INTRODUCTION TO ENERGY SOURCES AND ENERGY BALANCES

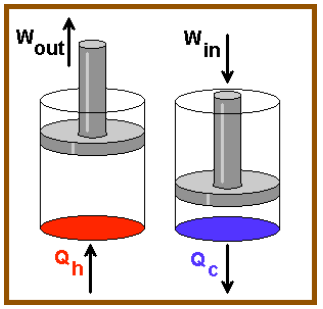
Ahmed F. Ghoniem
Professor of Mechanical Engineering

Lab4Energy for High School Students
January 2014
Eni Enrico Mattie Foundation FEEM

- Primary and secondary energy
- Energy transformation/conversion
- The global energy system: sources and use
- Energy units and measures
- Energy balances

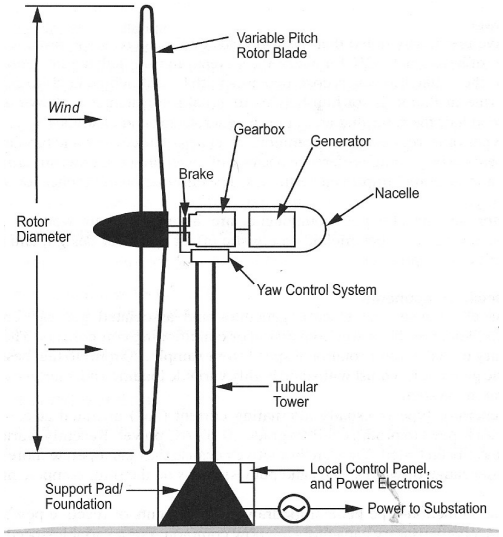
- **What is energy?**
  Can be transformed into work,
  a form that can lift weight.
  Heat is also energy.

Heating a gas makes it lift a weight



The reverse is also true

- **Important property:**
  Always conserved
  but can be can be transformed
  from one form to another.



- **Forms**

Primary or raw

Oil, gas and coal; (fossil fuels or hydrocarbons),
The Sun: light, heat, wind
The Earth: biomass, geothermal, waves, fissile material.

Secondary or product

Fuels: gasoline, diesel, kerosene, fuel gas ..
Electricity
Thermal energy or heat

We classify energy into two types:

- "Internal or stored" energy forms:
  - thermal energy (hot vs. cold, temperature, mass)
  - chemical energy (in fuels, molecular bonds)
  - Kinetic energy (motion, speed and mass)
  - potential energy (high vs. low in gravity)
  - electrical energy (motion of charged particles)
  - electromagnetic energy (light, photons)
  - nuclear energy (atomic bond, mass to energy, MC^2)
- Energy forms that can be transferred
  - Heat (moving thermal energy from hot to cold body)
  - work (lifting weight against gravity)

