Energy Sources

Solar

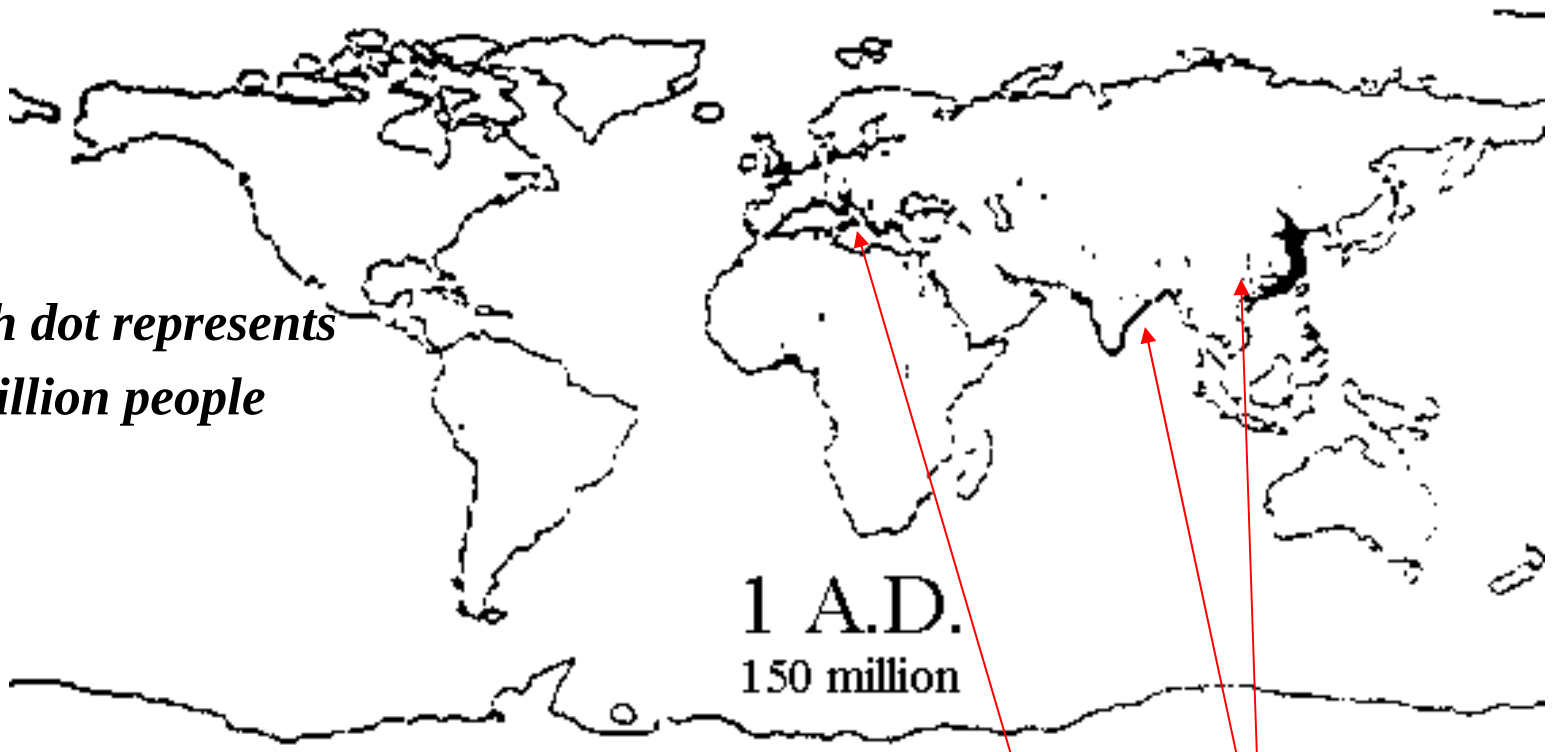
biomass

Energy Affects Society

- More energy available → better off you are.

- In some sense, biomass is “going backwards”.
  - Will it be enough?
  - How about solar?

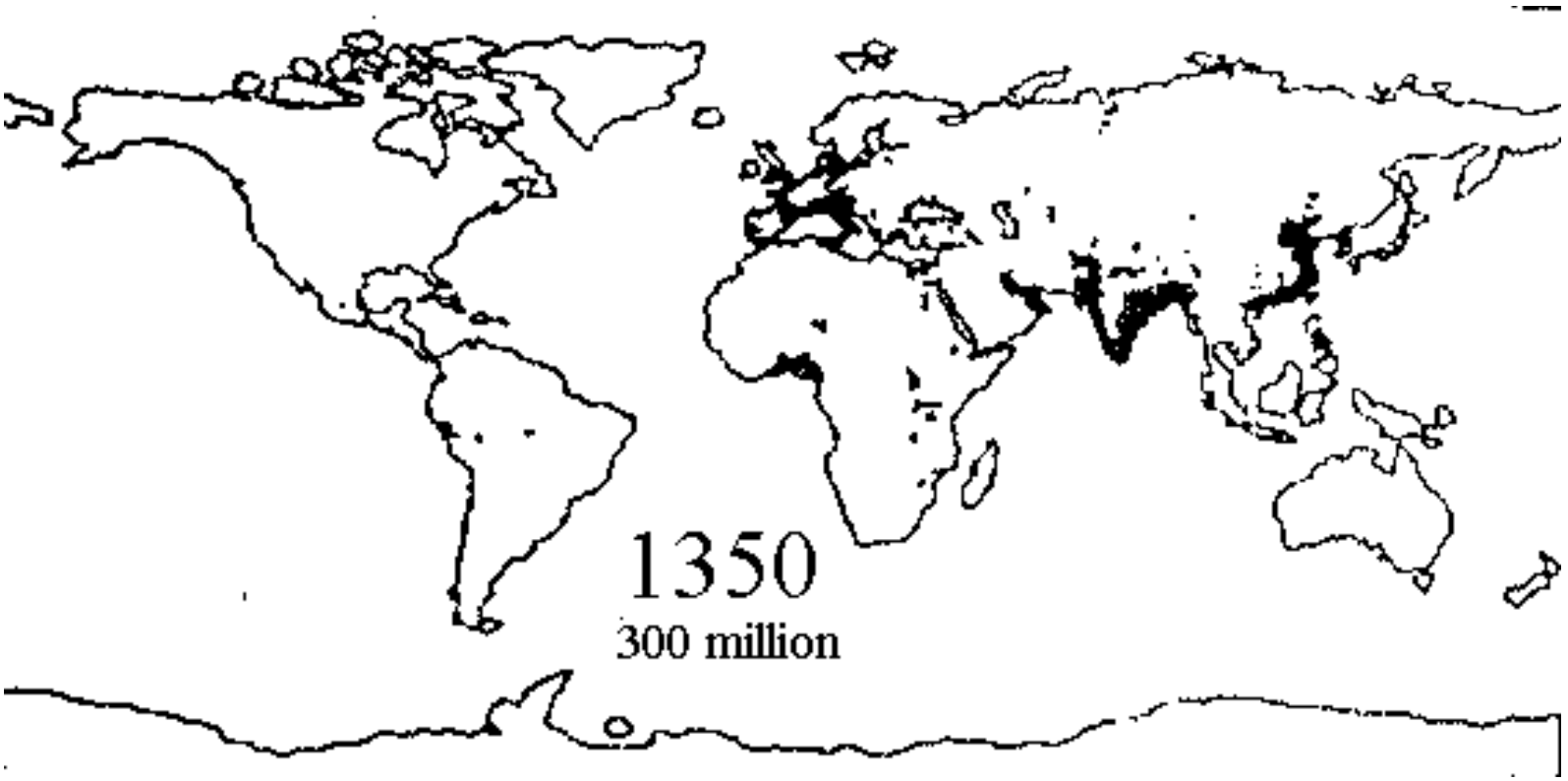
Energy Use Effects Population.



