# Energy Consumption and Sources of Renewable Energy

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SMAP
Piscataway HS, April 10, 2003

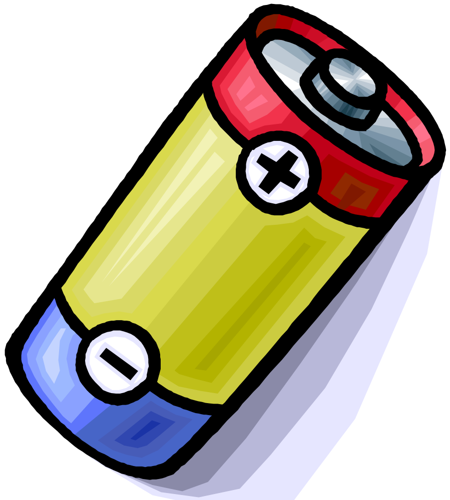
# What is Energy?

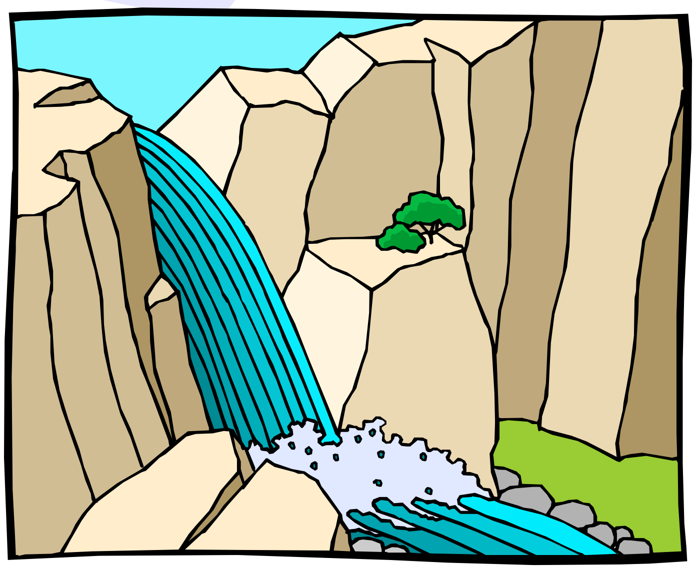
The Physics Definition: The capacity to do *Work*.

So, what is **Work**? To produce a *Force* on an object to move it a *Distance*.

**Force?** Accelerates an object of mass M.
$F = ma$.

# Different Types of Energy.





- Kinetic Energy.
  - Energy of a moving thing: $KE = \frac{1}{2} mv^2$
- Potential Energy.
  - Stored Up Energy that can be converted into KE.

**Examples**:

Mass on a hill (gravitational PE),

Compressed spring (mechanical PE),

Stick of dynamite (chemical PE),

Battery (electrical PE)

Energy Unit: Joules

Power: Joules/second = Watts.

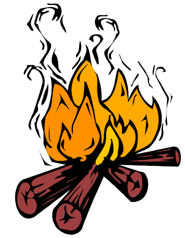
# Energy Use Through the Ages.

- Prehistory to Industrial Revolution:

  Heat: Direct Sun, Indirect (burnt biomass)

  Mechanical/Transport Systems: Biological (water, wind, animals)

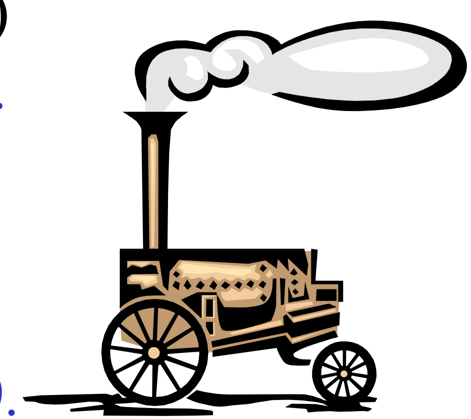
  *Units used: horsepower (746 Watts).*



- Early Industrial Revolution (1800s):

  Fossil Fuels (coal) → Steam Engine.

  *Units used: BTU (1055 Joules).*

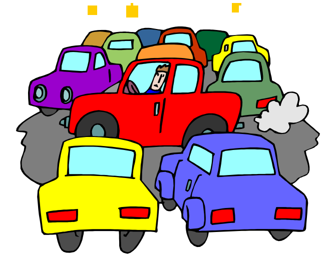


- Late Industrial Revolution (1880s):

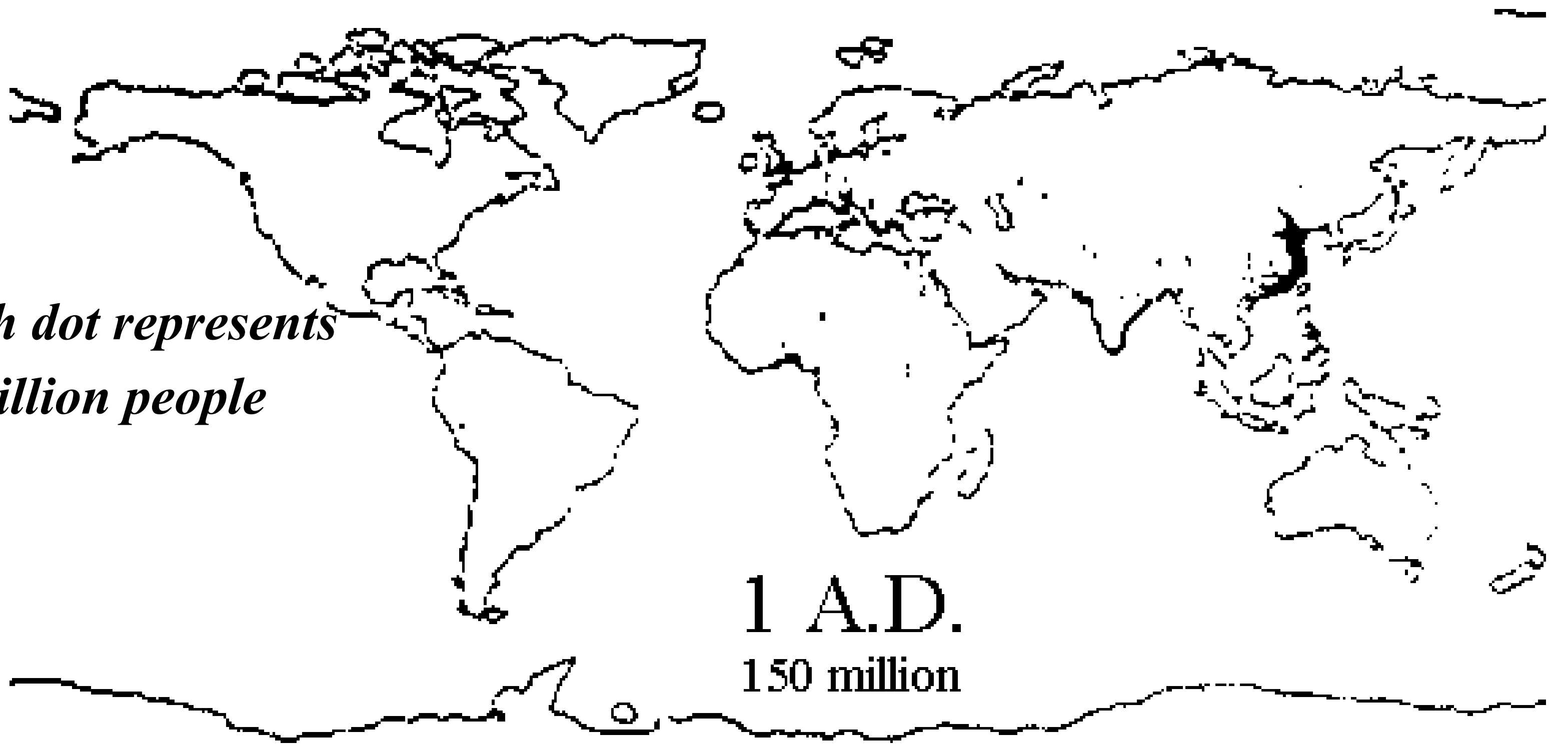
  Fossil Fuels → Turbines → Electricity.

  → Internal Combution → cars.