RENEWABLES

Solar | Geothermal | Wind | Wave | Hydro | Solar

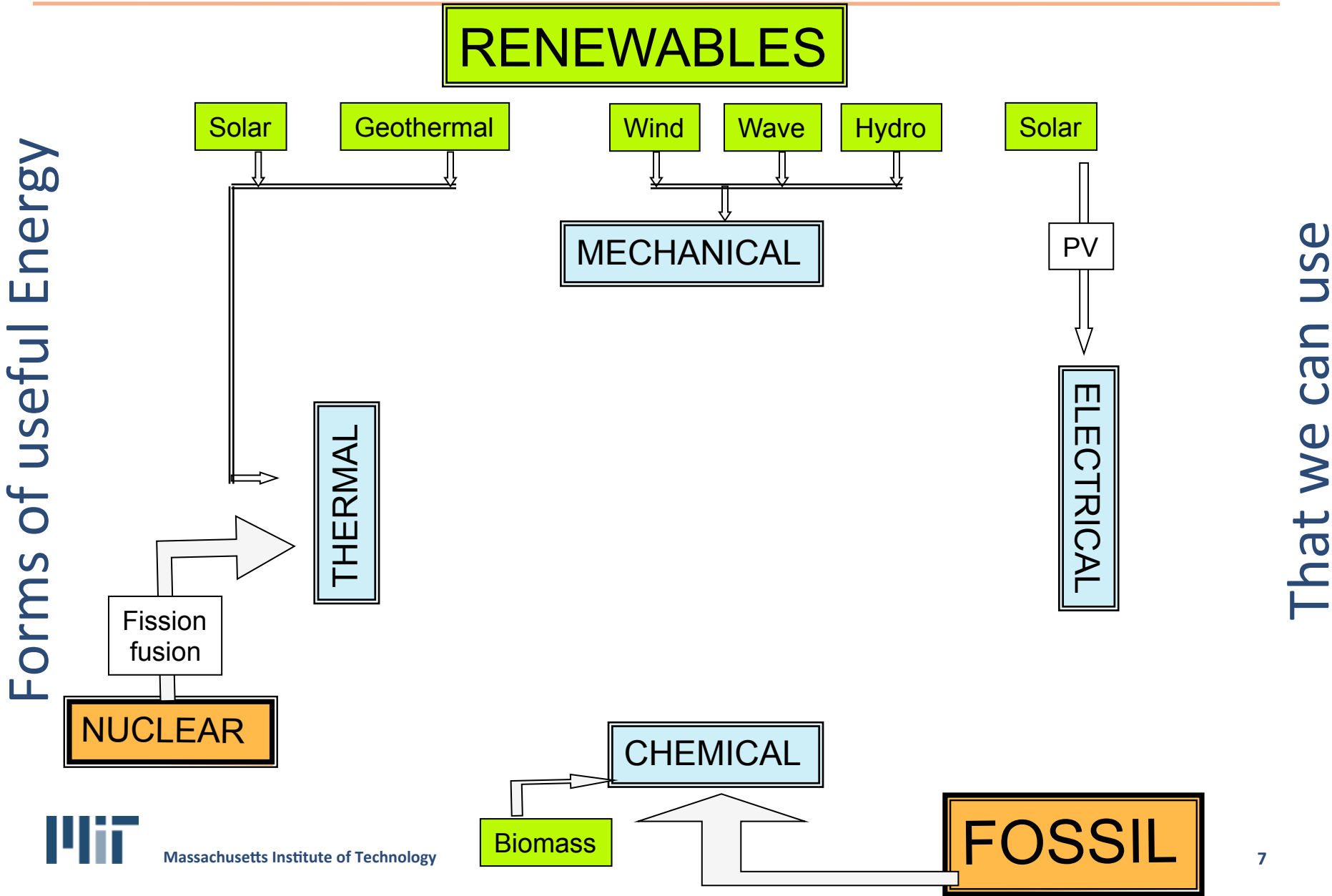
Primary Energy

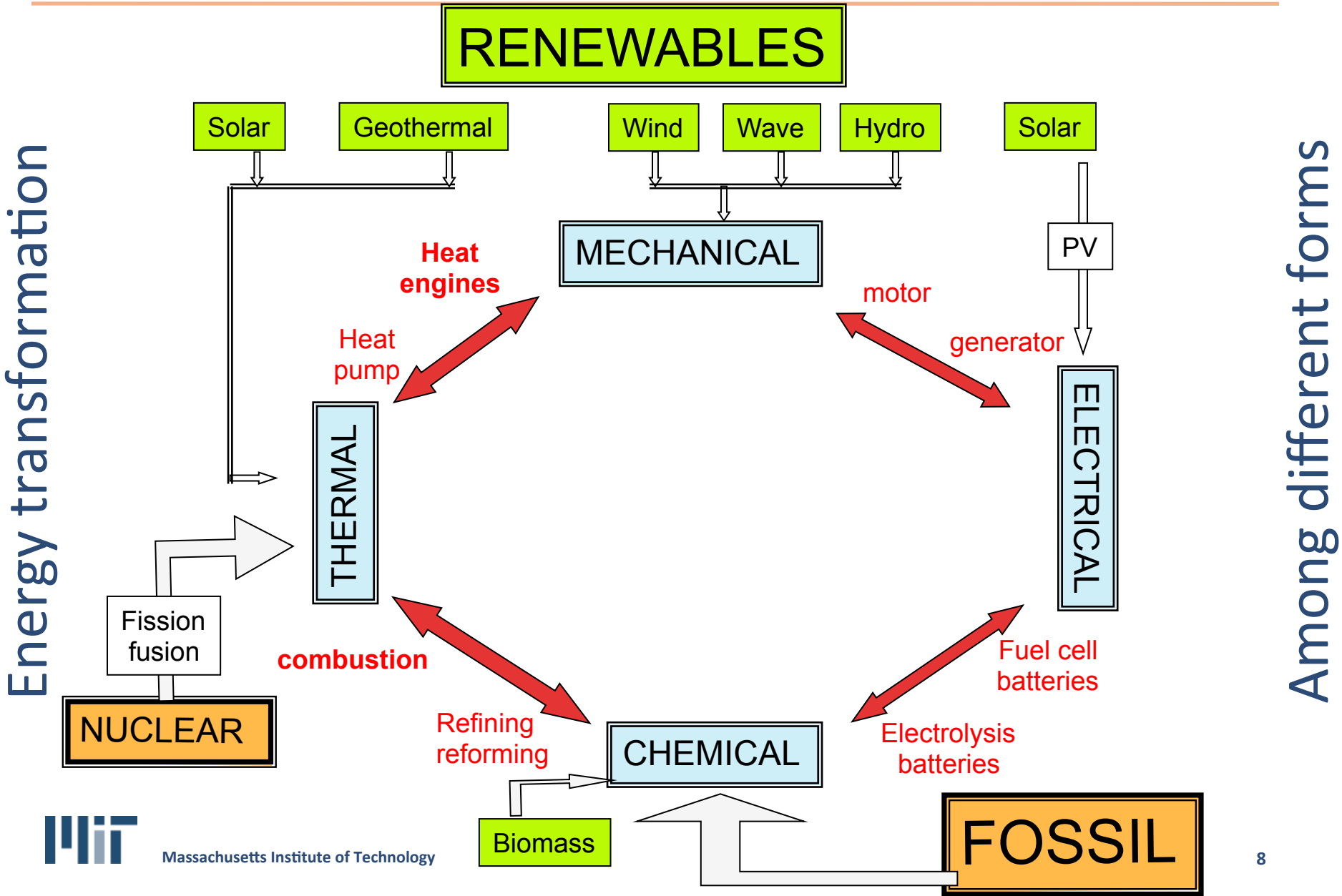
As we find it in Nature

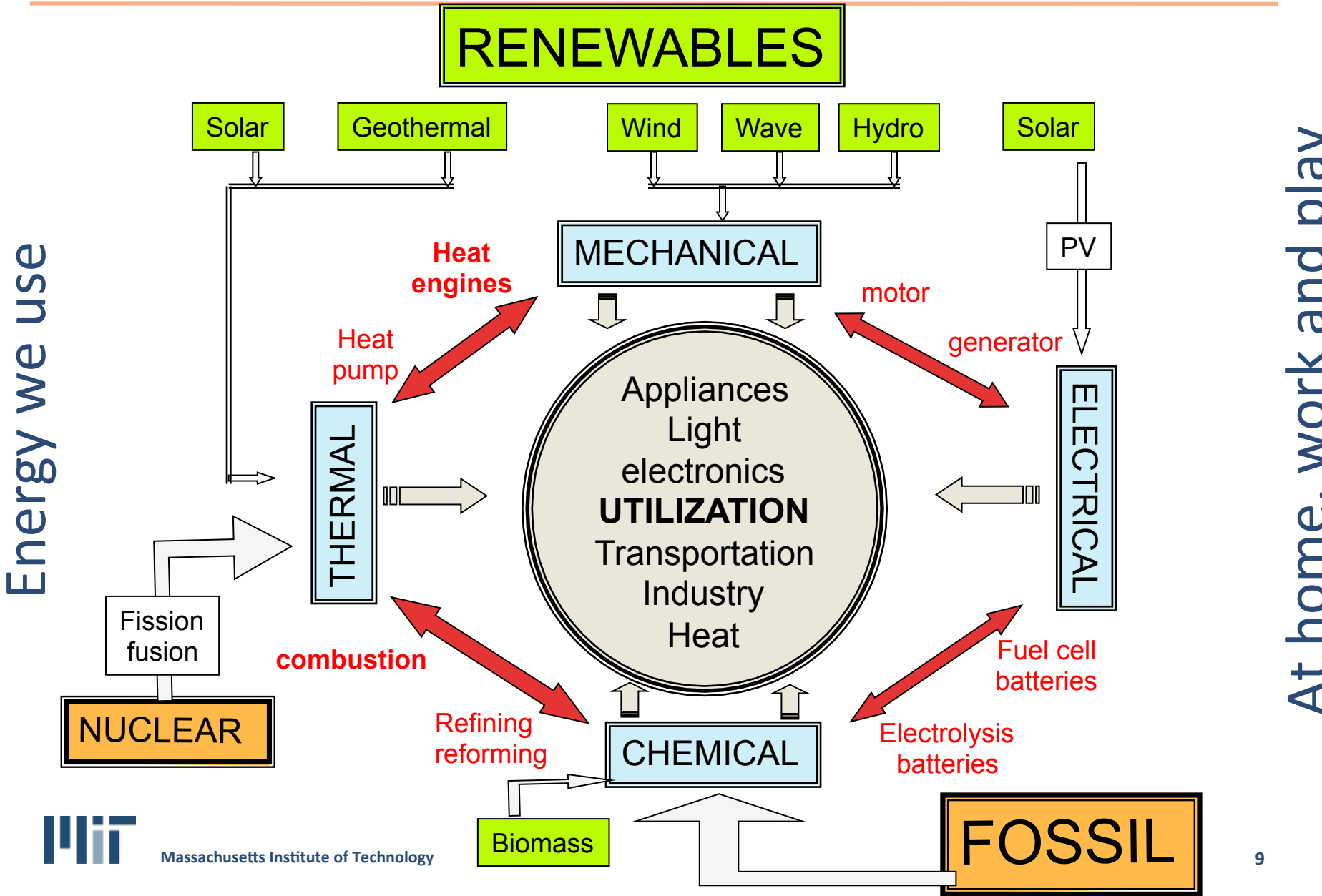
NUCLEAR

Biomass

FOSSIL

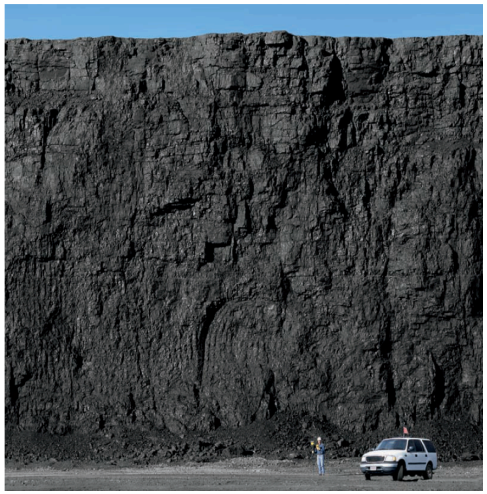

RENEWABLES
Solar
Geothermal
Wind
Wave
Hydro
Solar
MECHANICAL
PV
THERMAL
ELECTRICAL
Fission
fusion
NUCLEAR
CHEMICAL
Biomass
FOSSIL
Forms of useful Energy
That we can use


RENEWABLES
Solar
Geothermal
Wind
Wave
Hydro
Solar
MECHANICAL
PV
Heat engines
motor
Heat pump
generator
