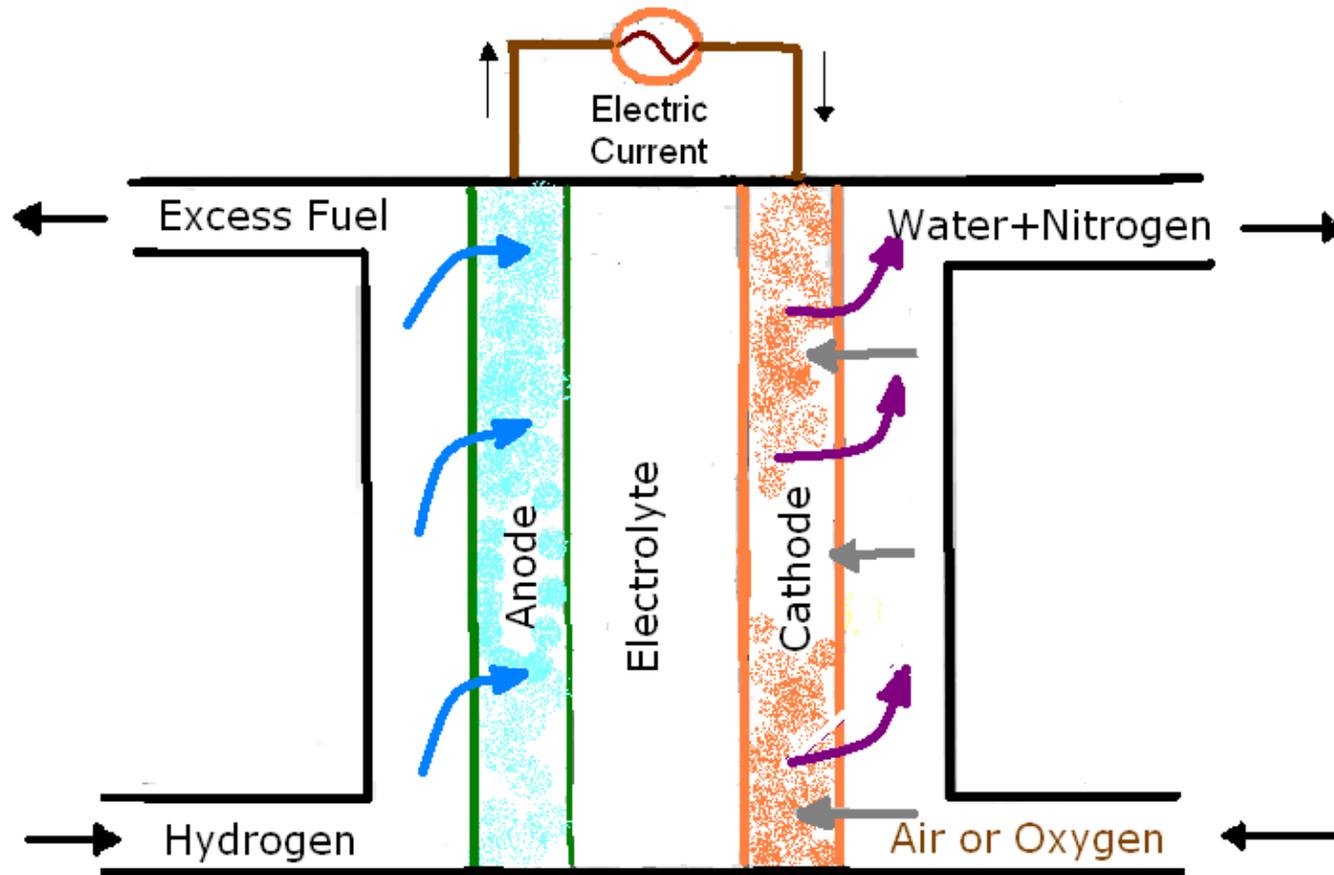
Steam power plant operating as a Rankine cycle heat engine