Settlements in Fertile Crescent, Asia, shore regions.

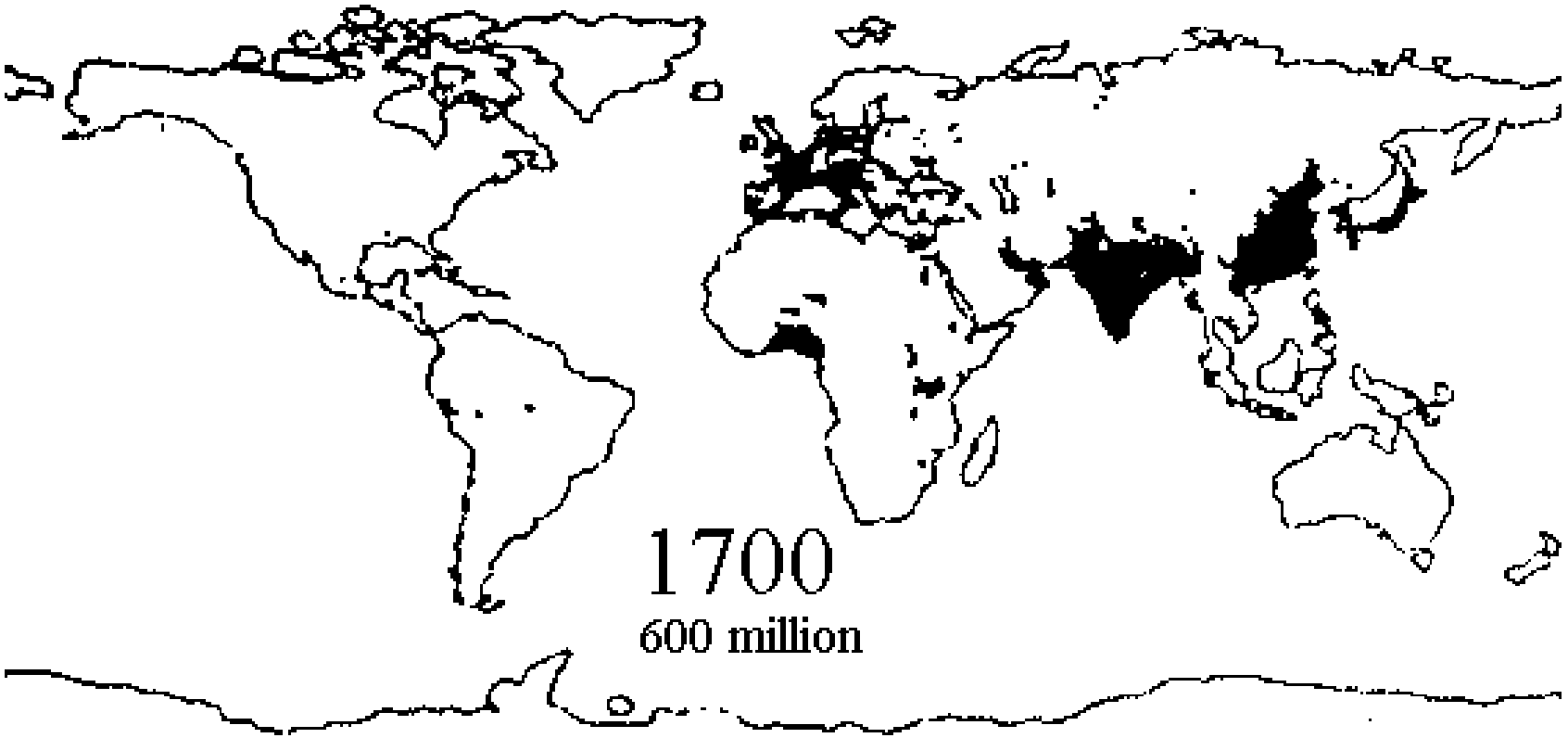
John H. Tanton, "End of the Migration Epoch,"
reprinted by *The Social Contract*, Vol IV, No 3 and Vol. V, No. 1, 1995.

Population Increases Gradually.



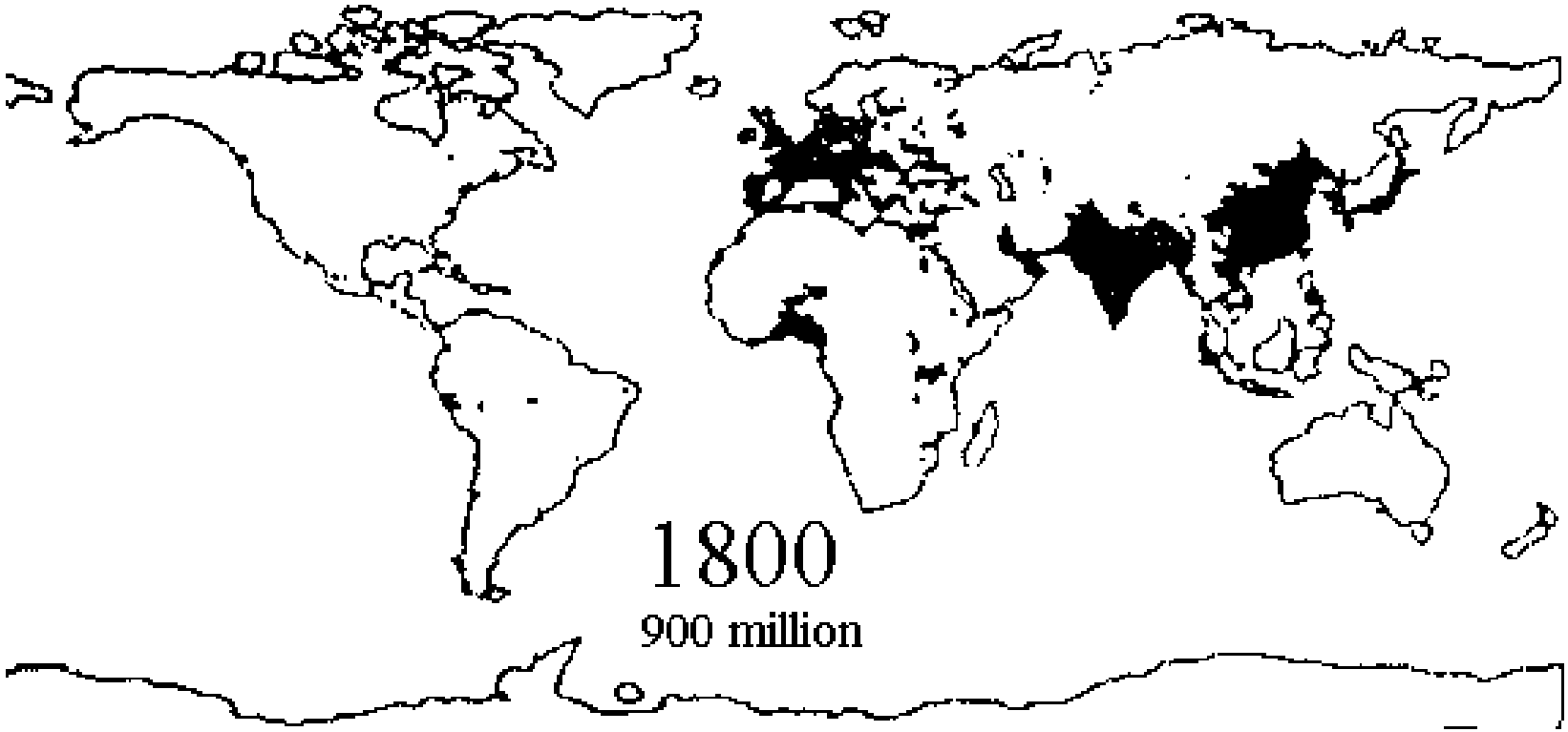
More settlement in temperate shore regions.
Organized Agriculture → reduction of forests.