THERMAL
ELECTRICAL
Fission fusion
combustion
Fuel cell batteries
NUCLEAR
Refining reforming
CHEMICAL
Electrolysis batteries
Biomass
FOSSIL
Energy transformation
Among different forms

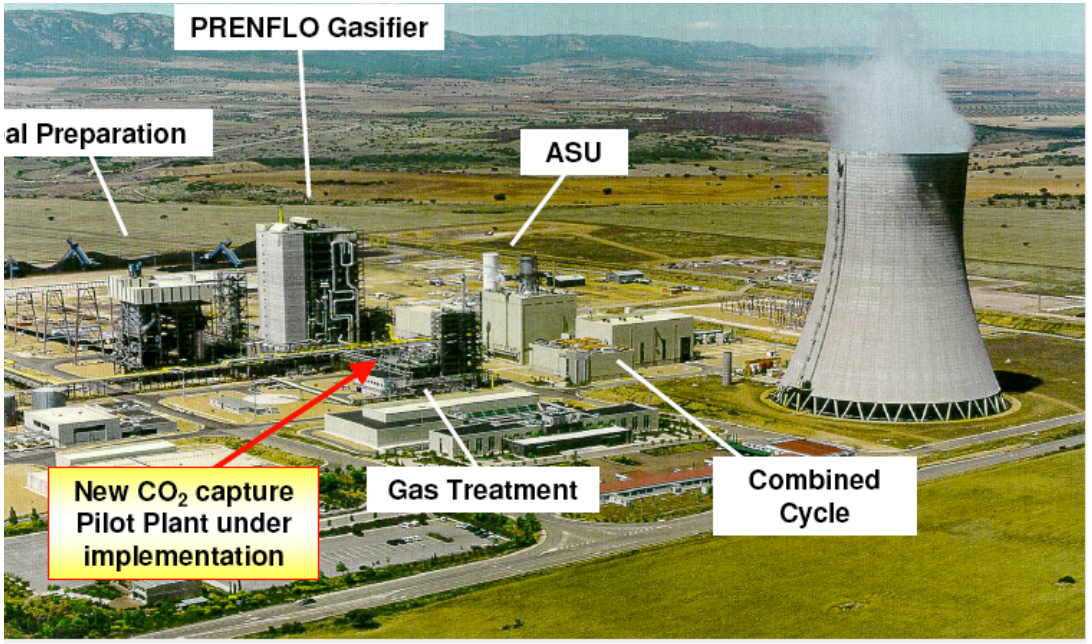

RENEWABLES
Solar
Geothermal
Wind
Wave
Hydro
Solar
PV
MECHANICAL
Heat engines
Heat pump
motor
generator
THERMAL
ELECTRICAL
Appliances
Light electronics
UTILIZATION
Transportation
Industry
Heat
Fission fusion
NUCLEAR
combustion
Refining reforming
CHEMICAL
Fuel cell batteries
Electrolysis batteries
Biomass
FOSSIL
Energy we use
At home, work and play

