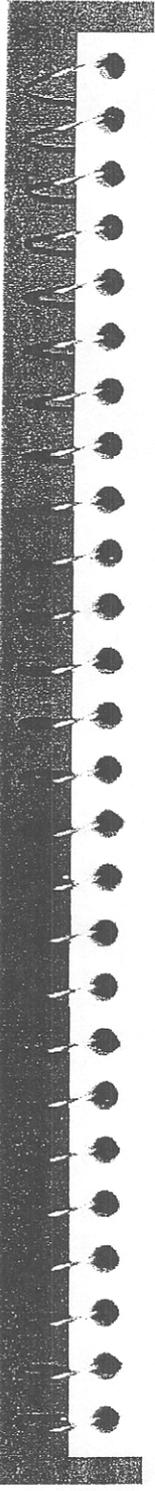


# Energy, Entropy and Climate

David Goodstein  
Caltech





# A Few Astounding Facts

- All Energy is Nuclear.
- There Can Never Be an Energy Crisis.
- Oil companies do not produce oil.
- Gas is the cheapest liquid.
- The Greenhouse Effect Keeps us Alive.
- There Are Real Problems, and they're much worse than you think.

# A Brief History of Energy

- Caloric
- Count Rumford (Sir Benjamin Thompson), 1753-1814
- Many others
- Credit
- James Prescott Joule, 1818-1889

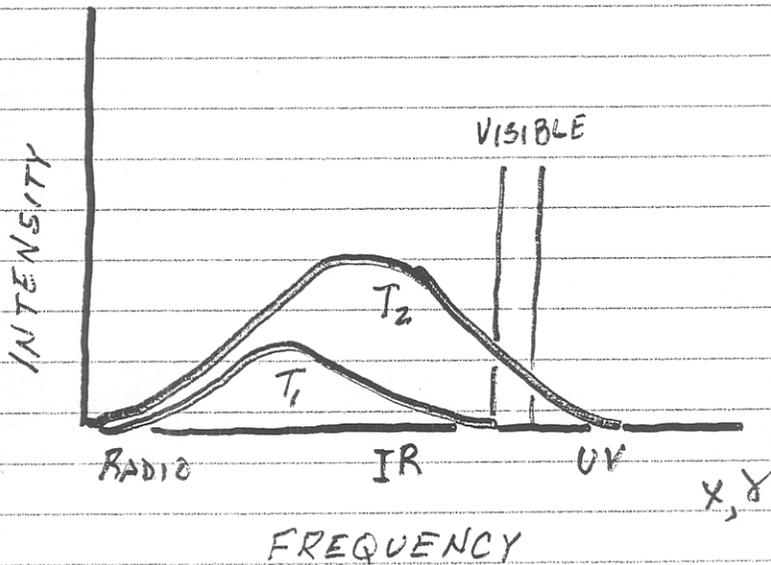
# Forms of Energy

- Radiant
- Kinetic
  - organized
  - random (temperature)
- Potential
  - gravitational
  - chemical
  - nuclear
  - electric, magnetic, etc.