  *Units used: Joules, Watts.*



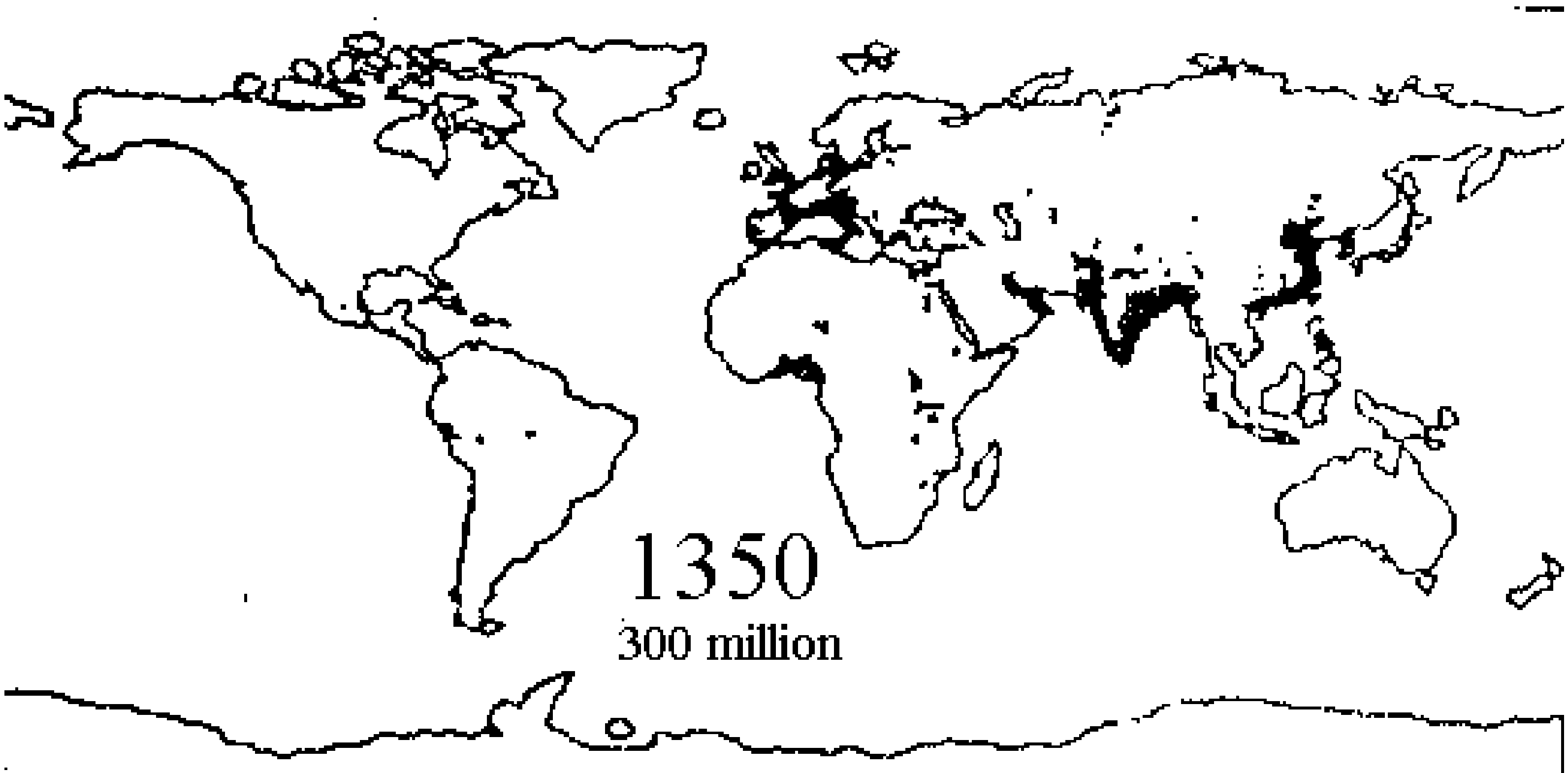
# Energy Use Effects Population.




Settlements in Fertile Crescent, Asia, shore regions.

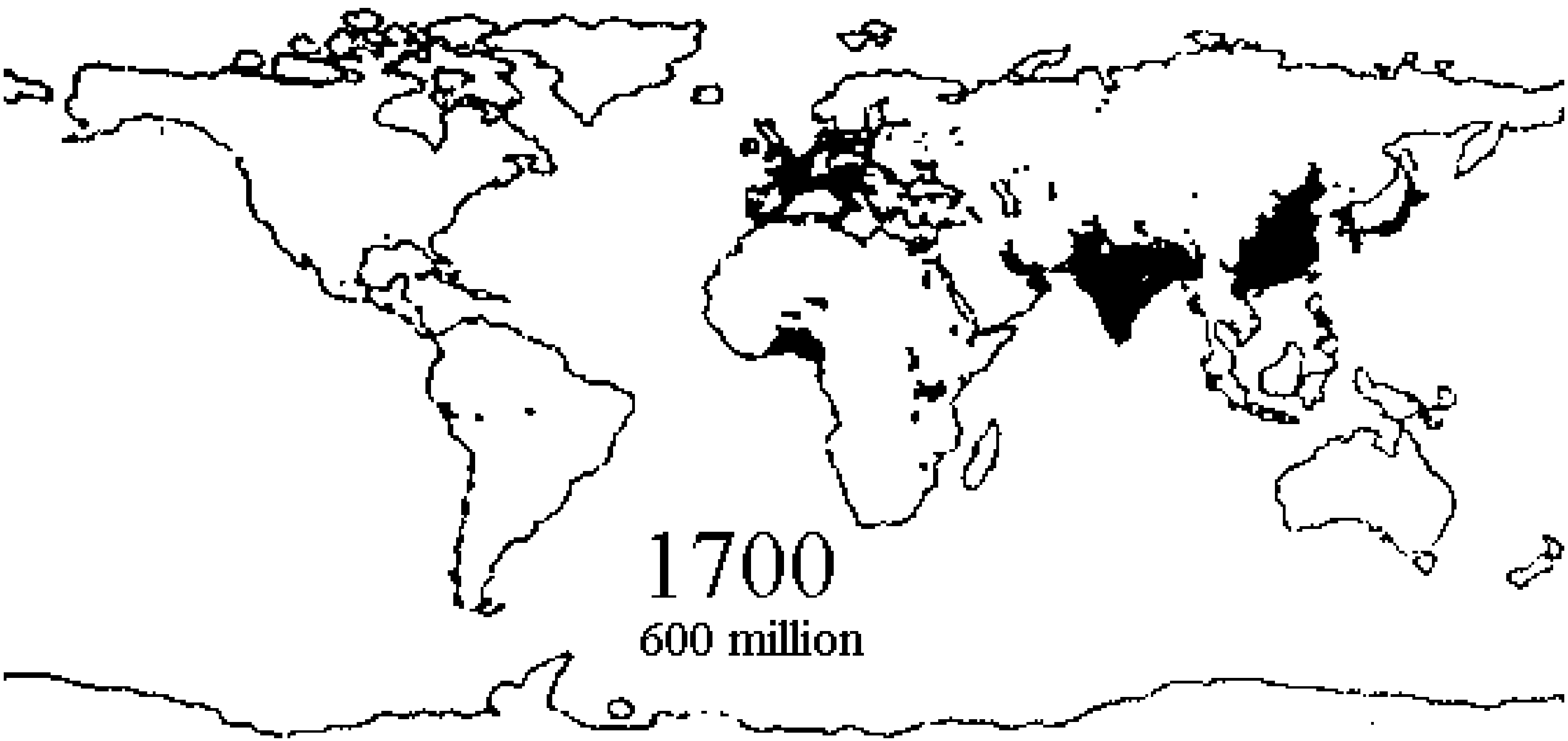
**John H. Tanton**, "End of the Migration Epoch,"
reprinted by *The Social Contract*, Vol IV, No 3 and Vol. V, No. 1, 1995.

# Population Increases Gradually.

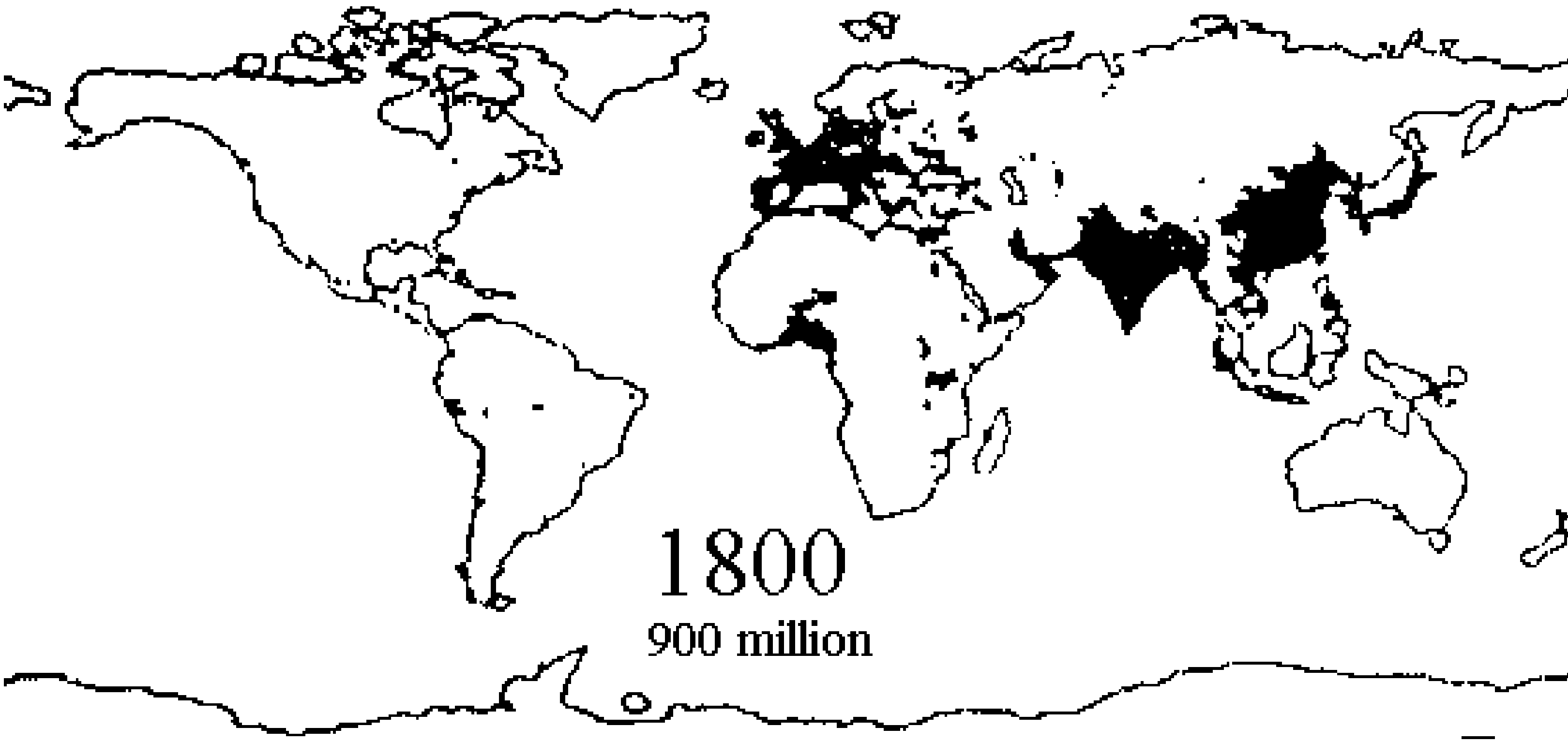



More settlement in temperate shore regions.
Organized Agriculture, reduction of forests.