Transformation in a power plant

transportation



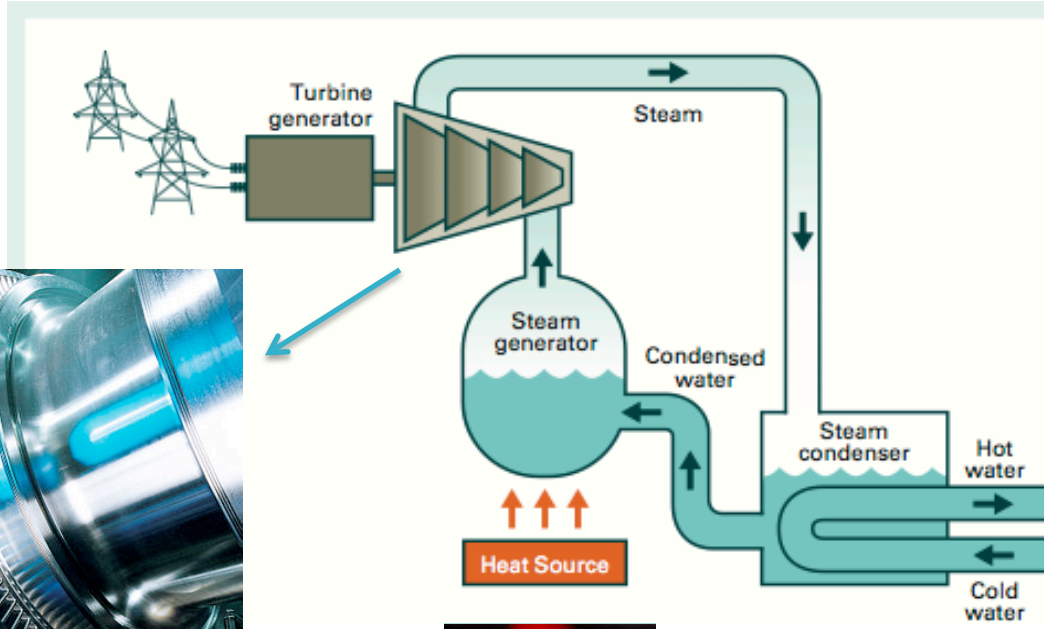
mining



transmission

Consumption by electricity users

Inside a thermo-electric power plant, more transformations

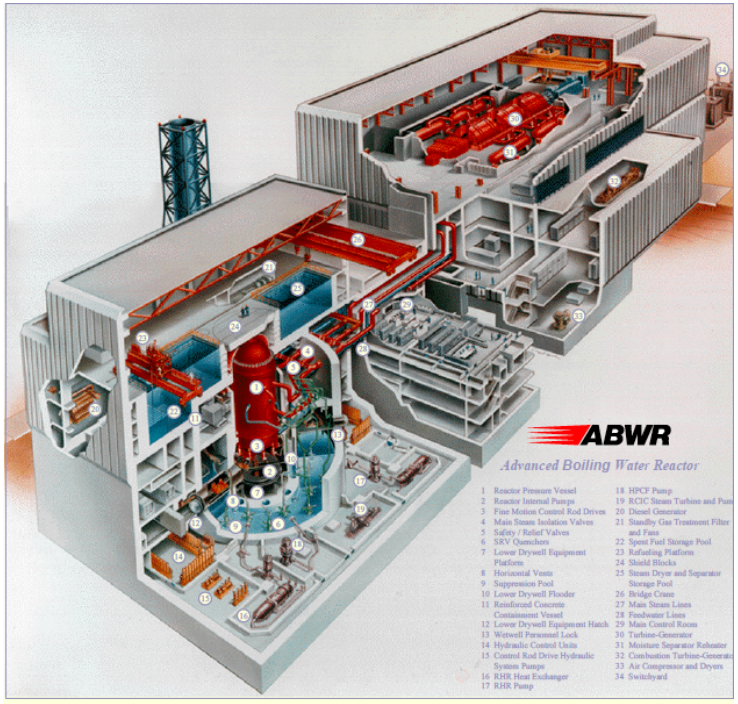


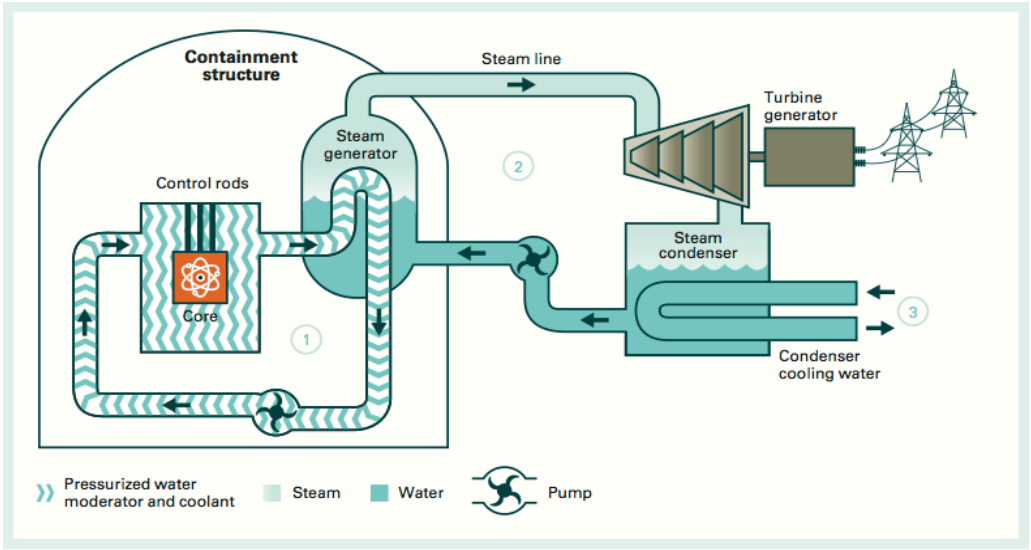
Coal
Gas
Oil

NUCLEAR PLANTS

Heat engines driven by thermo-nuclear reactions

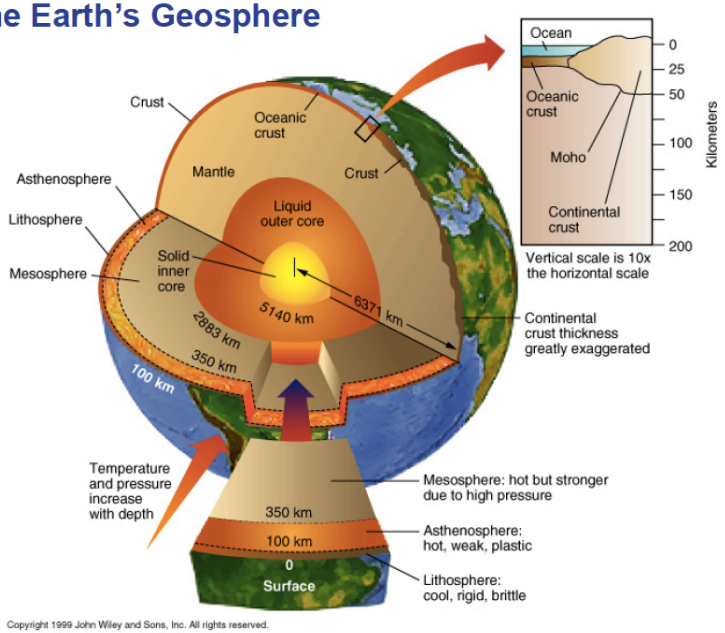
The splitting of atoms generates an enormous amount of heat by converting some of the mass according to: $E=MC^2$ and $C \sim 3\ 10^8$ m/s. Splitting 1 g of fissile material generates the equivalent of burning 3 million kg of coal.