Pre-Industrial Age Population



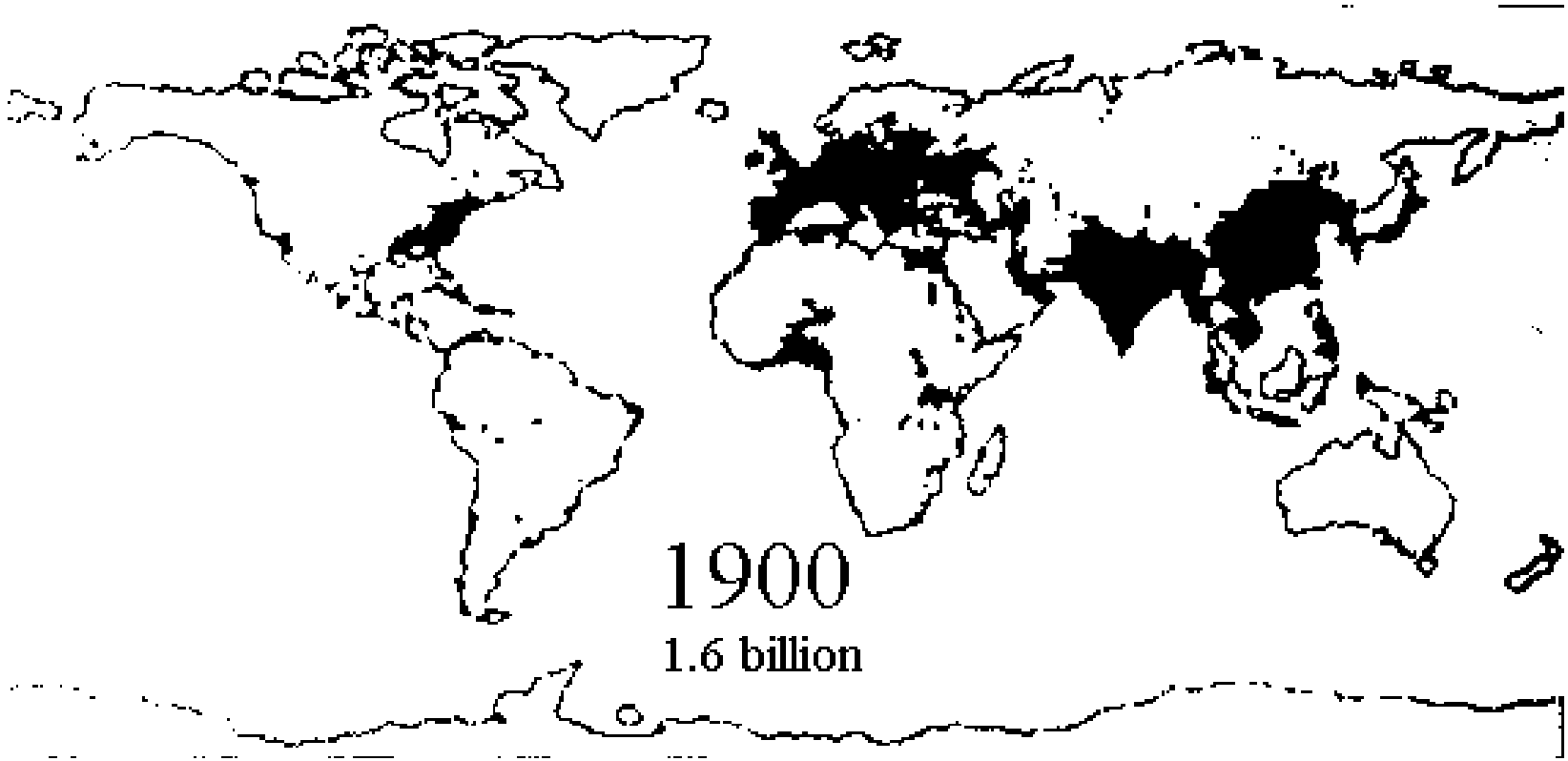
Forests depleted in Europe, Asia.
Wind power also in use for transport.

Dawn of Industrial Age.



Fossil Fuels → coal.

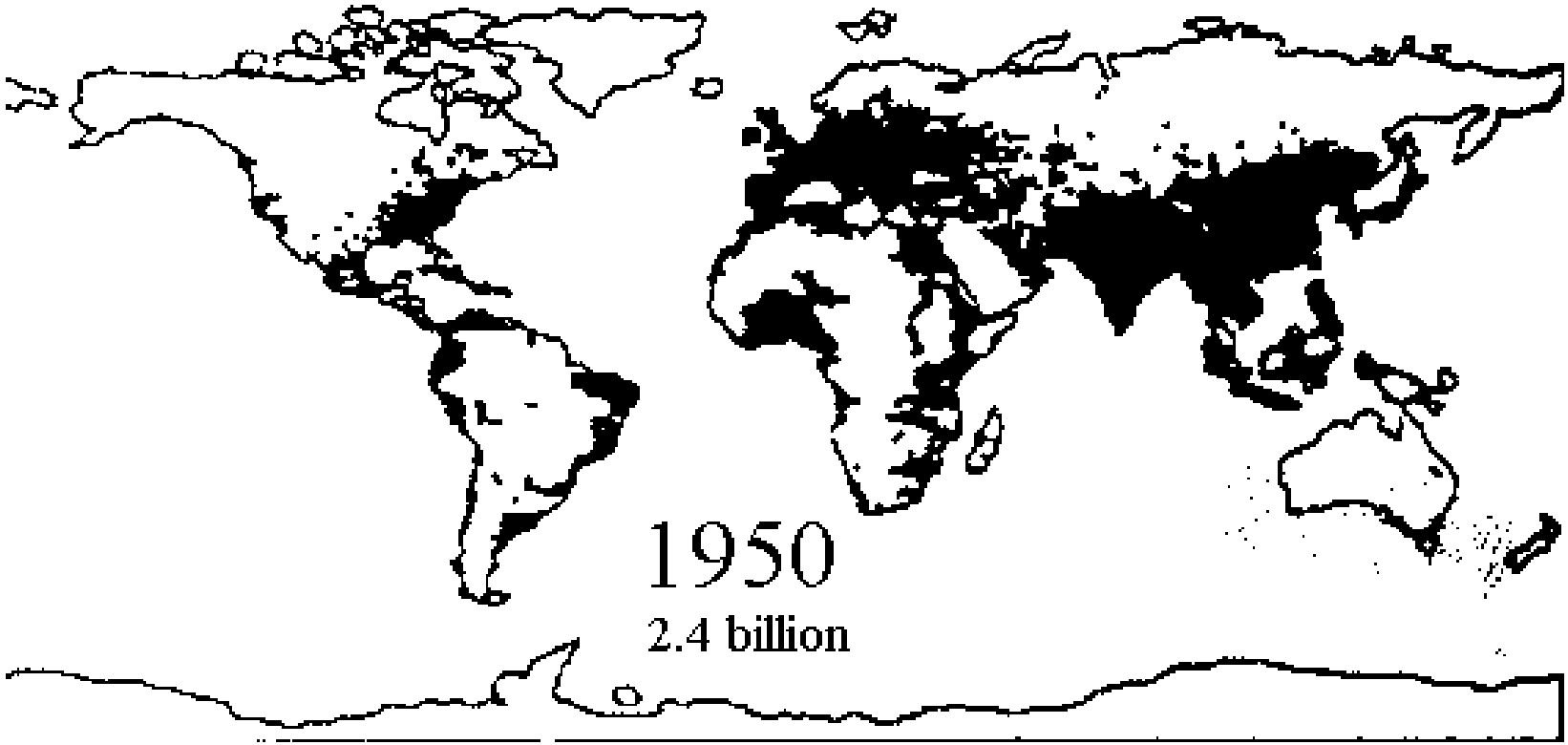
Industrial Age



Fossil Fuels→Electricity in use for Industry, Transport, Food, Medicine.