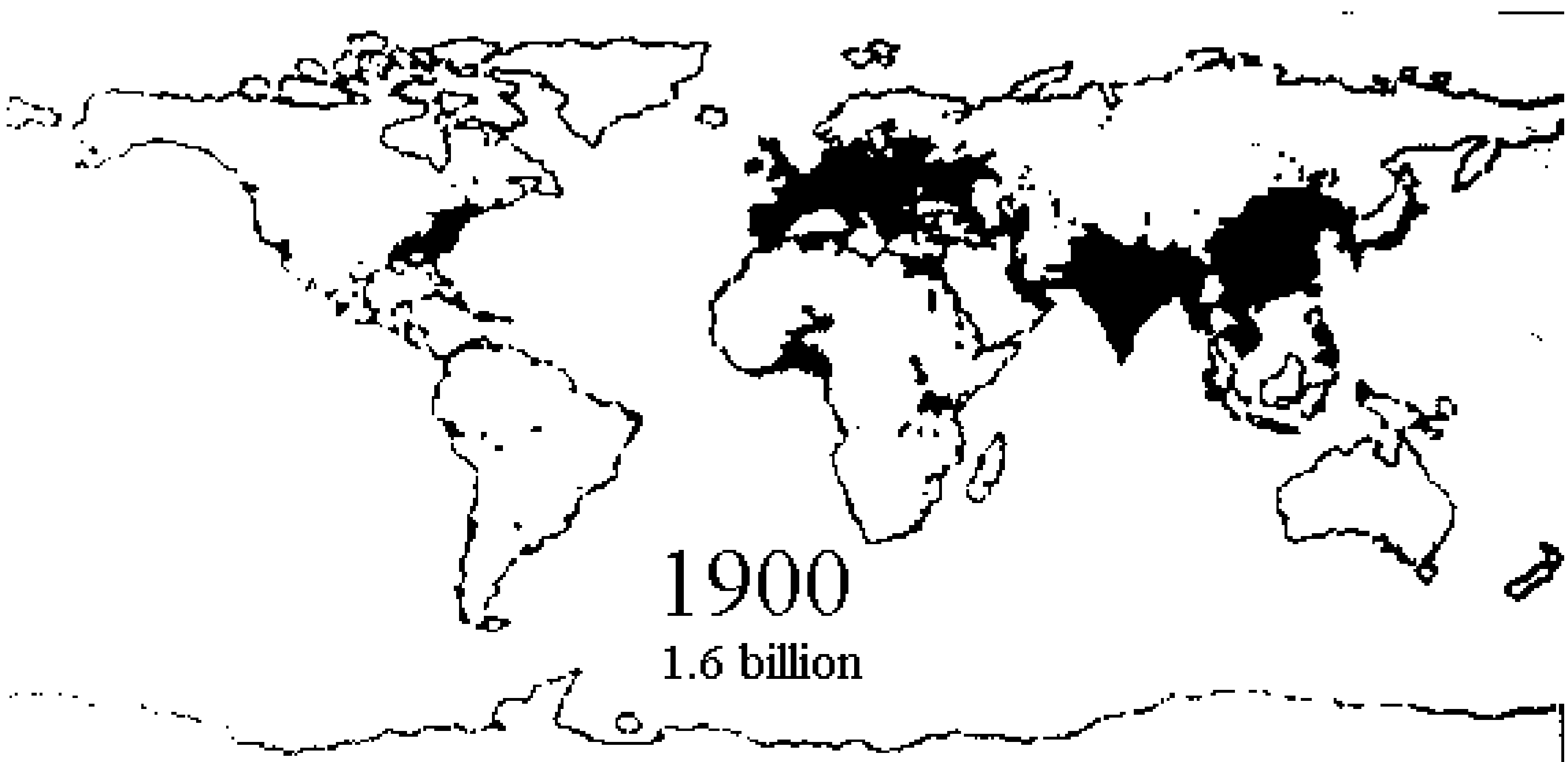
# Pre-Industrial Age Population



# Dawn of Industrial Age.



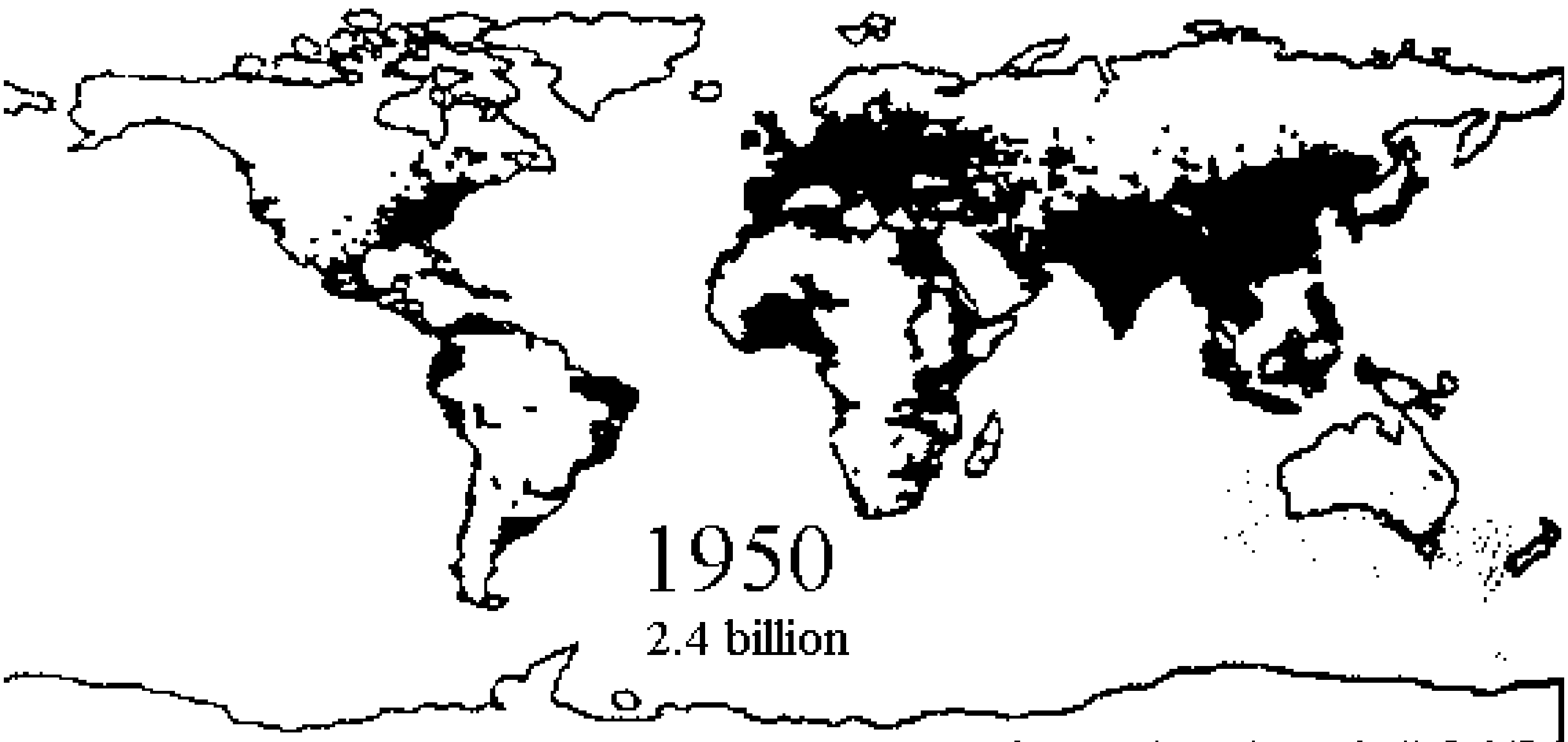
# Industrial Age




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

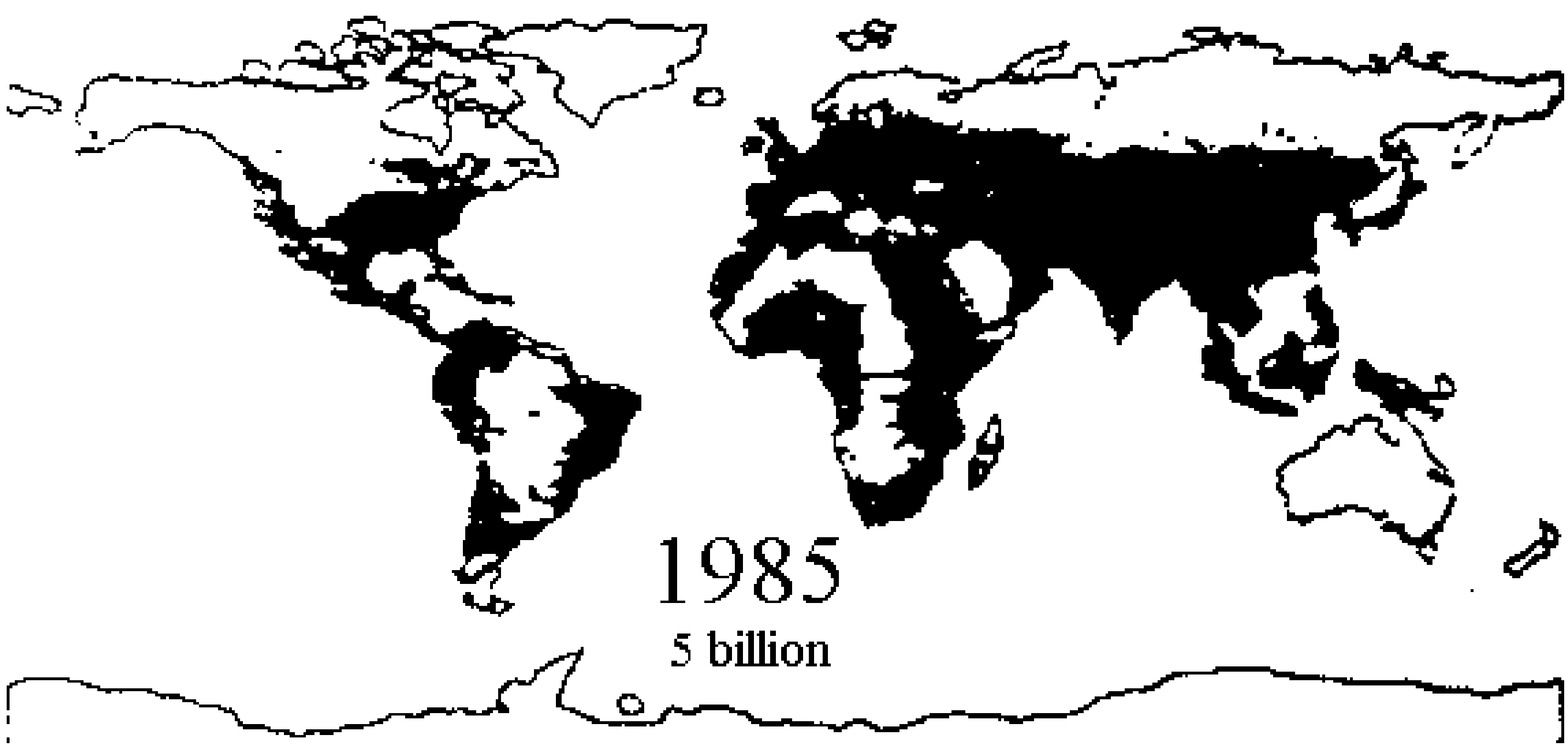
Allows previously non-habitable areas to be settled.