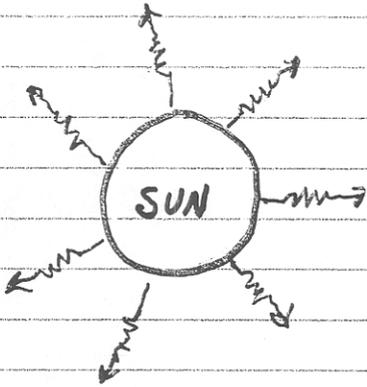
Heat, Work

# All Matter Radiates

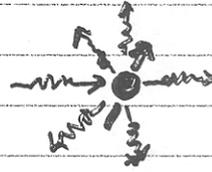
- The Color of Temperature



# A Simple Model



EARTH



30% REFLECTED

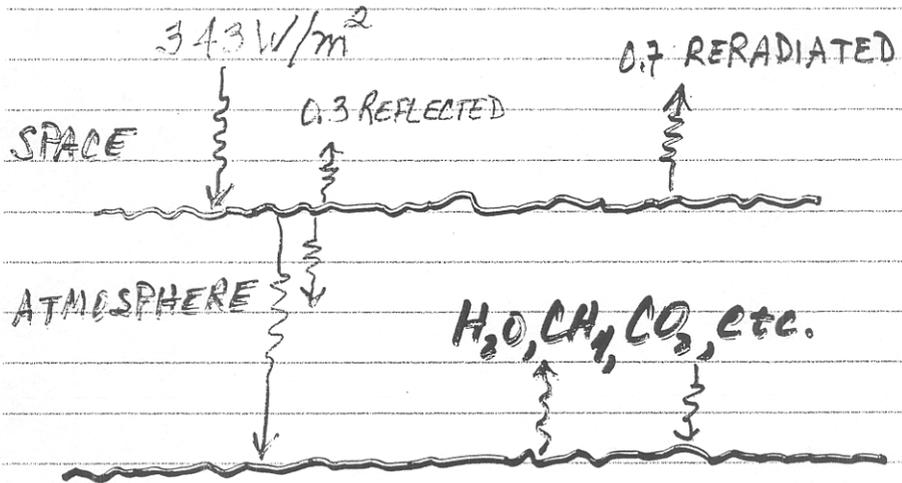
70% ABSORBED

$$T_{\text{EARTH}} = 255\text{K} = -18^{\circ}\text{C} = 0^{\circ}\text{F}$$

# The Climate

- The tilted axis
- The el Niño cycle
- The greenhouse effect

# Energy Budget



EARTH 88% GREENHOUSE

$$T_{\text{EARTH}} = 288 \text{ K} = 15^\circ \text{ C} = 59^\circ \text{ F}$$

Feedback  
Venus

# If Energy is Conserved, What Are We Using Up?

Sun

Earth

Nuclear → Radiation → Potential (fuel)

→ Heat, high T

→ Heat, low T  
(ambient)

→ Radiation, low T

# The Laws of Thermodynamics

Energy: That which is conserved.

Entropy: The disorganization of energy

Rudolph Clausius (1865):

1) The energy of the universe is constant.

2) The entropy of the universe tends to a maximum.

At each step, the entropy  
of the universe increases  
forever.

Sun

Earth

Nuclear → Radiation → Potential (fuel)

→ Heat, high T

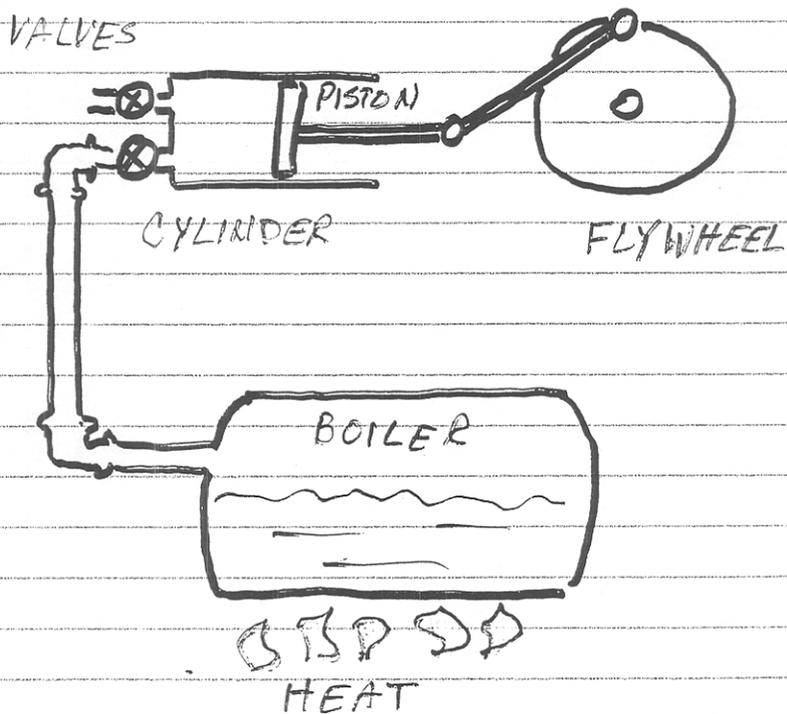
→ Heat, low T  
(ambient)

