CLIMATE CHANGE

LECTURE 1

CLIMATE SYSTEM OVERVIEW

\[
\frac{dE}{dt} = 0 = \text{ENERGY FROM SUN} - \text{ENERGY RADIATED OUT FROM EARTH}
\]

\[
S = \text{FLUX FROM SUN}
\]

\[
\frac{5\pi R^2S}{4\pi r^2} = \frac{S}{4} \quad (1 \text{ ACRE})
\]
Some is reflected, $\alpha$.

$$\alpha = \text{Albedo}$$

"Reflectivity" $$(0 - 1)$$

$$(1 - \alpha) \frac{S}{4} = \text{Radiated from Surface Back}$$

Energy in

$$S = 1371 \text{ W/m}^2$$

$$= \frac{\varepsilon}{(\pi)} \sigma T_e^4$$

$$\sigma = \text{Stefan-Boltzmann Constant}$$

$$= 5.67 \times 10^{-8} \text{ W/m}^2 \text{K}^4$$

$$(\varepsilon) = \text{Emmissivity, How Efficient at Radiating}$$

What is black, $\text{100\%}$ perfect

$$\varepsilon (x, T)$$

$\varepsilon (x, T) = 1$$

$\varepsilon (x, T) = \text{Silver} < 1$
$$T_e^4 = \frac{(1 - 0.3)(1370 \text{ W/m}^2)}{5.67 \times 10^{-8} \text{ W/}\text{m}^2\text{K}^4}$$

$$= 256 \text{ K}$$

$$= -0.24 \text{ F}$$

To cold.

So something is happening in "greenhouse effect".

Svante August Arrhenius 1896

CO$_2$ in arm allows start wave energy in, traps lower Feb 18.

That is radiated back, like gas on the ceramics.
Figure 1.1: Schematic view of the components of the global climate system (bold), their processes and interactions (thin arrows) and some aspects that may change (bold arrows).
Figure 1.2: The Earth's annual and global mean energy balance. Of the incoming solar radiation, 49% (168 Wm\(^{-2}\)) is absorbed by the surface. That heat is returned to the atmosphere as sensible heat, as evapotranspiration (latent heat) and as thermal infrared radiation. Most of this radiation is absorbed by the atmosphere, which in turn emits radiation both up and down. The radiation lost to space comes from cloud tops and atmospheric regions much colder than the surface. This causes a greenhouse effect. Source: Kiehl and Trenberth, 1997: Earth's Annual Global Mean Energy Budget, *Bull. Am. Met. Soc.* 78, 197-206.
WATER VAPOR IS A GREENHOUSE GAS. A MUCH HIGHER CONCENTRATION OF CO2 (P16, FIG. 11) PLUS THE BALANCE OF THE ATMOSPHERE TENDS TO PUSH THE THERMOSERUM AWAY FROM THE EARTH. THE EXPERIMENT SHOWED THAT THE BALANCE OF ICE CO2 IS CRUCIAL.
Humanity’s Top Ten Problems for next 50 years

1. ENERGY
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION
The biggest single challenge for the next few decades:

ENERGY
for $10^{10}$ people

- At MINIMUM we need 10 Terawatts (150 M BOE/day) from some new clean energy source by 2050
- For worldwide energy prosperity and peace we need it to be cheap.
- We simply can not do this with current technology.
- We need Boys and Girls to enter Physical Science and Engineering as they did after Sputnik.
- Inspire in them a sense of MISSION (BE A SCIENTIST SAVE THE WORLD)
- We need a bold new APOLLO PROGRAM to find the NEW ENERGY TECHNOLOGY
The ENERGY REVOLUTION
(The Terawatt Challenge)

14 Terawatts
210 M BOE/day

2003

Source: International Energy Agency

The Basis of Prosperity
20th Century = OIL
21st Century = ??

2050

30 -- 60 Terawatts
450 -- 900 MBOE/day
World Energy

Millions of Barrels per Day (Oil Equivalent)

Figure 1b  Increased CO$_2$ Emissions Causing a Rise in Atmospheric CO$_2$ Associated with a Rise in Global Temperature (Sources: CO$_2$ data from Ethridge et al. 2001, Keeling and Whorf 2002; temperature data from Jones et al. 1998, Peterson and Vose 1997)
# PRIMARY ENERGY SOURCES

## Alternatives to Oil

### TOO LITTLE
- Conservation / Efficiency -- not enough
- Hydroelectric -- not enough
- Biomass -- not enough
- Wind -- not enough
- Wave & Tide -- not enough

### CHEMICAL
- Natural Gas -- sequestration?, cost?
- Clean Coal -- sequestration?, cost?

### NUCLEAR
- Nuclear Fission -- radioactive waste?, terrorism?, cost?
- Nuclear Fusion -- too difficult?, cost?
- Geothermal HDR -- cost?, enough?
- Solar terrestrial -- cost?
- Solar power satellites -- cost?
- Lunar Solar Power -- cost?
165,000 TW of sunlight hit the earth every day
6 Boxes at 3.3 TW Each = 20 TWe
Similarly

Earth Warms → Warmer MB vs LCE

Dark Assimilates More

But Also:

Earth Warms

Clouds Reflected

5 Wt. Less

Reducing MB

More Clouds

More

Ocean Water Evaporates
Stability of climate is also an issue in circulation.

If circulation get switched around, could get very significant changes in climate.