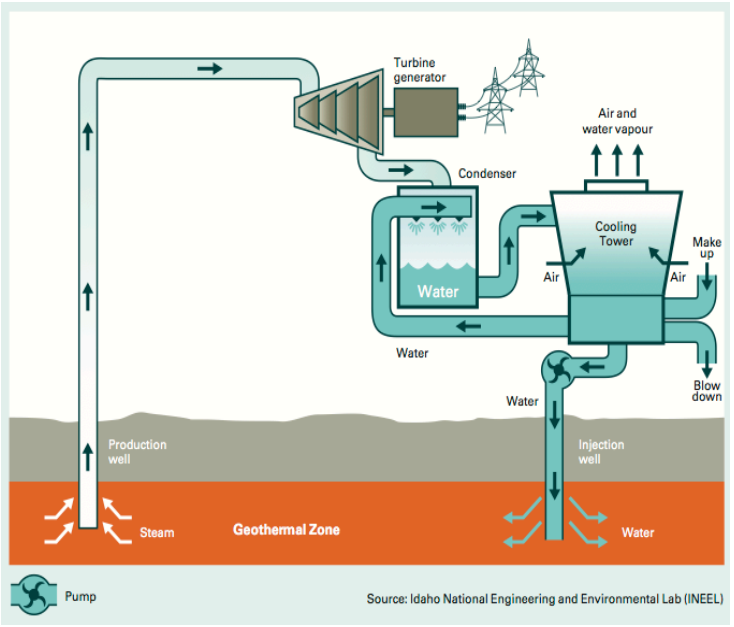


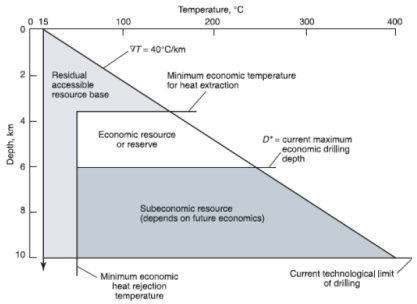


GEOTHERMAL PLANTS

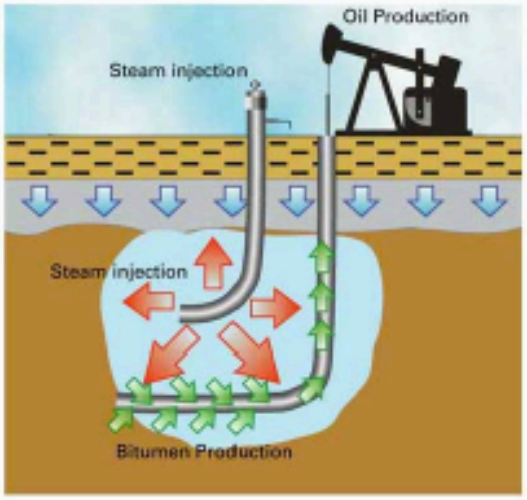
Looking to "inner space" for opportunities in the Earth's Geosphere

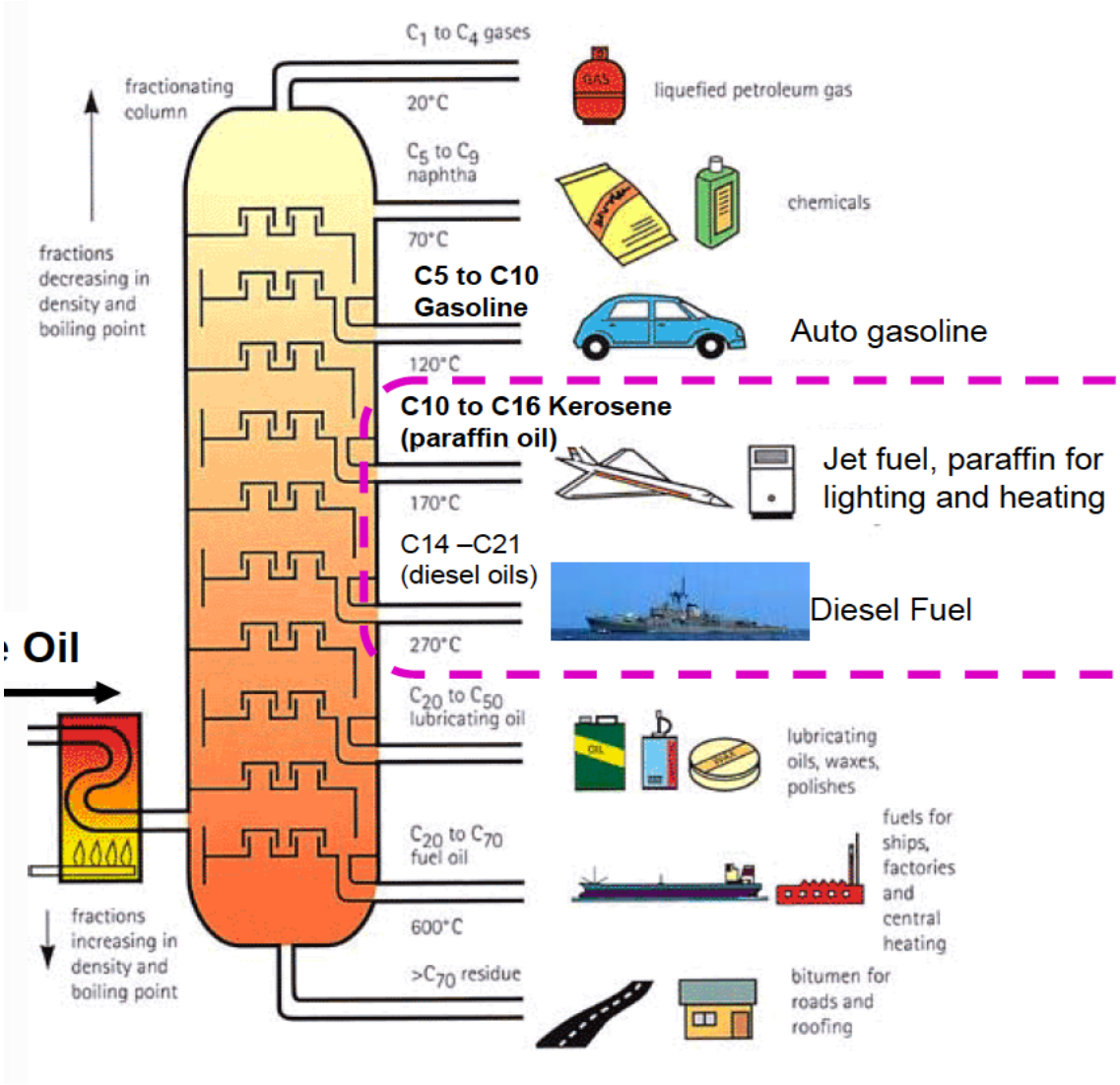






Crude Oil Distillation and the production of fuels:





Energy and Power Units

All forms of energy (thermal, mechanical, electrical, chemical ..) are measured in Joules, but also in calories, British thermal unit (Btu), Watt hour, tons of oil equivalent (Toe), and other units. The units are related.