# Post WWII



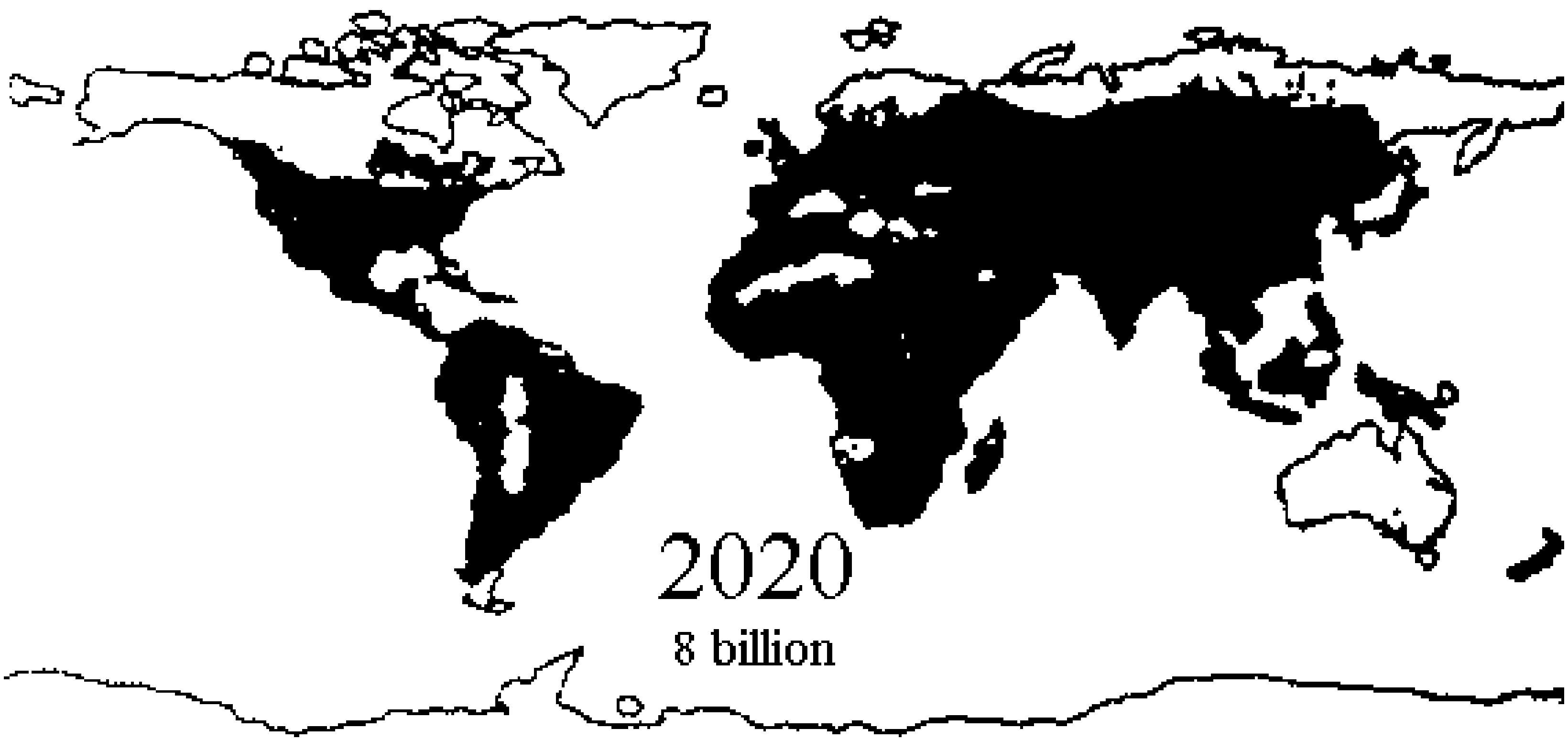

Refined oil (gasoline) in use for transport. Nuclear power introduced. Population spreads through commercial air transport.

# 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.

# Why Fossil Fuels?

- What's so special about fossil fuels?

  Energy content. Coal: 15,000 BTU/lb = 15 MJoules/lb

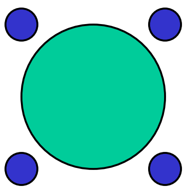
  Gasoline: 115,000 BTU/gal = 120 MJoules/gal
- Wood has roughly half the energy content of coal.

- A "horse" working for an hour would give: 2.5 MJoules.
- A "human" would probably give less than a tenth of that.

Fossil Fuels deliver lots of energy in a small volume.

Fossil Fuels are transportable.

# How Do Fossil Fuels Work?



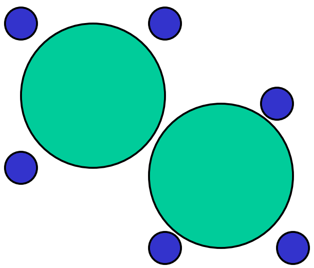
$CH_4$ Methane, the simplest Hydrocarbon, burns (all hydrocarbons burn):

***Burning*** is a process of combining with oxygen.

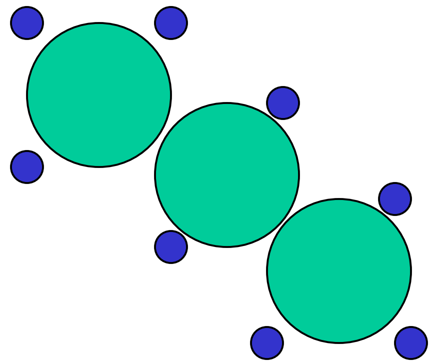
1 Methane + 2 $O_2$ ➔ 2 $H_20$ + $CO_2$ + ***Energy***

Hydrocarbons burn fast.
Hydrocarbon burning releases water and $CO_2$

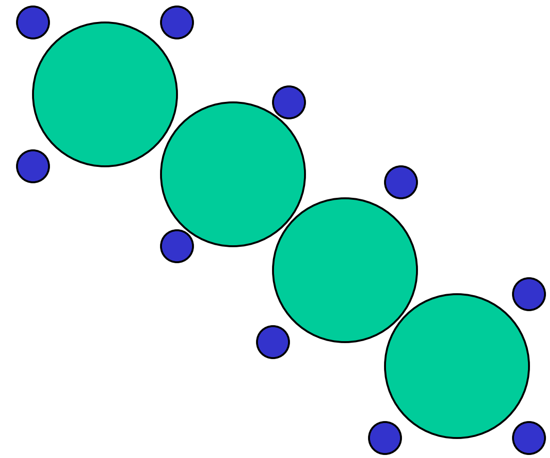
# More Hydrocarbons



2 Carbon Atoms
ETHANE



3 Carbon Atoms
PROPANE



4 Carbon Atoms
BUTANE

And so on.

Five Carbon Atoms give you PENTANE.

Six Carbon Atoms give you HEXANE.

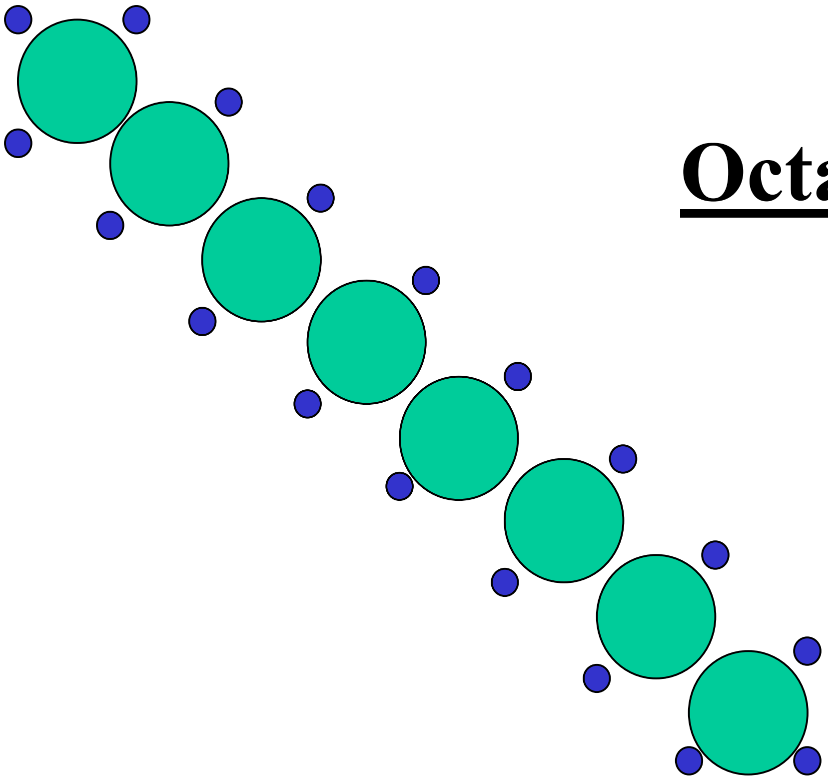
Seven give you HEPTANE.