→ Radiation, low T

*We are squandering the Earth's  
supply of fossil fuels*

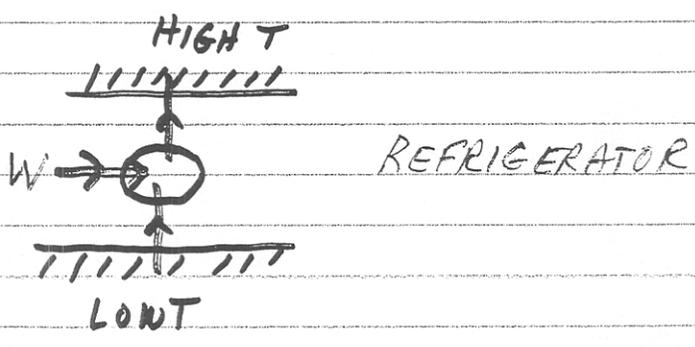
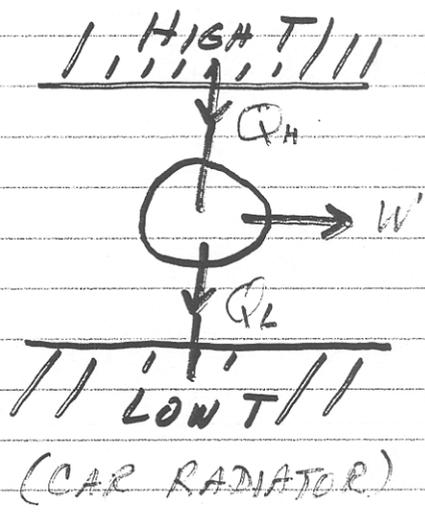
# Eighteenth Century Technology

## The Steam Engine



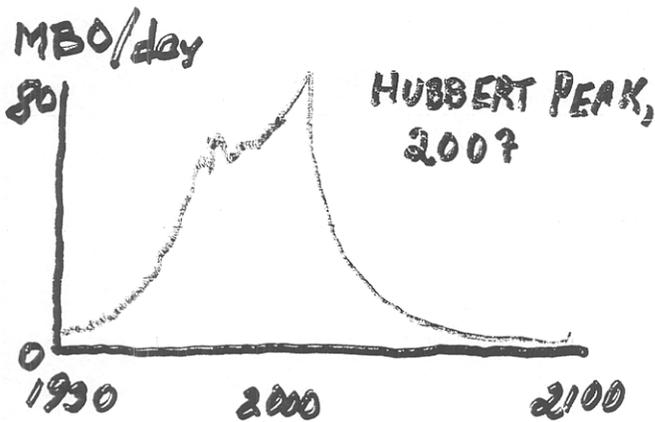
# Heat Engines

- Steam
- Otto
- Diesel
- Turbine
- Stirling (CAR RADIATOR)



# The Hubbert Peak

- U.S. oil "production"
- World oil "production"



LA TIMES 6/11/01

# Oil Users

- Petrochemicals
- Stationary power plants
- Automobiles and trucks

Gas and diesel

Electric

Hybrid

Others

# What does the future hold?

- Oil crisis very soon
- Fossil fuel will run out
- Solar flux plus nuclear
- Dilemma
  - Technical
  - Social, political

# Prediction

Civilization as we know it will come to an end sometime in this century, when the fuel runs out.