A Joule (the modern and universally used unit) is the amount of thermal energy required to raise the temperature of one g of water by 0.24 ^{o}C.
Or to lift a small apple (100 g) upwards by 1 m.
10 Joules are needed to lift the weight of 1 kg by 1 m.
Joule = Netwon.meter = kg . m/s^2. m

Calorie = 4.184 joules (J) (heat required to raise 1 gm of water by 1 ^{o}C)
1 Wh = 3600 Ws = 3.6 kJ (kilo J) (lights a 60 W lamp for 60 s or 1 min)
1 kWh = 3600 kJ = 3.6 MJ (Mega J)
1 BTU = 1.054 kJ
1 TOE (tonne of oil equivalent) = 42 GJ (42 10^{9} J) (42Giga J)
= 1000 kg (or 1000 liters oil = 7.4 barrel oil) (heat released by burning that much oil)

Human 2000 kcal/day ~ 10 MJ/day (10 candy bars!)
~ 100 J/s or 100 W
One person consumes the same amount of energy per second as a 100 W lamp (W is a unit of power)

Power is rate of energy consumption, measured in W = J/s

1 kg of gasoline ~ 50 MJ (varies).
also called the heating value or the calorific value of the fuel.
It is the amount of heat generated by burning one kg of fuel.

1 kg of coal ~ 30 MJ (varies with coal quality)
1 kg of wood ~ 15 MJ (varies with type and moisture)

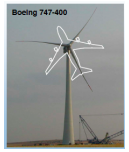
These are also measured per unit volume.
The density of gasoline is ~ 900 kg/m^3,
The heating value of gasoline is 55.6 kJ/m^3 = 55.6 MJ/liter
= 210 MJ/gallon (gallon = 3.785 liter) (about 200 candy bars)

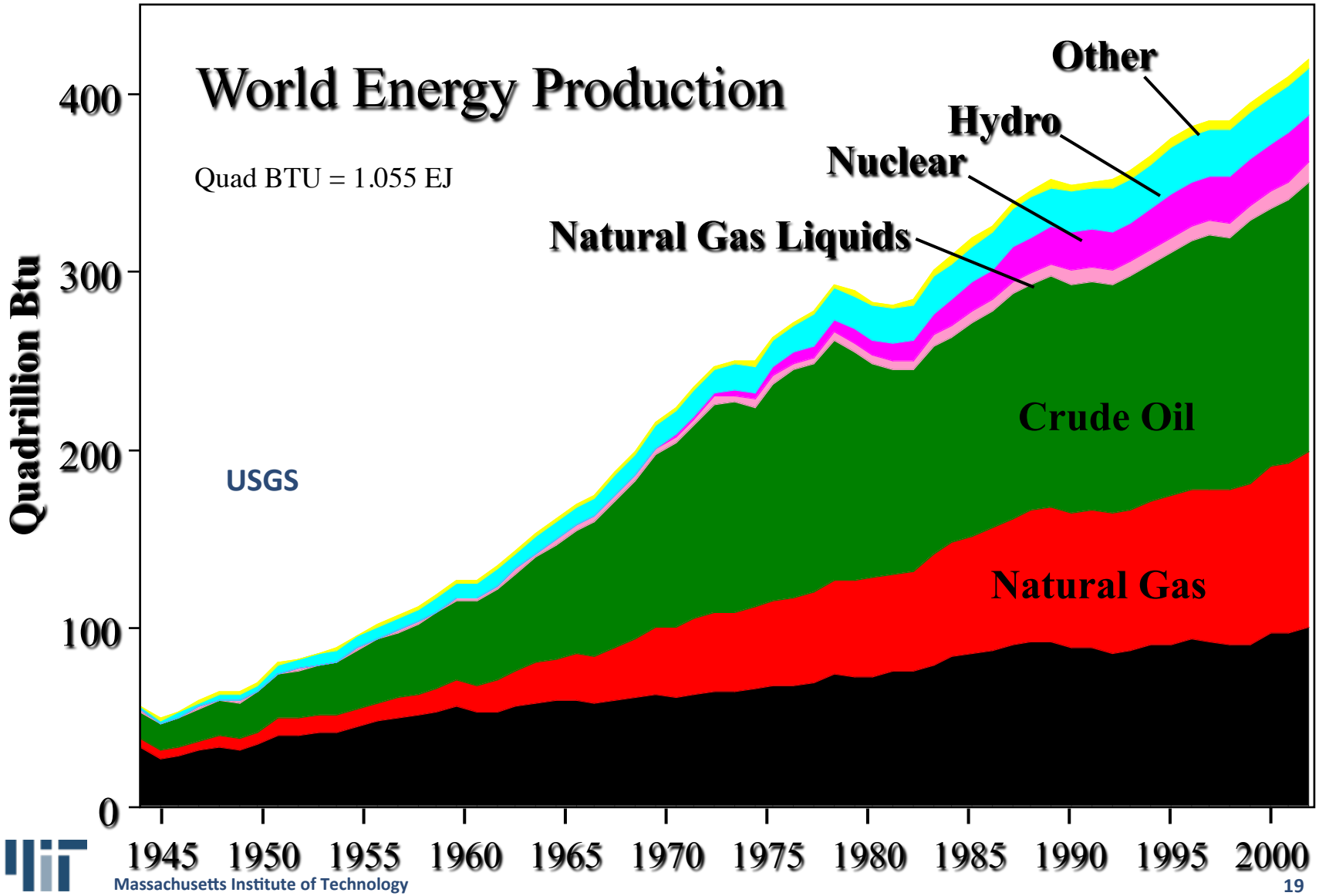
Power Rating of Different Machines

Human 2000 kcal/day ~ 10 MJ/day ~ 100 W (J/s) = 0. 1kW

Horse	0.75 kW
Human running	0.5 kW
Car	150 kW
Truck	300 kW
Plane	10 MW (50 kN thrust)
Rocket	1 GW
Power plant	1 GW
Large wind mill	2-3 MW
Human heart	2 W
Cell phone	1-2 W
Laptop	10 W