# Bigger is Better

The bigger the hydrocarbons get:
- The more energy per molecule you get from burning.
- The easier it is to ***Liquefy*** them.

Methane is very difficult to liquefy.
Propane will liquefy at 40 below zero.
Butane will liquefy on a cold winter day.

# The World's Favorite Hydrocarbon



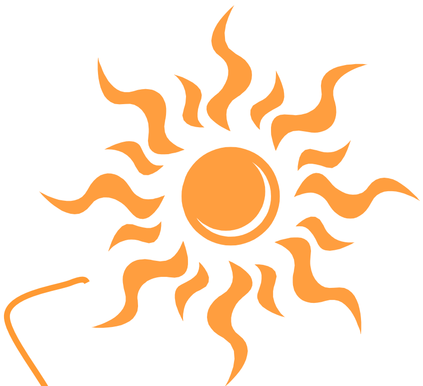
**<u>Octane.</u>** **Eight** Carbons. The main ingredient in **gasoline**.

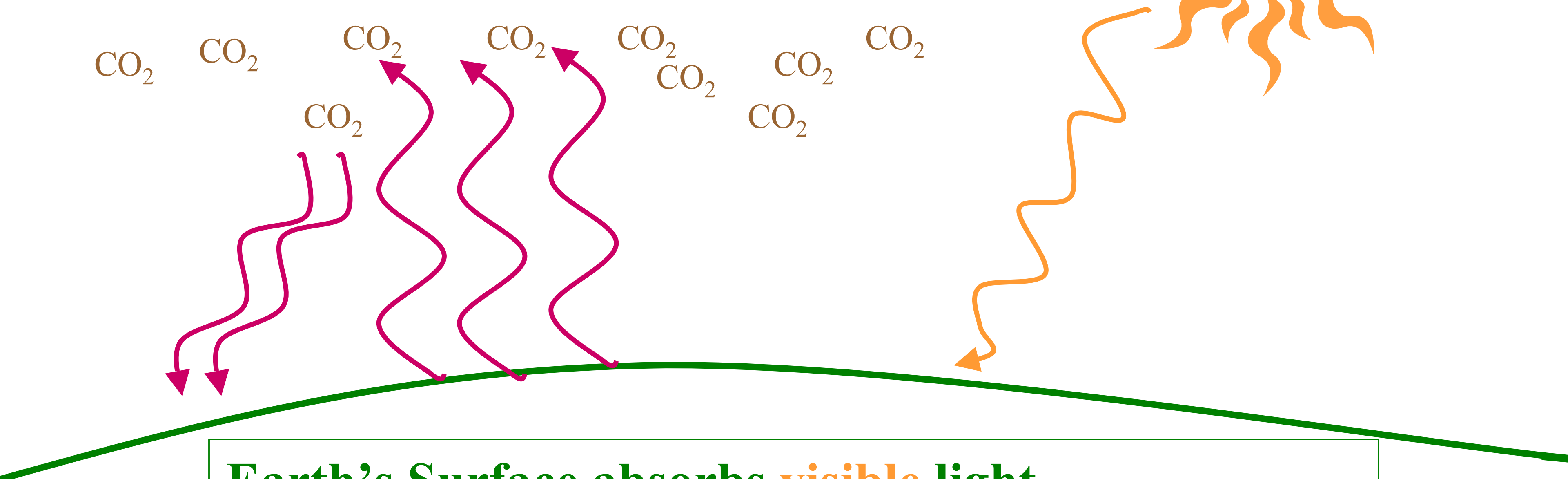
# The Trouble with Hydrocarbons

It's all those Carbon atoms.

$CO_2$ is a greenhouse gas.