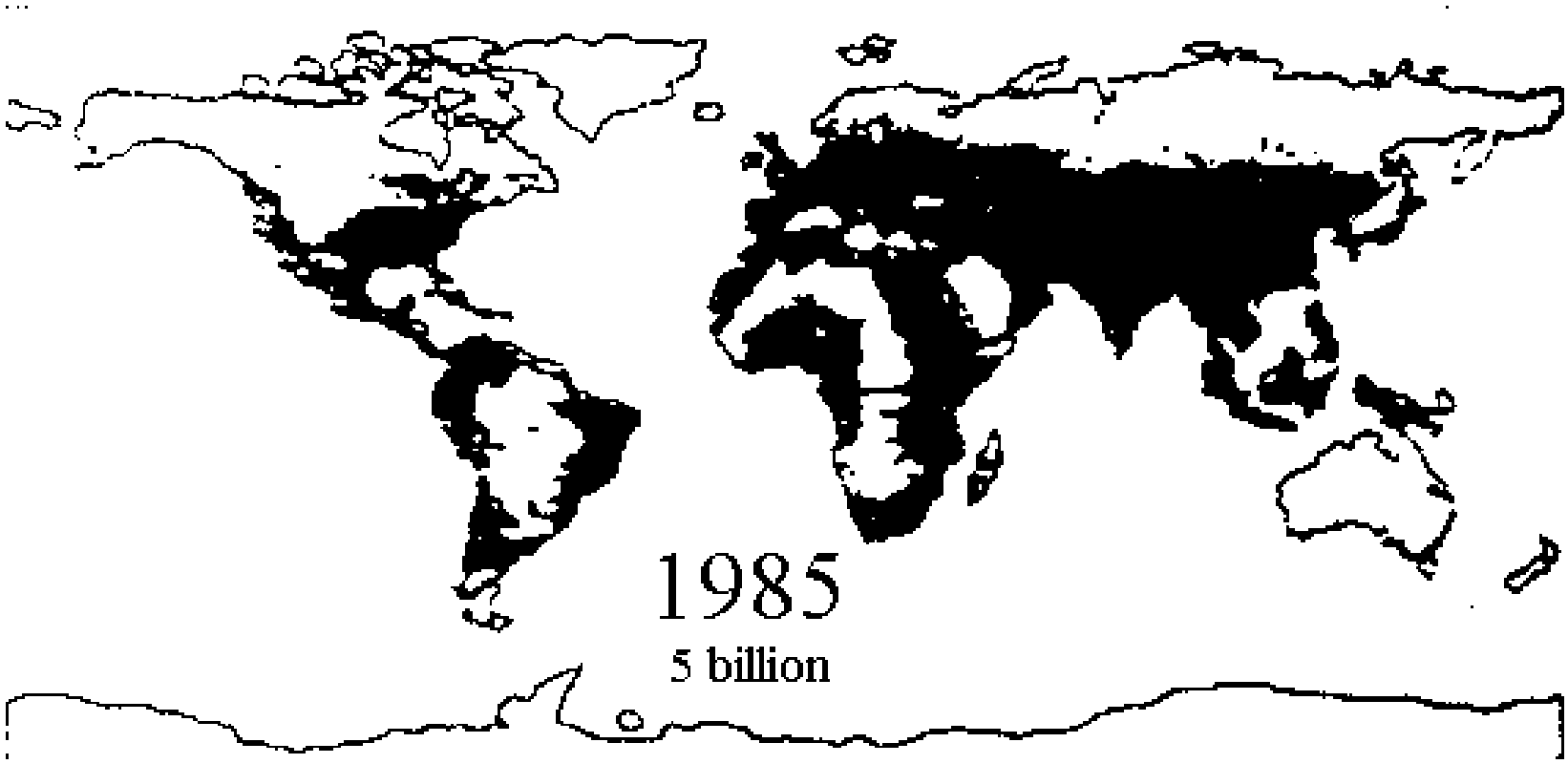
Allows previously non-habitable areas to be settled.

Post WWII



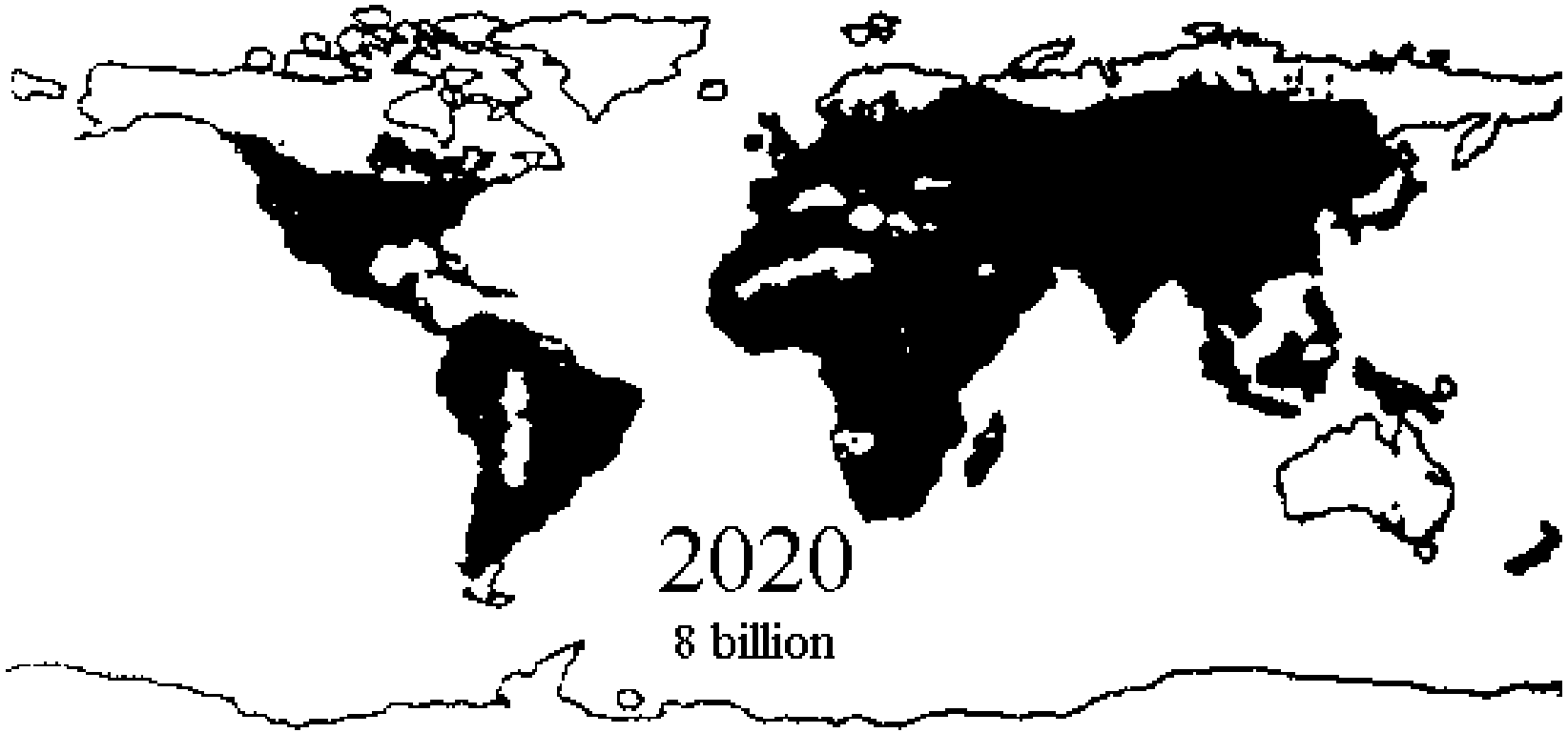
Gasoline/Diesel in use for transport.
Nuclear power introduced.
Population spreads through commercial air transport.

