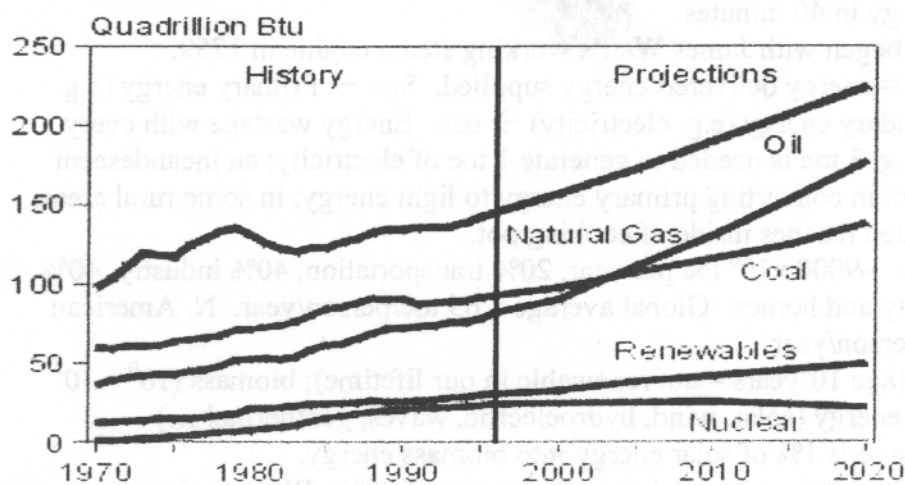
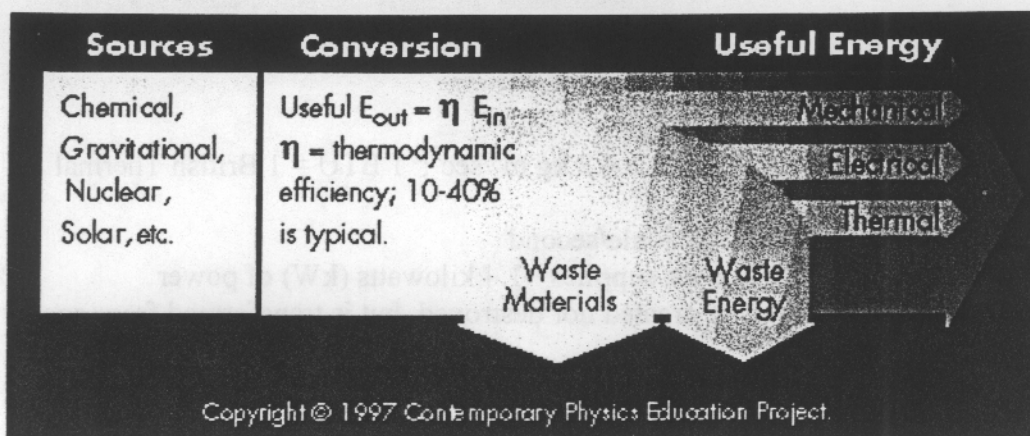


1. Units: Energy: 1 calorie = 4.2 joules = 4.2 kg m²/sec²; 1 BTU = 1 British Thermal Unit = 252 calories
Power = Energy/time = 1 watt = 1 joule/second
Toe = tonnes oil equivalent → 1 toe supplies ~1.4 kilowatts (kW) of power
2. Energy is conserved: it is neither created nor destroyed, but is transformed from one form to another.
3. Recall energy cycle. Ultimate energy source: sun. 180×10^{15} watts incident on the surface of Earth. 1-2% of solar energy is converted to kinetic energy of the atmospheric circulation, 20% is used for evaporation. Global energy use equivalent to incident solar energy in 40 minutes.
4. The industrial era began with James Watt's working steam engine in 1759.
5. Energy efficiency = energy delivered/energy supplied. Sun → Primary energy (e.g. coal, oil) → Secondary energy (e.g. electricity) → use. Energy wastage with every transformation. E.g. 3 toe is needed to generate 1 toe of electricity; an incandescent bulb is 3% efficient in converting primary energy to light energy; in some rural areas, 5% of heat generated reaches inside of cooking pot.
6. Global energy use: $\sim 9000 \times 10^6$ toe per year, 20% transportation, 40% industry, 40% commercial activity and homes. Global average 1.65 toe/person/year. N. American average: ~ 8 toe/person/year
7. Fuels: fossil fuel (age 10^8 years – not renewable in our lifetime); biomass (10^0 — 10^1 years); renewable energy (solar, wind, hydroelectric, waves, geothermal ...) . Photosynthesis converts 1% of solar energy into biomass energy.
8. Solar energy: photovoltaic cells can have efficiencies of 20%. Black surfaces can absorb 1 kW/m².
9. Biomass energy: (a) domestic, industrial and agricultural waste materials as fuel to power electricity generators; (b) biomass → liquid fuels (e.g. alcohol from sugar cane) or (c) biomass → biogas → gas turbines to produce electricity
10. Wind energy: energy produced is proportional to (wind speed)³. Average wind speed of 7.5 m/s can generate an average of 100kW.
11. Geothermal energy : Use hot water or steam from a couple of miles beneath the surface to rotate turbines. Most geothermal power plants in the US are located in the west – e.g. regions of geysers.
12. Nuclear power: uranium reserves may be an energy source of as high as $3000\text{-}9000 \times 10^{15}$ toe. Issues: cost and safety.
13. Future: 50-100 years of oil and gas, 1000 years of coal at current consumption rates. Human co-opt 40% of NPP for our energy needs. How to accommodate energy needs of a growing population?



Percent Increase in Electricity Consumption for US and California (1988-2000)

Percent Increase Over 1988 Level