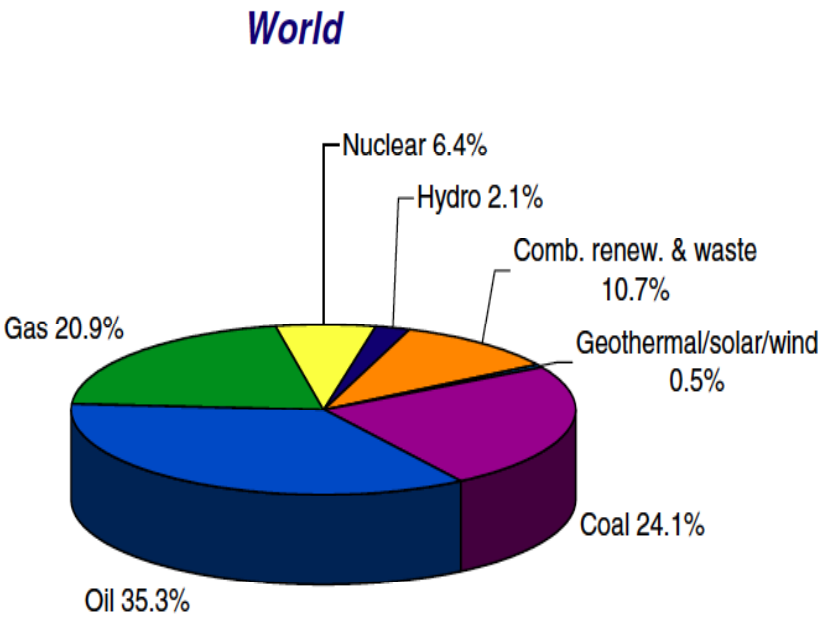
First Flight: 4Q 2008




World Energy Production
Quad BTU = 1.055 EJ
USGS
Quadrillion Btu
0
100
200
300
400
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Other
Hydro
Nuclear
Natural Gas Liquids
Crude Oil
Natural Gas