The Recent Past, and Today.



Improvements in efficiency (agriculture, medicine,transport).
Air conditioning allows arid climates to be settled.

The Near Future



Energy effectively decoupled from geography.

How much does it cost?

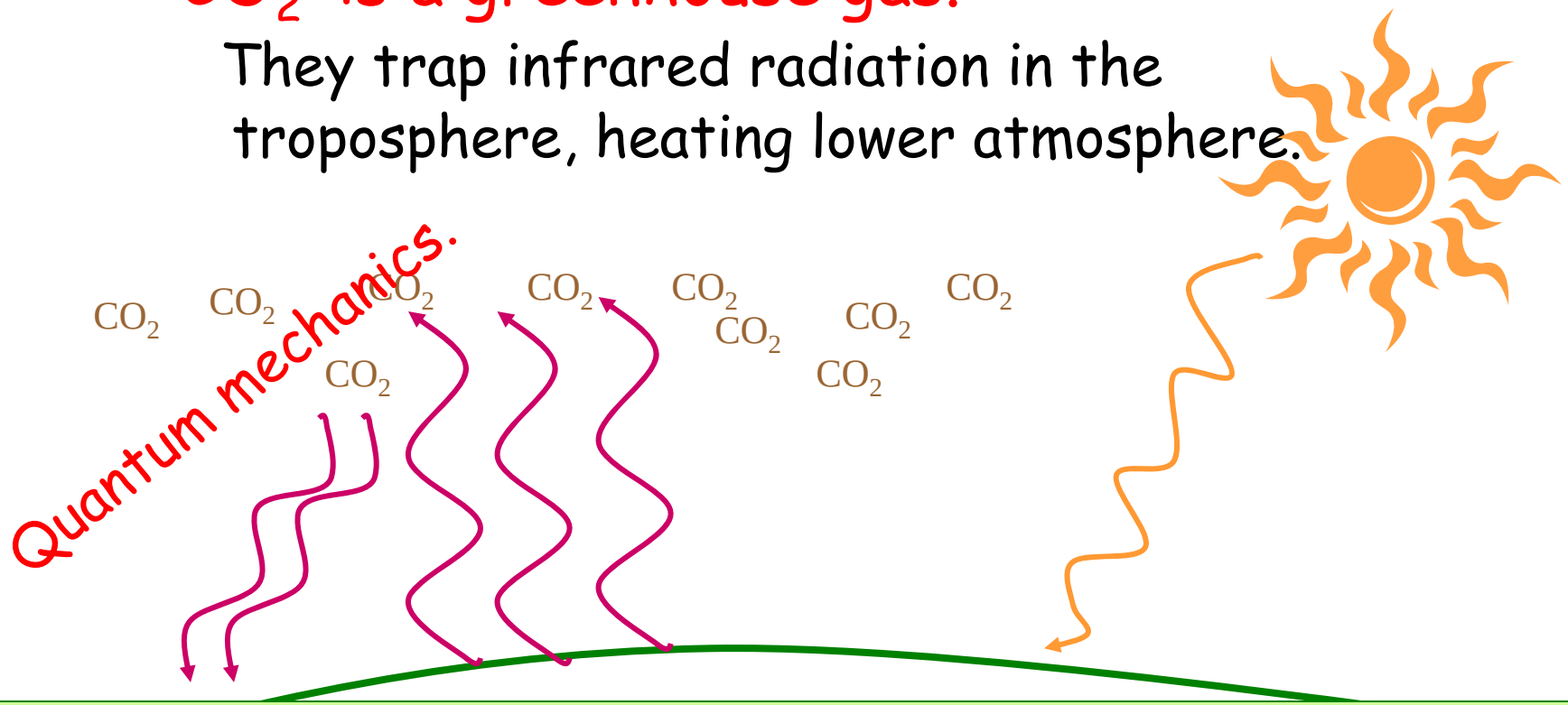
- How do you calculate cost?
  - Material (concrete, steel, cables, inverters…)
  - Labor (people)
  - Energy!
  - Maintain, repair, replace…
- Hard to untangle all this!
- We will look at cost/kWh (market knows best)

The Trouble with Hydrocarbons

It's all those Carbon atoms.

CO_2 is a greenhouse gas.

They trap infrared radiation in the troposphere, heating lower atmosphere.

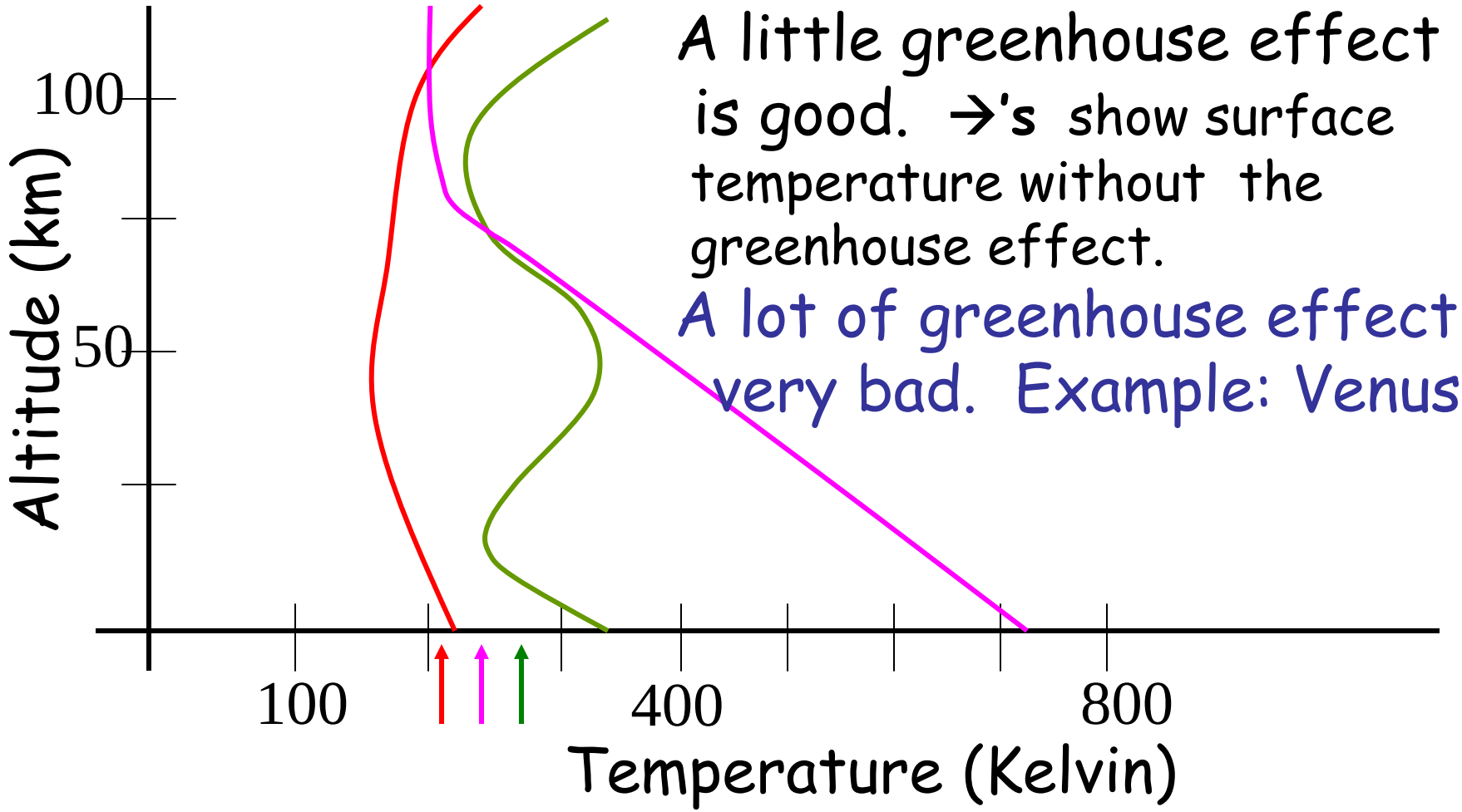


Earth's Surface absorbs visible light.

emits thermal radiation in infrared.