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



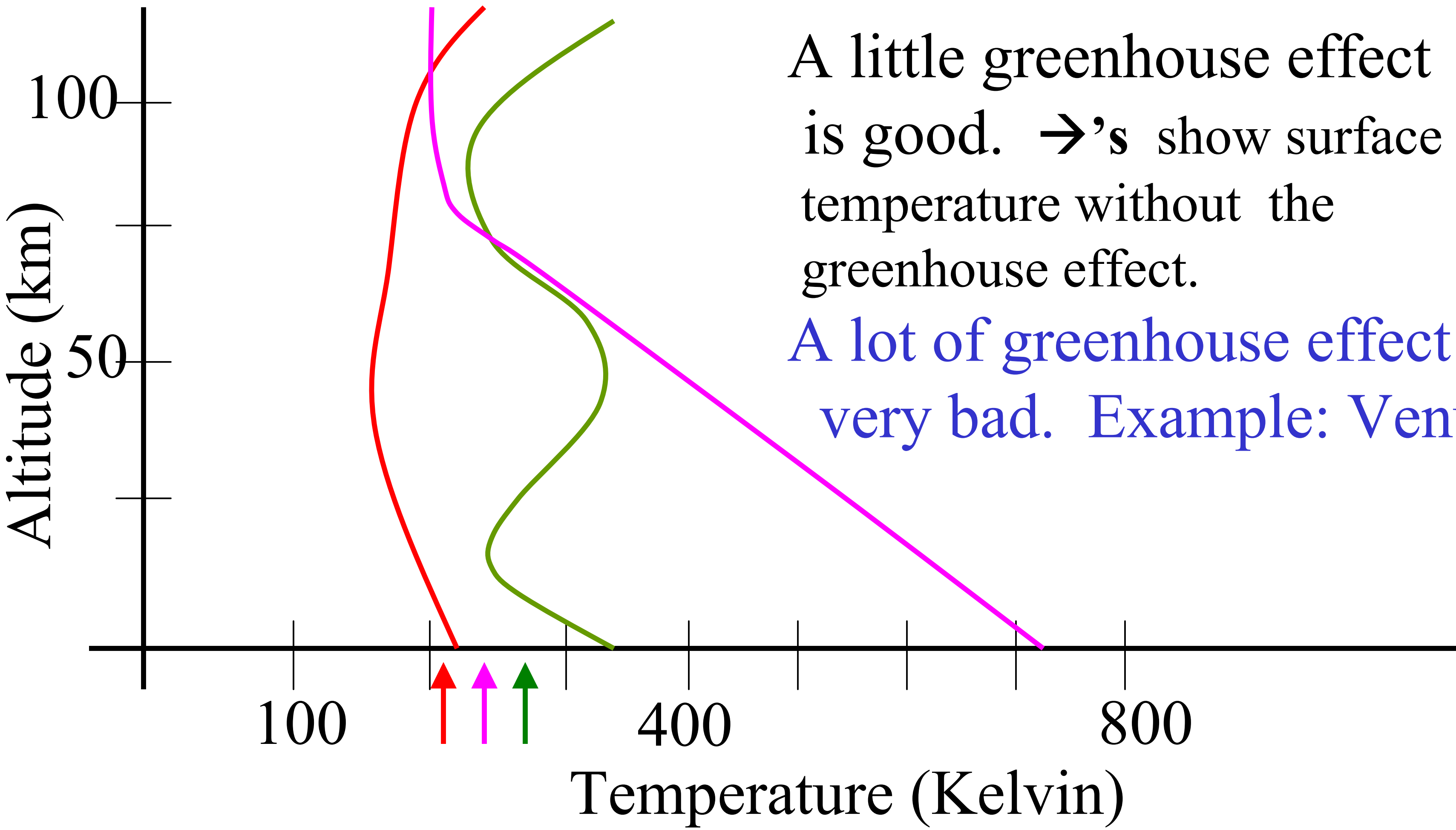



**Earth's Surface absorbs visible light.**

**emits thermal radiation in infrared.**

# Is Greenhouse Effect Bad?

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

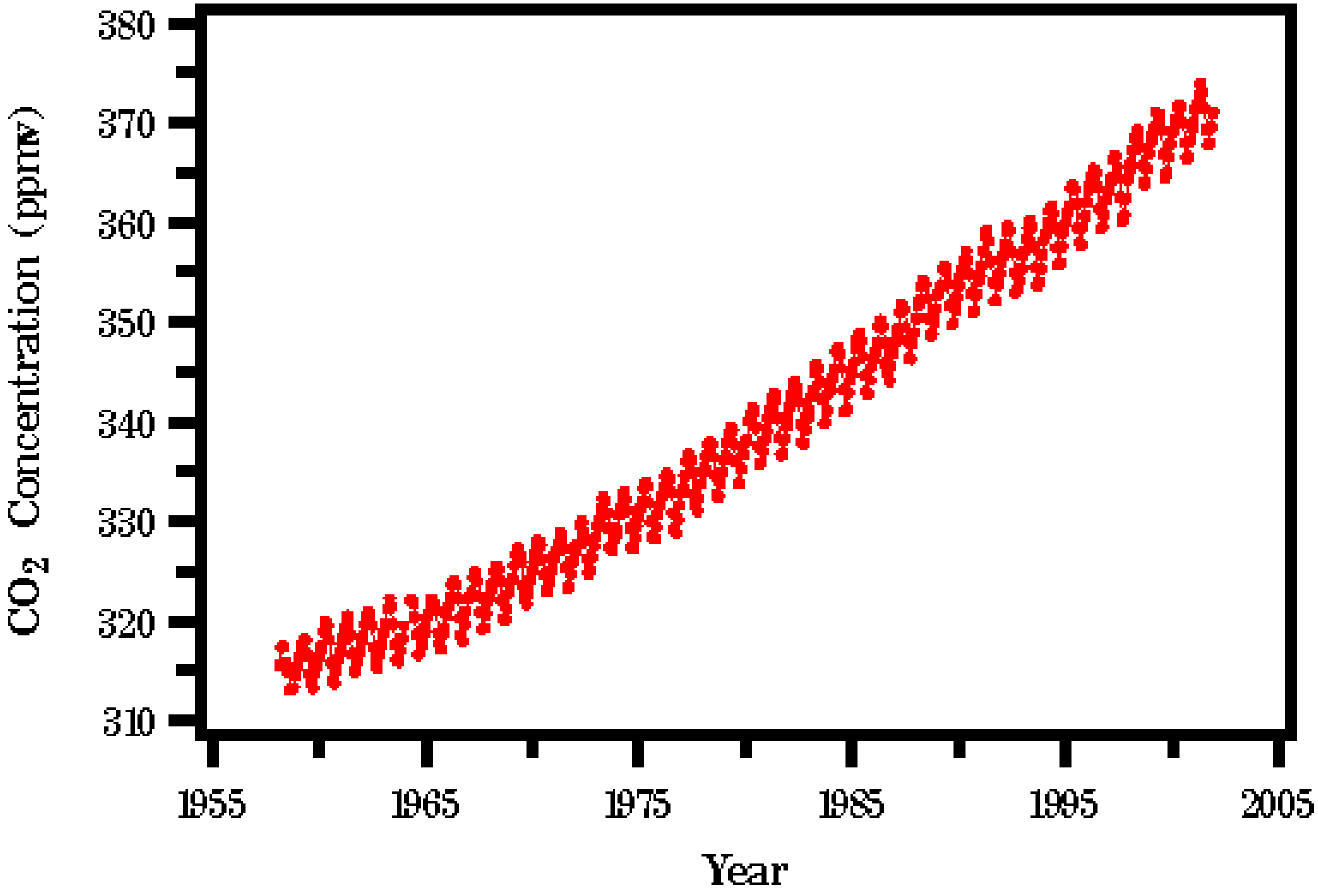



A little greenhouse effect is good. →'s show surface temperature without the greenhouse effect.

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

# Can We See the Increase in $CO_2$

Carbon dioxide concentration as measured at Mauna Loa, Hawaii. These measurements represent the globally mixed concentration.




Source: Dave Keeling and Tim Whorf (Scripps Institution of Oceanography)

# $CO_2$ Levels Historically

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

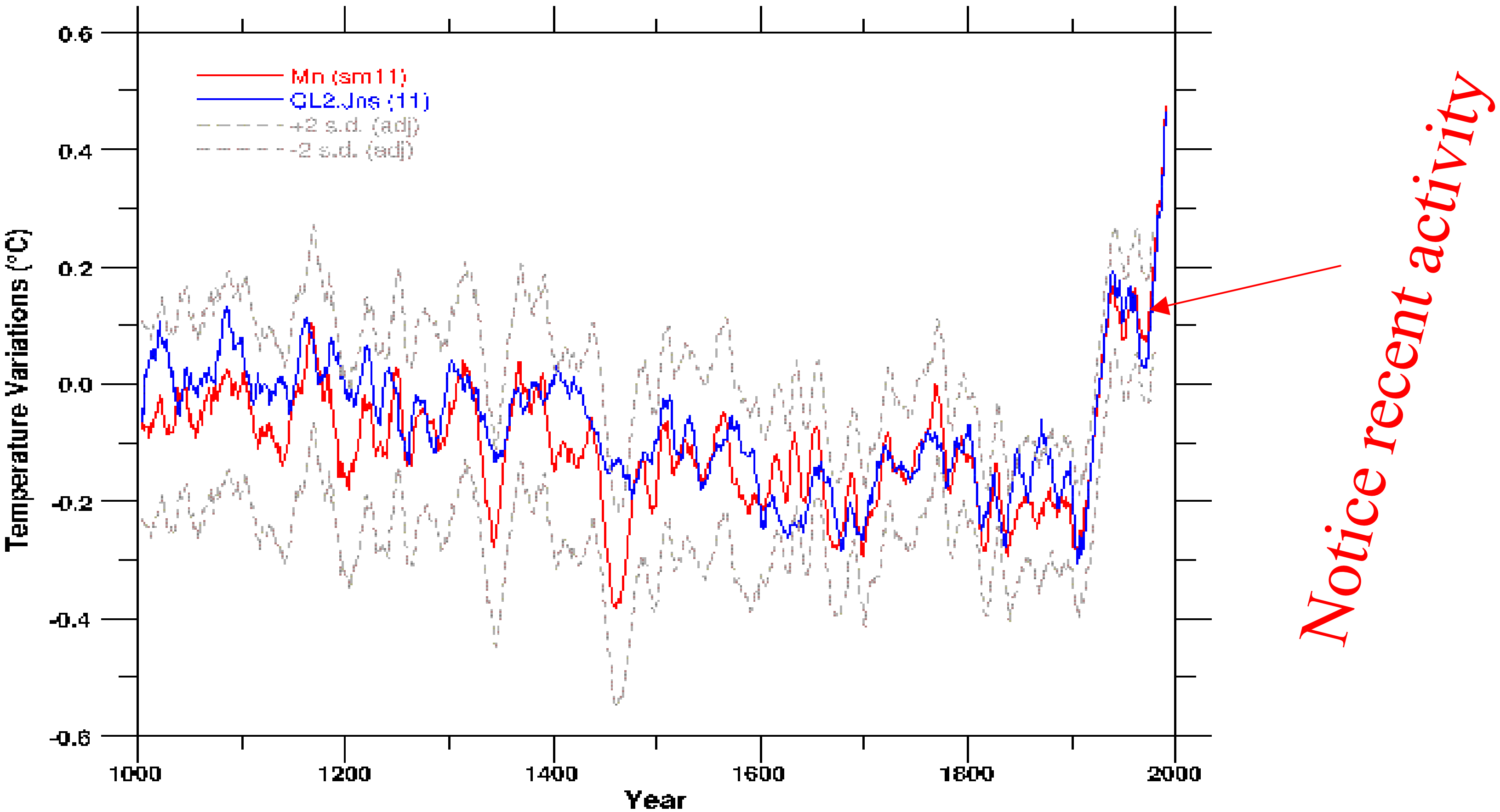
10 ppm in 50 yrs (pioneer effect)

20 ppm in 100 yrs (industrial rev.)

55 ppm in 40 yrs.

# Does it Affect Temperature?

**Problem**: We've only been looking for a few decades.
**Answer**: Paleoclimatology: ice cores, tree rings, etc.




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

# Global Warming Impact

**THE EPA SAYS:**

Rising global temperatures are expected to **raise sea level**, and **change precipitation** and other local climate conditions….**Deserts may expand** into existing rangelands….

**Most of the United States is expected to warm**, …. likely to be an overall trend toward increased precipitation and evaporation, **more intense rainstorms**, and drier soils.

Unfortunately, many of the potentially most important impacts depend upon **whether rainfall increases or decreases**, which can not be reliably projected for specific areas.

**http://yosemite.epa.gov/oar/globalwarming.nsf/content/impacts.html**

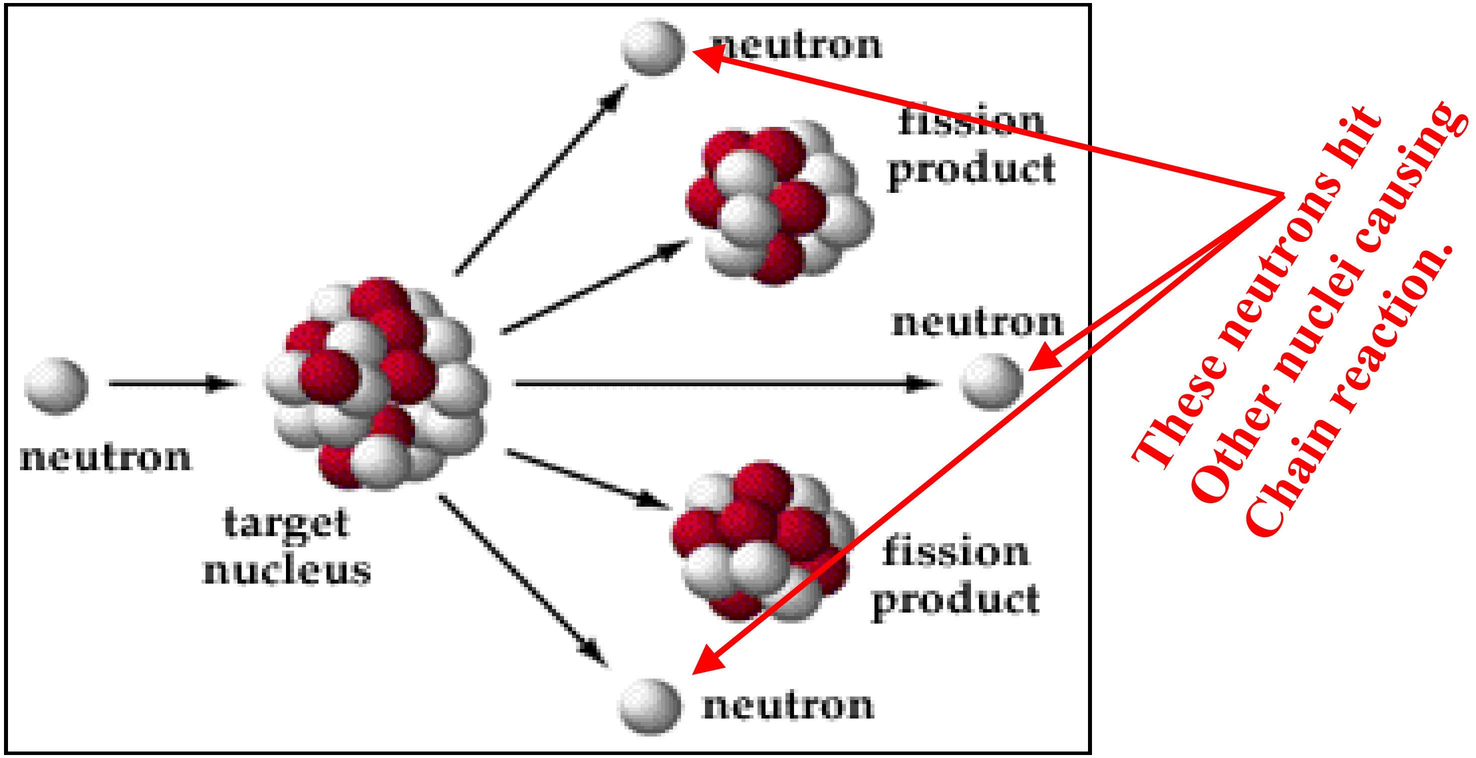
# Alternate Forms of Energy

- Fossil fuels will be hard to replace.