The Consumption

~ 10^{21} J/y, 85% fossil fuels



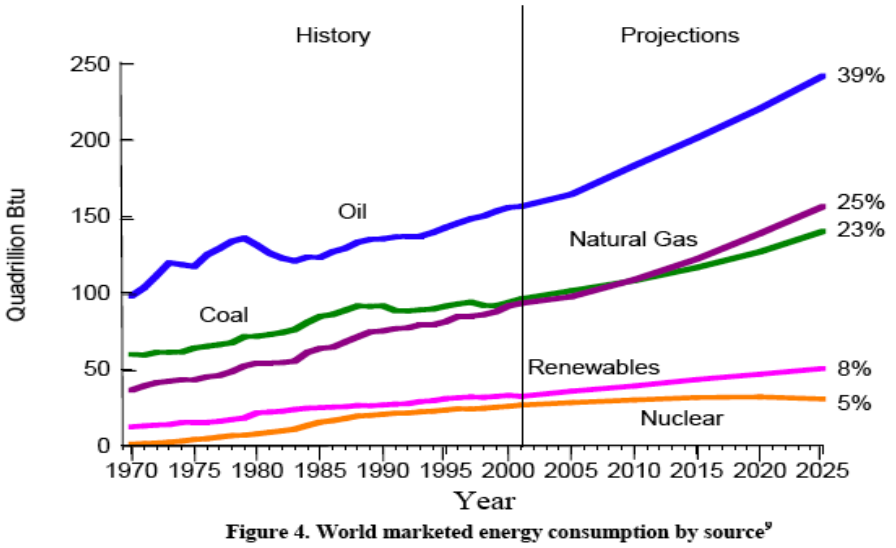
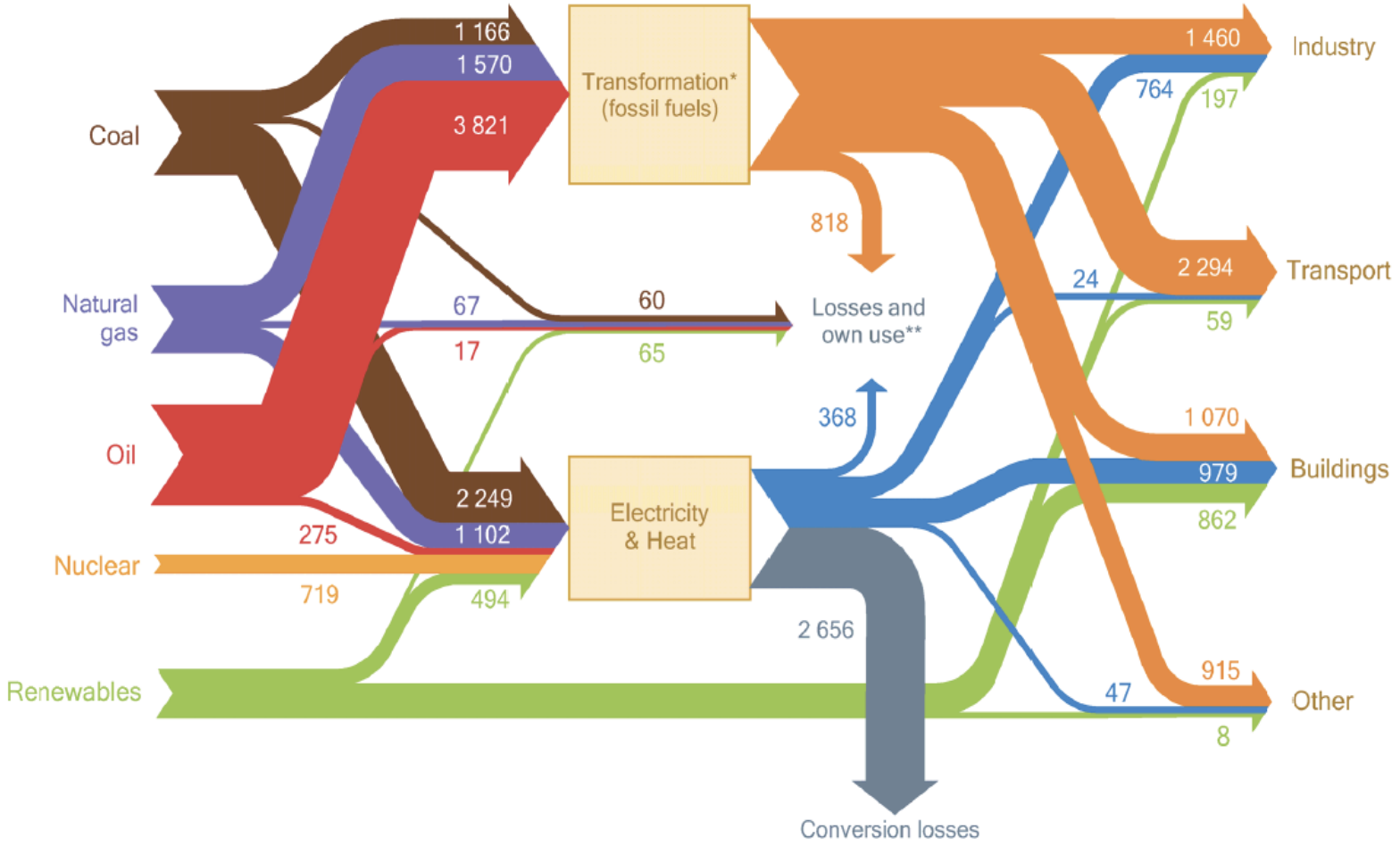
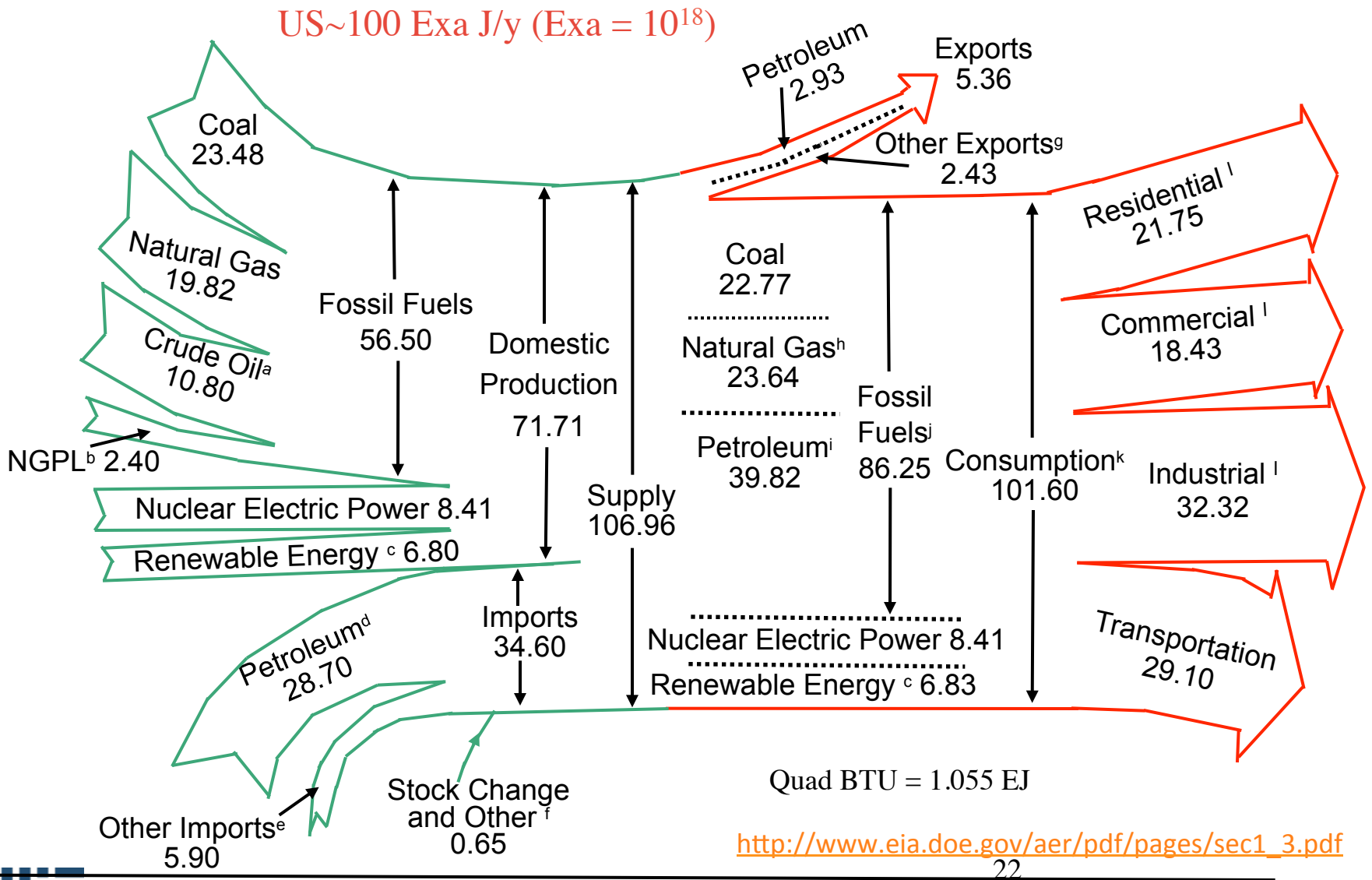


Figure 4. World marketed energy consumption by source[9]

Energy Information Administration, EIA 2007



* Transformation of fossil fuels from primary energy into a form that can be used in the final consuming sectors. ** Includes losses and fuel consumed in oil and gas production, transformation losses and own use, generation lost or consumed in the process of electricity production, and transmission and distribution losses.


US~100 Exa J/y (Exa = 10^18)
Coal 23.48
Natural Gas 19.82
Crude Oil[a] 10.80
NGPL[b] 2.40
Nuclear Electric Power 8.41
Renewable Energy [c] 6.80
Petroleum[d] 28.70
Other Imports[e] 5.90
Stock Change and Other [f] 0.65
Fossil Fuels 56.50
Domestic Production 71.71
Imports 34.60
Supply 106.96
Petroleum 2.93
Exports 5.36
Other Exports[g] 2.43
Coal 22.77
Natural Gas[h] 23.64
Petroleum[i] 39.82
Fossil Fuels[j] 86.25
Nuclear Electric Power 8.41
Renewable Energy [c] 6.83
Consumption[k] 101.60
Residential [l] 21.75
Commercial [l] 18.43
Industrial [l] 32.32
Transportation 29.10
Quad BTU = 1.055 EJ
http://www.eia.doe.gov/aer/pdf/pages/sec1_3.pdf