Is Greenhouse Effect Bad?

Let's compare **Mars**, **Earth**, **Venus.**



A little greenhouse effect is good. →'s show surface temperature without the greenhouse effect.

A lot of greenhouse effect is very bad. Example: Venus.

CO_2 Levels Historically

- 1800: 280 ppm
- 1850s: 290 ppm
- 1850 – 1960 310 ppm
- 1960 – 2000 365 ppm

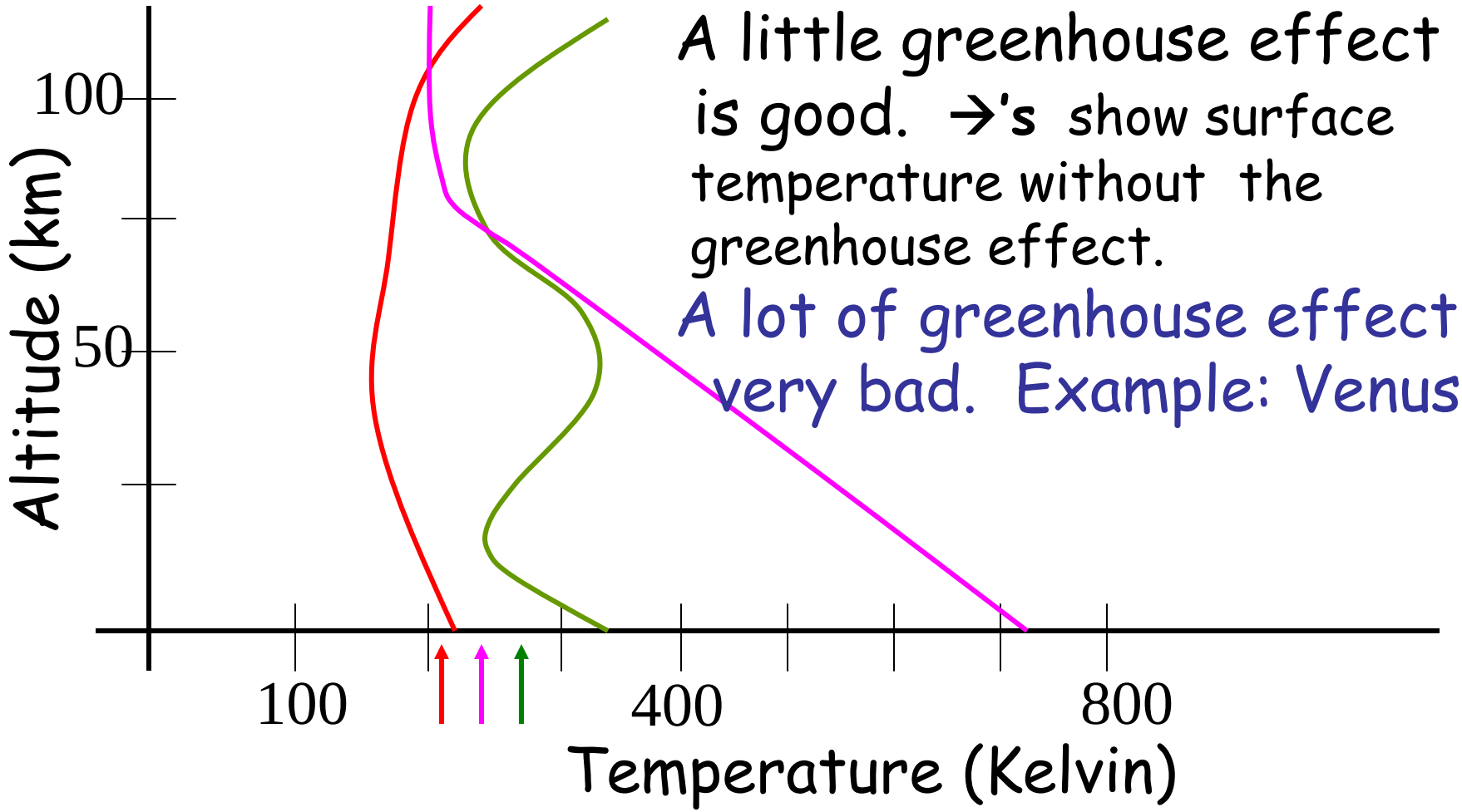
10 ppm in 50 yrs (pioneer effect)

20 ppm in 100 yrs (industrial rev.)

55 ppm in 40 yrs.

Is Greenhouse Effect Bad?

Let's compare **Mars**, **Earth**, **Venus.**



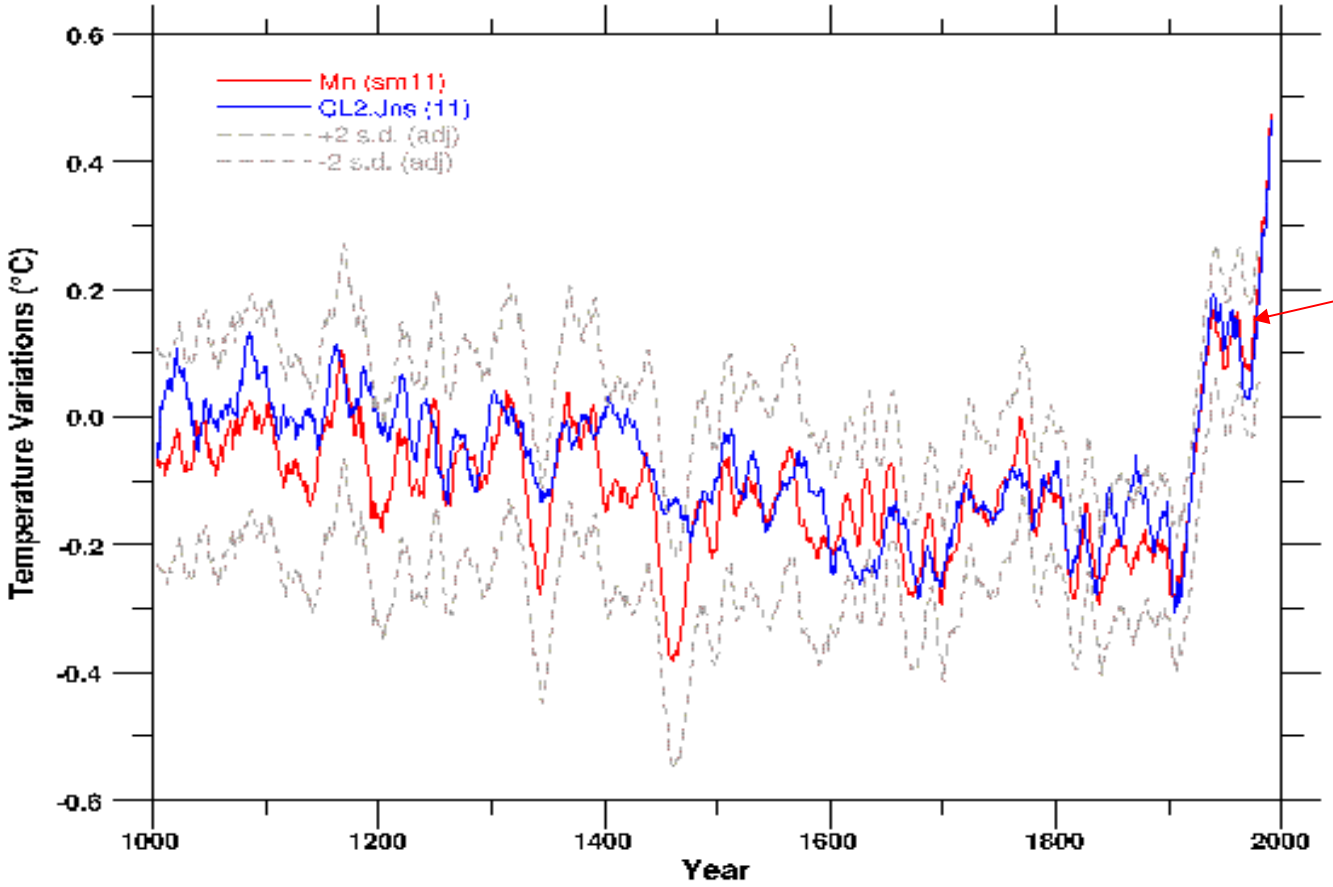
A little greenhouse effect is good. →'s show surface temperature without the greenhouse effect.