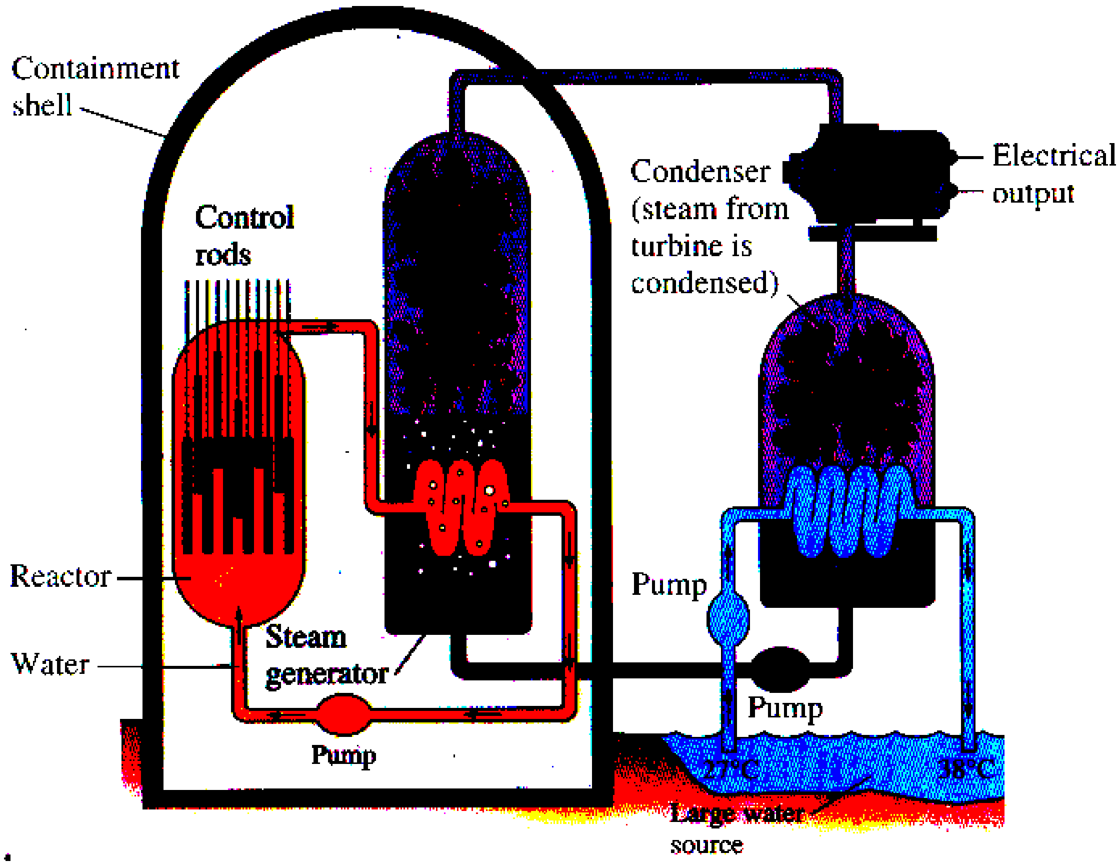
  Small volume ➔ large energy release.

- Atomic nuclei? Most are very stable.

  A few large ones can be induced to fission.



# Nuclear Power

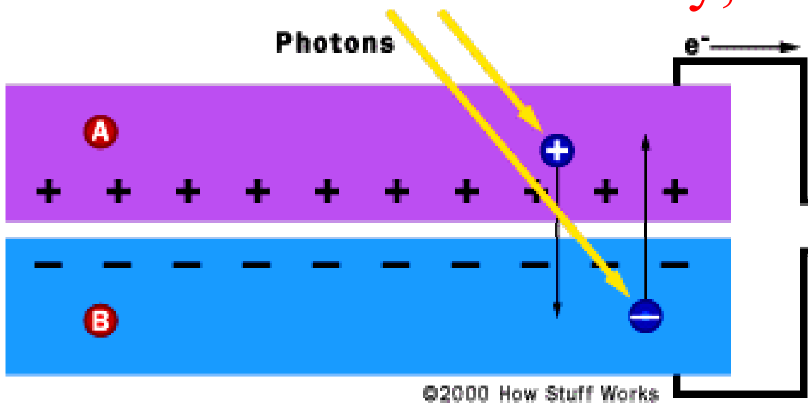



- Excellent energy output: $10^{14}$ J/kg, = 10,000 gallons of gasoline.
- Need good, solid containment vessels.
- Final products are still radioactive, (alpha, beta decay). Need long term disposal solution.

# Solar Power

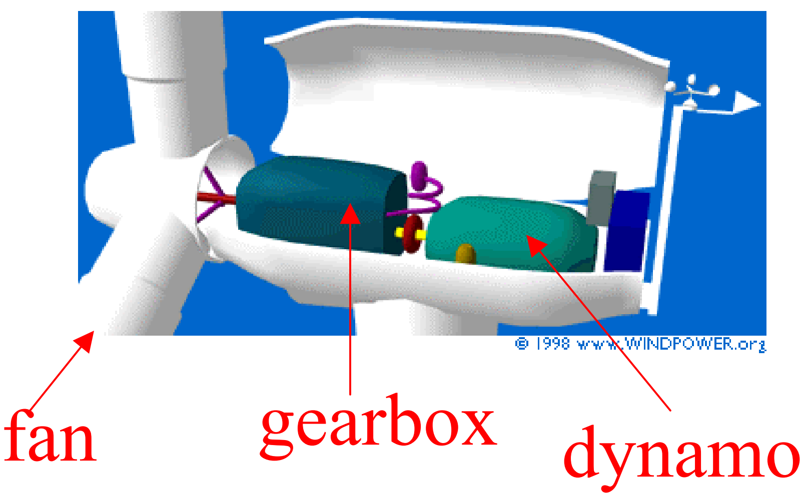
- Sun's main process: Turning H to He (fusion).
- Sun's output 4 x $10^{26}$ Watts (or Joules/sec).
- We see ~200 $W/m^2$ (in the US).

So at 15% efficiency, 1 $m^2$, 10 hrs of sunlight ➔ **1 MJoule/day**.




- **Problem:**
  Night, clouds.
- **Answer:**
  Storage.
  (batteries, fuel cells).

# Wind Power



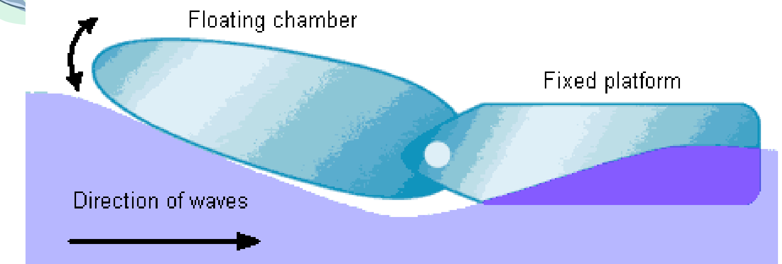

- Turbines can provide ~ ½ MWatt when running.
- Wind farms can have up to 200 turbines.

  → over 500 gallons of gas/day.

**BBC NEWS:** **The Irish Government has approved plans for the world's largest offshore electricity-generating wind farm, to be built on a sandbank in the Irish Sea south of Dublin.**
When completed, the 200 turbines will produce 10% of the country's electricity needs.

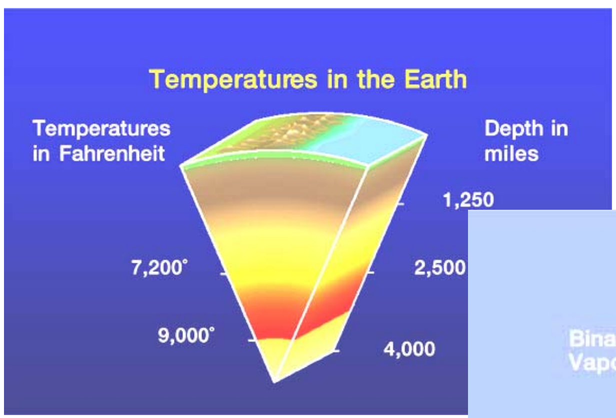
- **Problem:** calm.
- **Answer:** storage.