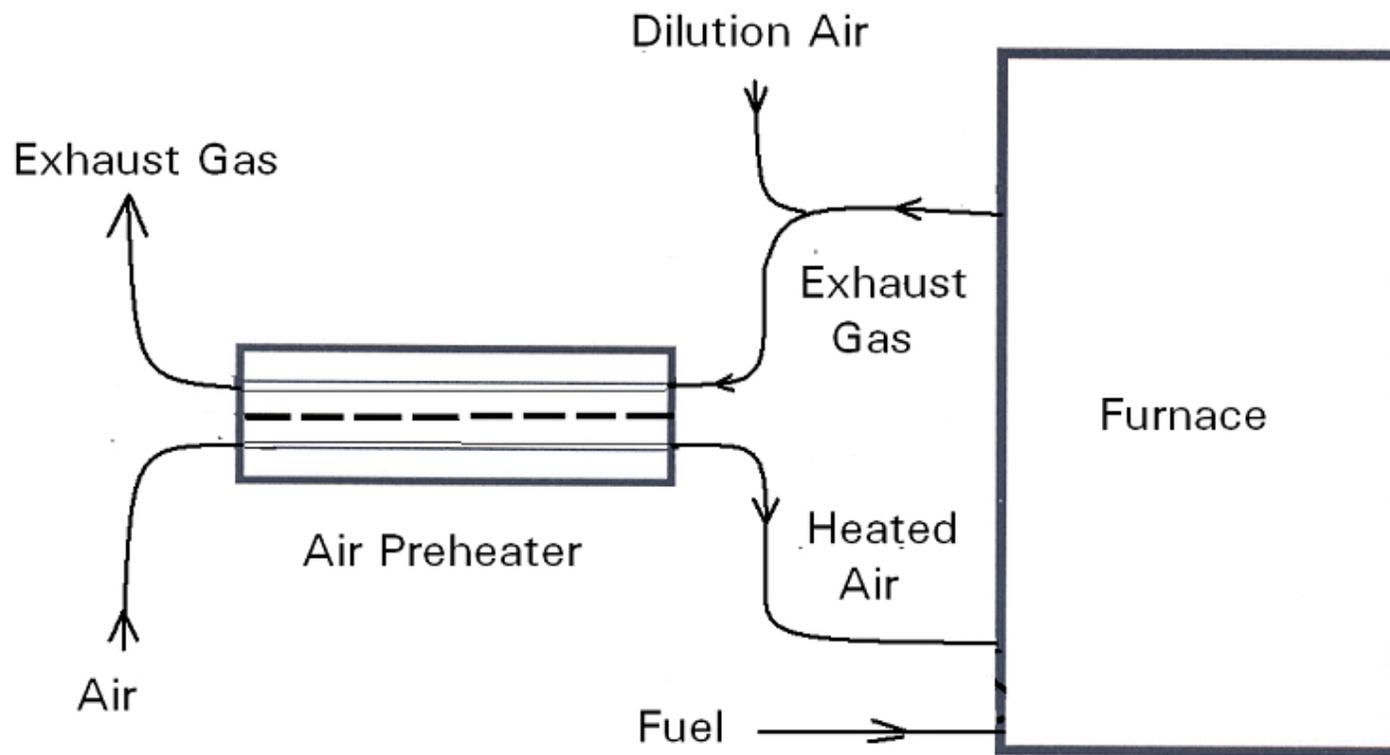
Schematic representation of a turbocharged engine installation employing exhaust gas recirculation, (EGR)