A lot of greenhouse effect is very bad. Example: Venus.

Does it Affect Temperature?

Problem: We've only been looking for a few decades.

Answer: Paleoclimatology: ice cores, tree rings, etc.



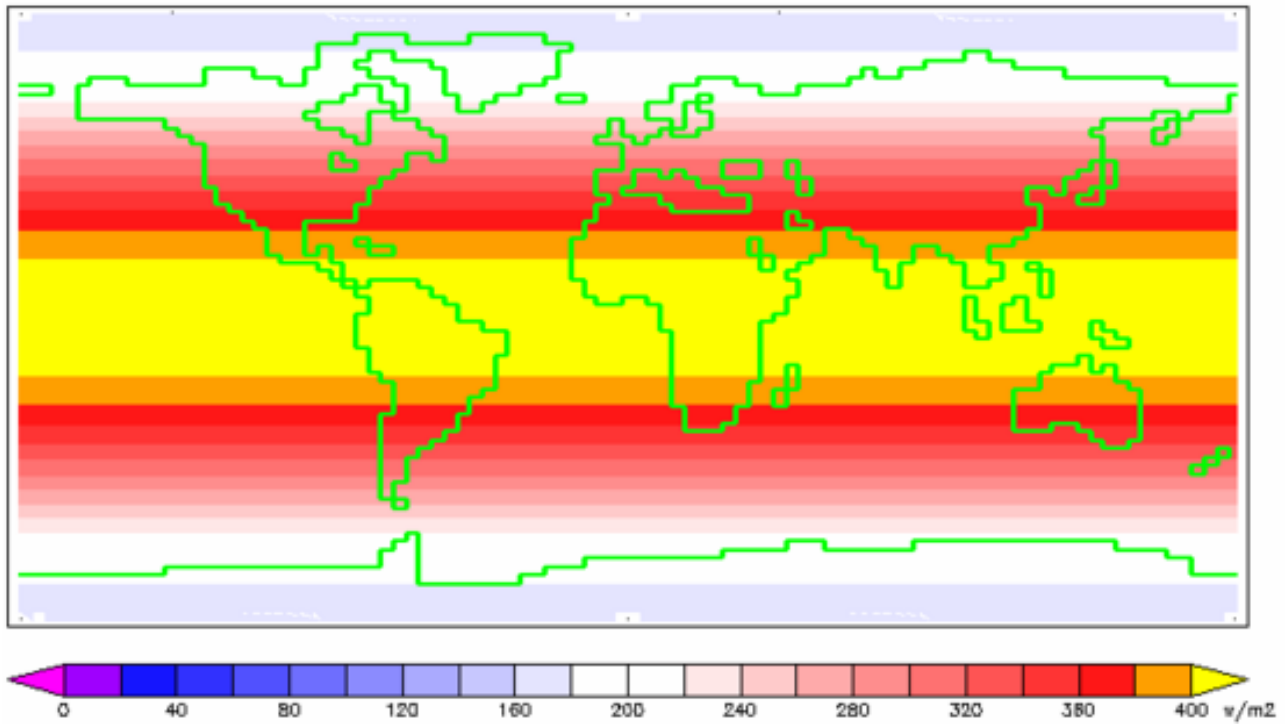
Notice recent activity

Crowley et al July 14, 2000 ***Science***, 289: 270-277

Need Non Fossil Fuel Solution!

Solar radiation incident on earth

(upper atmosphere)



Unfortunately, the developed world does not sit in maximum sunlight.

Solar Cells

- Sun's main process: Turning H to He (fusion).
- Sun's output 4×10^{26} Watts (or Joules/sec).
- We see ~200 W/m^2 (in the US)

So at 15% efficiency,

1 m^2 …

10 hrs of sunlight …

➔ **1 MJoule/day.**

so… **100 m^2, will give equivalent of 1 gallon of gas per sunny day.**

Solar Thermal

- Mirror Farms concentrate sunlight on a tower, heating water.
- This is used to drive a turbine.

100 MW Solar Thermal Electric Project in South Africa

Solar Thermal Example

- Solar Two
  - Mojave Desert near Barstow, California

- total area of 82,750 m² (891,000 ft²)
- Equivalent to 600 suns!
- Used molten salt in the tower (not water)
- Generated 10MW

COSTS?

- **Solar**
- US production costs are 26-35cents/kwhr from solar panels,
- [about 5 times higher than wind].

NJ BPU study: $78000/10kW for home installation.

Payback time = 50 years without subsidies and

10 years with NJ subsidies.

[Payback time for a compact bulb is about a month.
Efficiency always wins.]

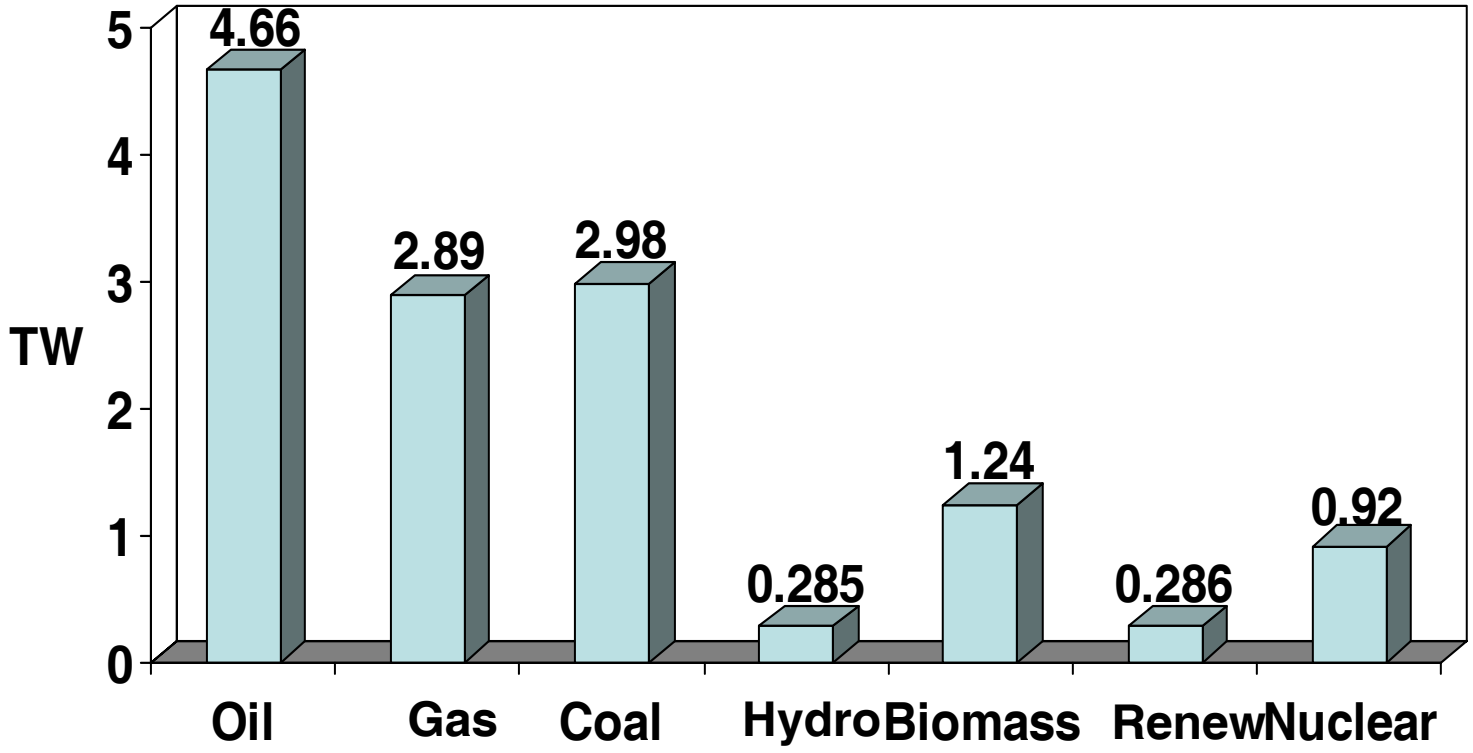
Production costs for solar thermal electricity (mirror farms) is coming down to 9-12c/kwhr (w/o subsidies).