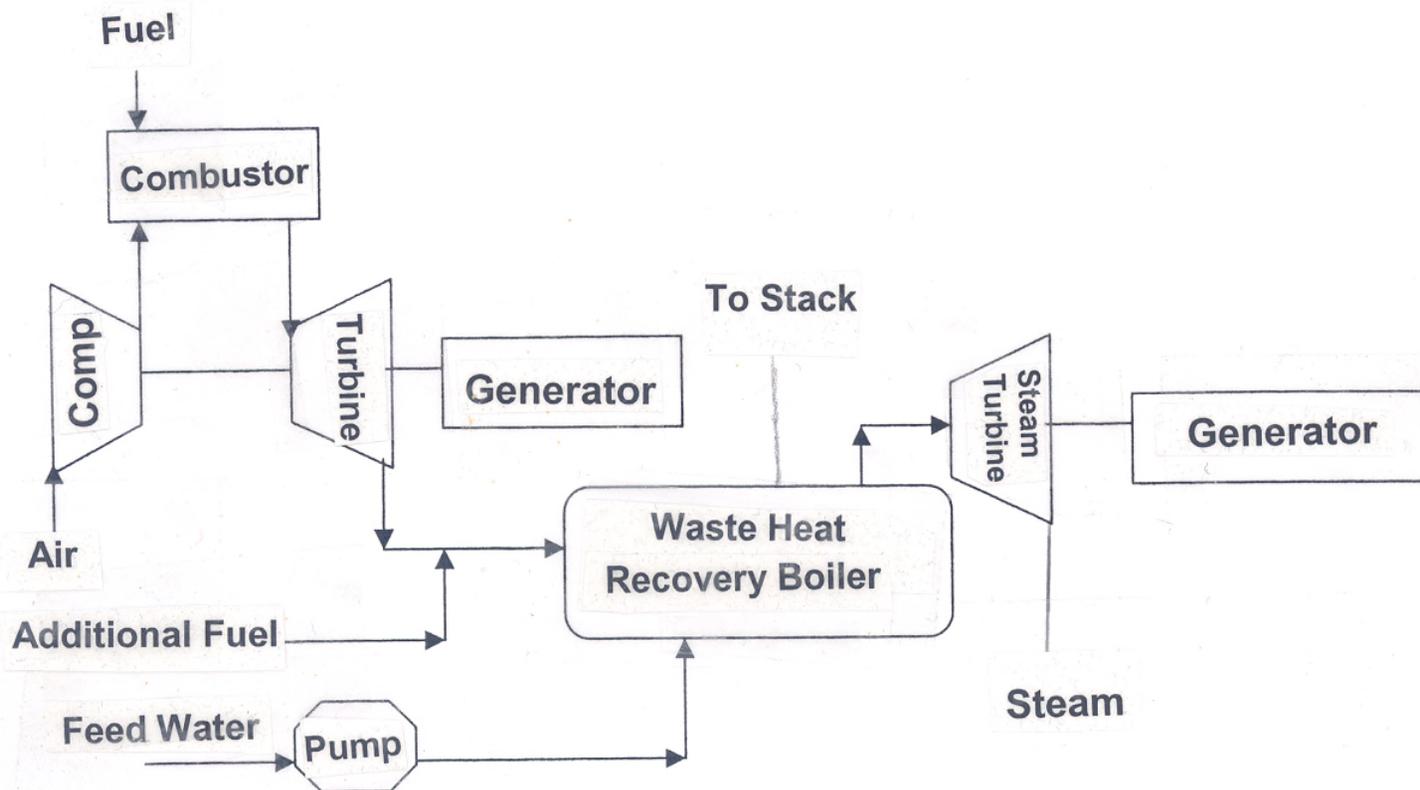
Schematic arrangement of a PEM fuel cell



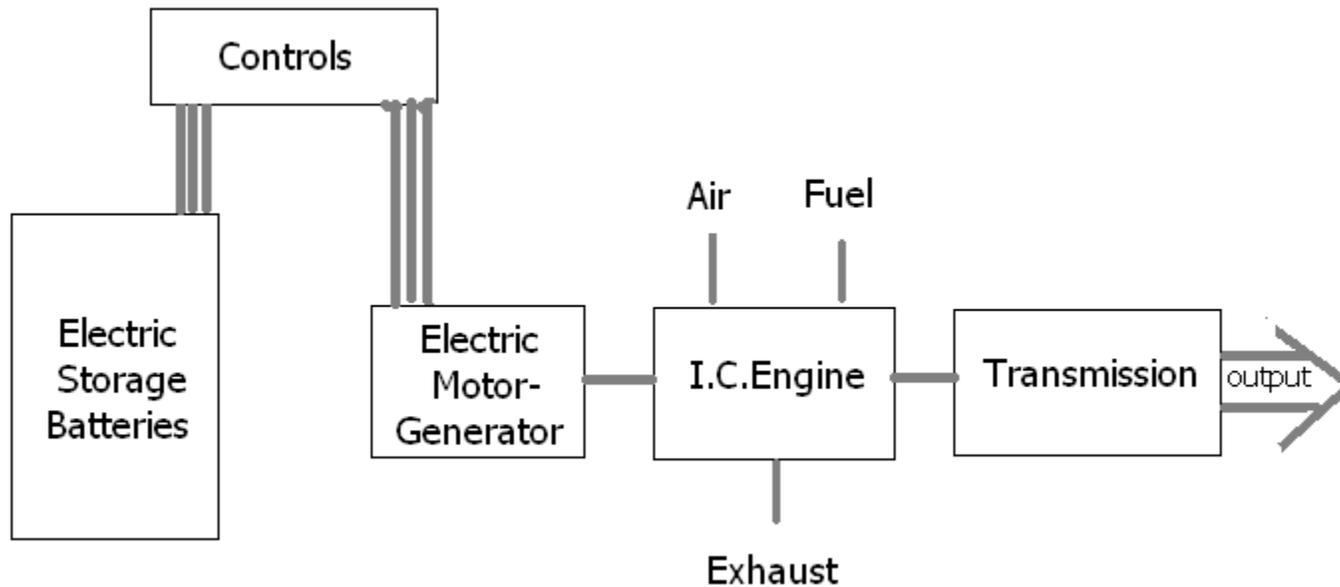
Schematic representation of a co-generation system



Schematic representation of a gas turbine-steam turbine coupled cogeneration system



Arrangement of a hybrid type vehicle employing an IC Engine



Arrangement of a typical vehicle employing electric drive