US approved 30% tax credit in 2006 so a boom is coming.

Costs?

- Cost to commission a new power plant in 2015:
- wind 5.6c/kwhr,
- Natural gas and coal 5.3c/kwhr,
- Nuclear 5.9c/kwhr.
- Solar Cells 26-35cents/kwhr
- Solar Thermal 9-12c/kwhr
- (Coal?) 1-2c/kwhr

Global Energy Consumption, 2001



Total: 13.2 TW U.S.: 3.2 TW (96 Quads)

Nathan Lewis, Caltech

Biomass

Solar energy converted via photosynthesis (ie, plants)

CO2 + H20 + light energy => O2 + carbohydrates

"less than 1% efficient in converting light energy to chemical energy"

Facts and figures (from Nathan Lewis lecture)

World: total land with crop potential = 2.45 x 10^13 m^2,
(0.897 x 10^13 m^2 already cultivated)

Optimistic:

8.5 tons per hectare/year (1 hectare = 10,000 m^2)

20 GJ heating value per ton ➔ 17 MJ/m^2 per year

10% of all (cultivable) land produces 7 TW of power
(total in 2001 was 0.2 TW)

US land (from book)

2260 million acres = 9.1 billion m^2

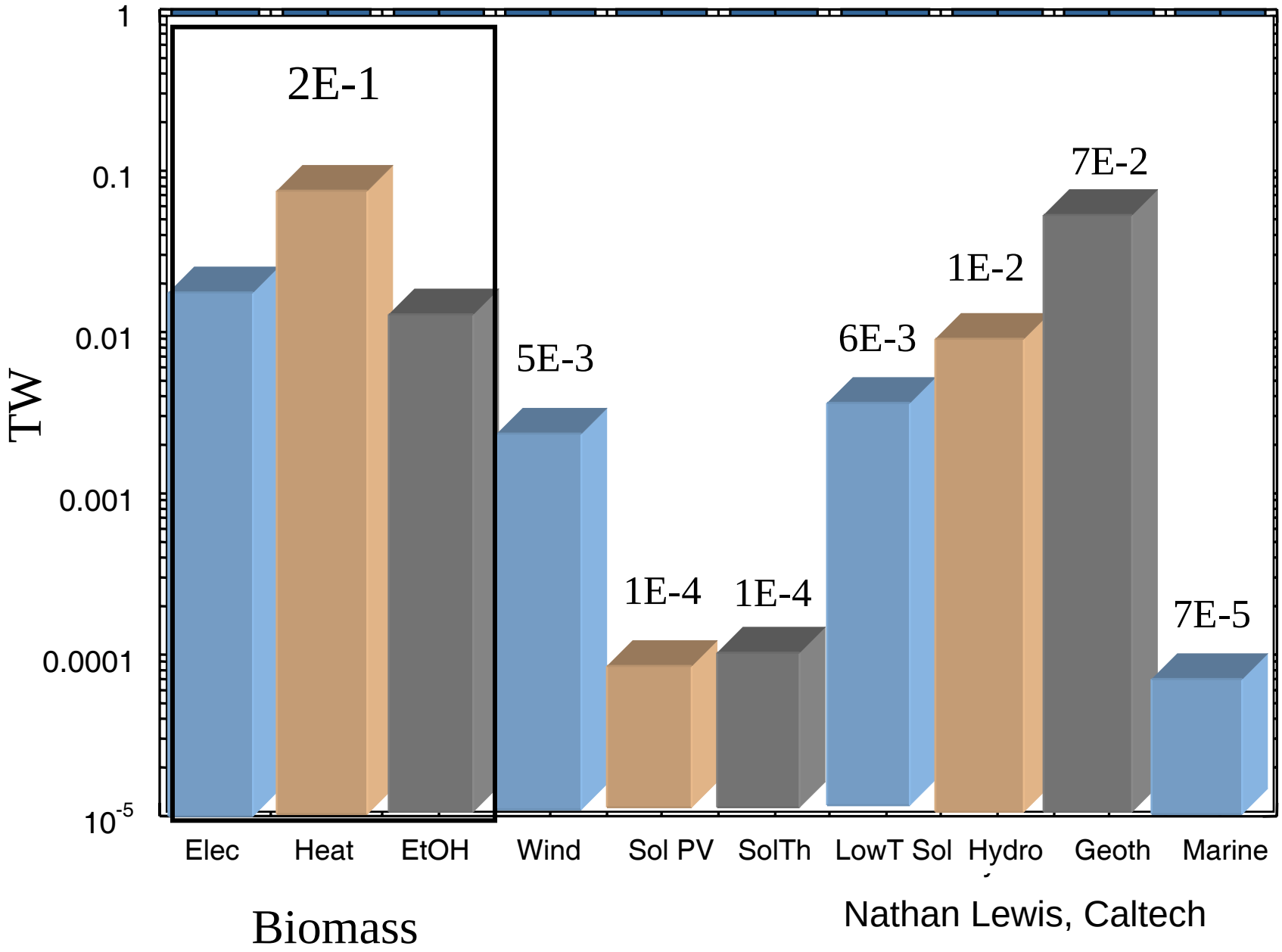
20% cropland

30% commercial forest and woodlands

➔4.6 billion m^2 ➔ 2.5 GW (0.0025 TW from all available US land)

Don't forget, biomass energy production needs FRESH WATER!

Energy From Renewables, 2001



Nathan Lewis, Caltech

Biomass conversion

- Biochemical: decomposition (methane), fermentation (ethanol and methanol)
- Combustion (space heat, electricity)

Ethanol

- Corn, sugar, wood & grasses (cellulosic)
- Process
- Energy balance! Net CO2 emission?! Economics – corn from ethanol requires huge government subsidies
- Displaces food production
- Brazil vs US

Soybeans, palm oil

- Used vegetable oil for diesel

Win-win, but supply is very small

Soybeans

Palm oil

Methane from decomp

- Sewage treatment / Landfill gas – mentioned in lecture 2
- Manure—small scale (family-size) digesters