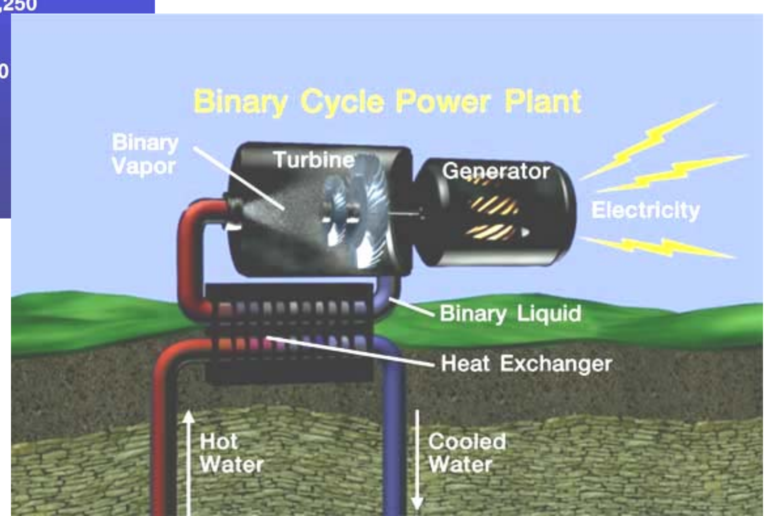
# Wave and Geothermal Power




Salter ducks

- Wave farms:  Convert wave motion to circular → drive turbines:   ~50 kWatts/m




- At tectonic plate boundaries, geothermal plants can tap the heat of the earth's interior

# Problem with Alternatives to Hydrocarbons

- Hydrocarbons: 1) store a lot of energy compactly.
  2) are cheap.

- Alternatives: 1) have large footprint.
  2) enough total energy,
  but at low power rates.
  3) low duty cycle.

# Fuel Cells

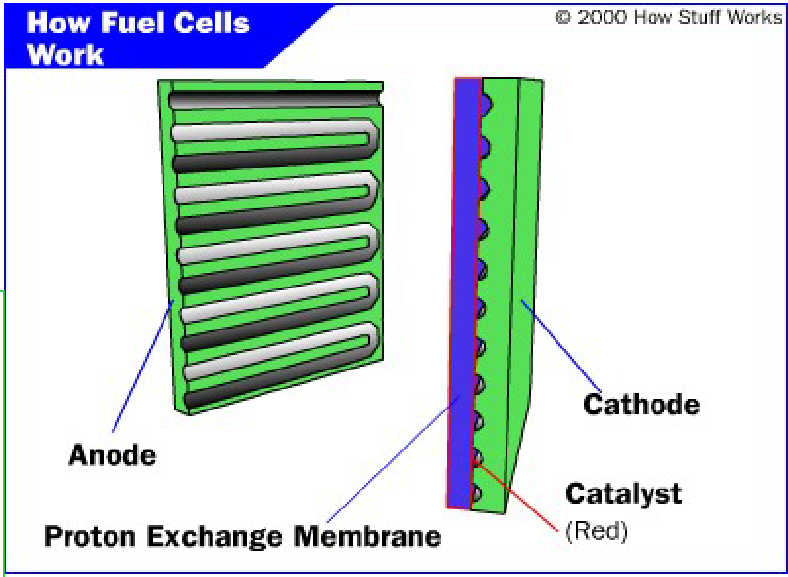
- A simple but effective chemical reaction:

  $2\,H_2 + O_2 \rightarrow 2\,H_2O$ + **Energy**

- Principal components:

  **Anode, Cathode, & Membrane.**

- **Can be run in reverse!**

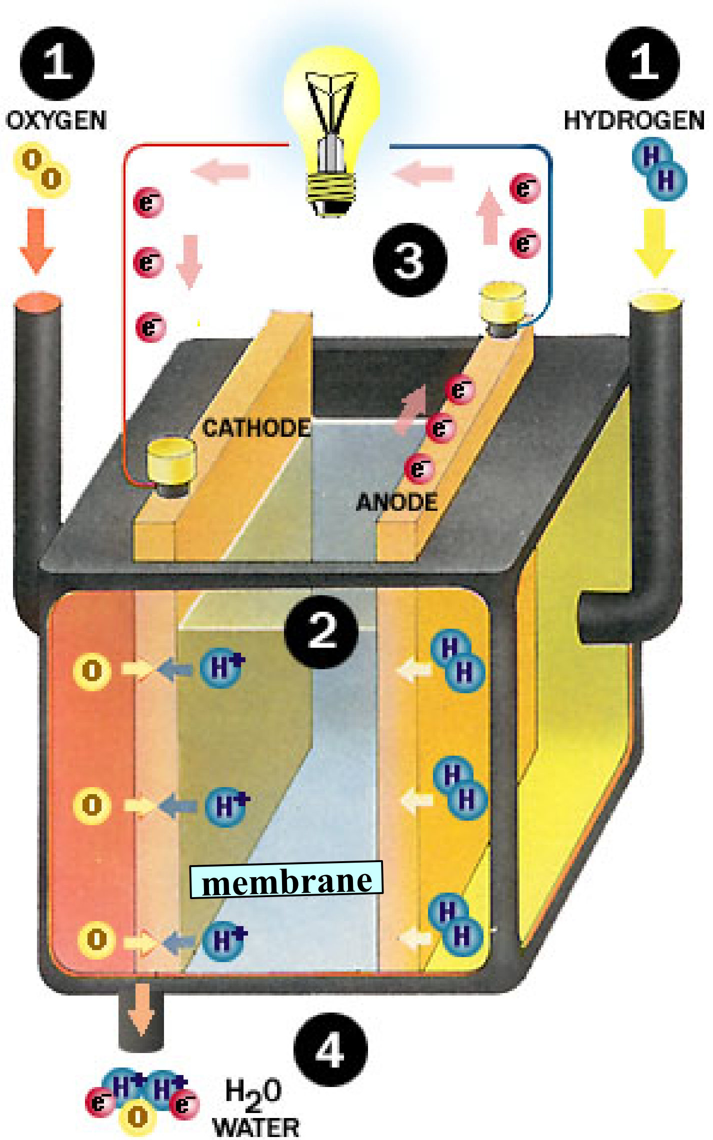



**Anode:** Strips the e- from the hydrogen
sends it through a wire,
provides power.

**Membrane:** Separates Anode and Cathode.
Takes the proton (hydrogen stripped of e-)
and pushes it through to the Cathode.

**Cathode:** Strips $O_2$ into two O (platinum *catalyst*).
Grabs two protons through the membrane
combine with one O to make one water
molecule

# Fuel Cell Detail

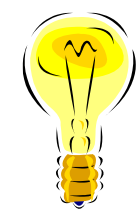



Office of Fossil Energy, U.S. Department of Energy

1. Hydrogen goes to Anode,
   (can use hydrocarbon fuel)
   Oxygen goes to Cathode.

2. Anode strips electrons from hydrogen, H+ ions enter the membrane

3. Since electrons cannot enter the membrane they go through the external circuit.



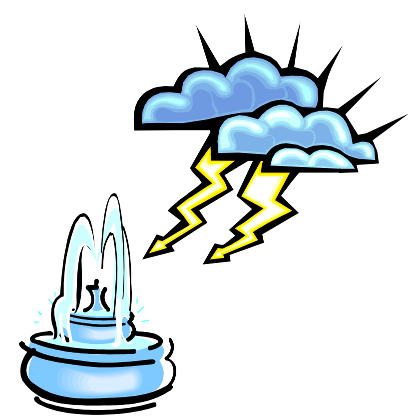
4. When electrons get back to the Cathode, they combine with H+ and O to form water.

# Fuel Cell Points

- Each individual cell provides ~0.7 V.
  → Use many in a stack.

- Where do you get Hydrogen?
  → can use hydrocarbons, wastewater digesters, landfills, biomass.

  → can also run the fuel cell *backward* (use solar, wind, etc. power to convert water to H and O).



# Possibilities with Fuel Cells

- Clean power (solar, wind, etc.) have
  - large footprint.
  - small duty cycle.

- Can use this power to run a fuel cell backwards!

  - Disassociate water into $H_2$ and $O_2$ gas.

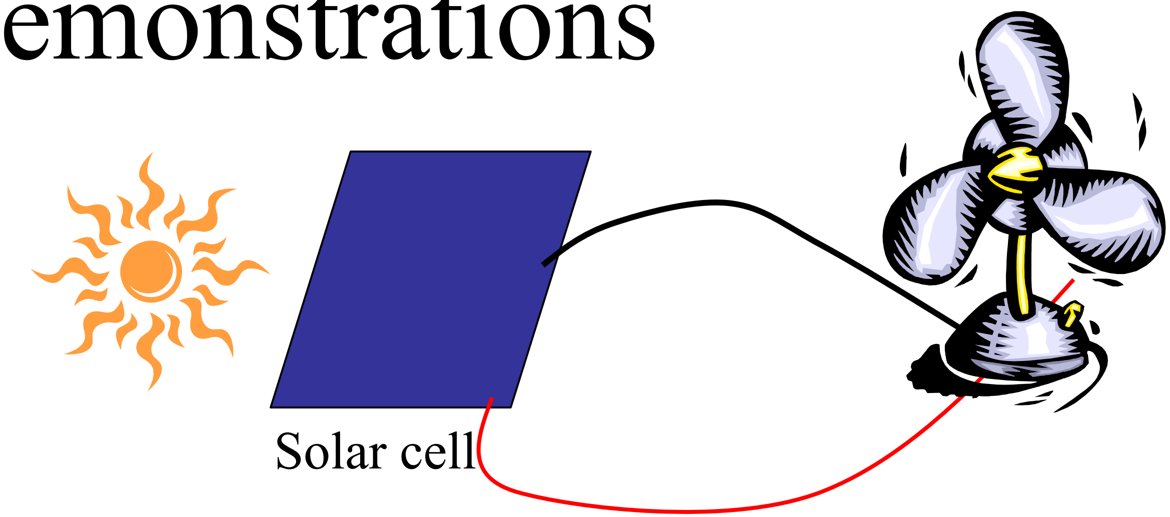
  - Store the gases until needed (*safely*).

  - Pump gases into fuel cell and make electricity.

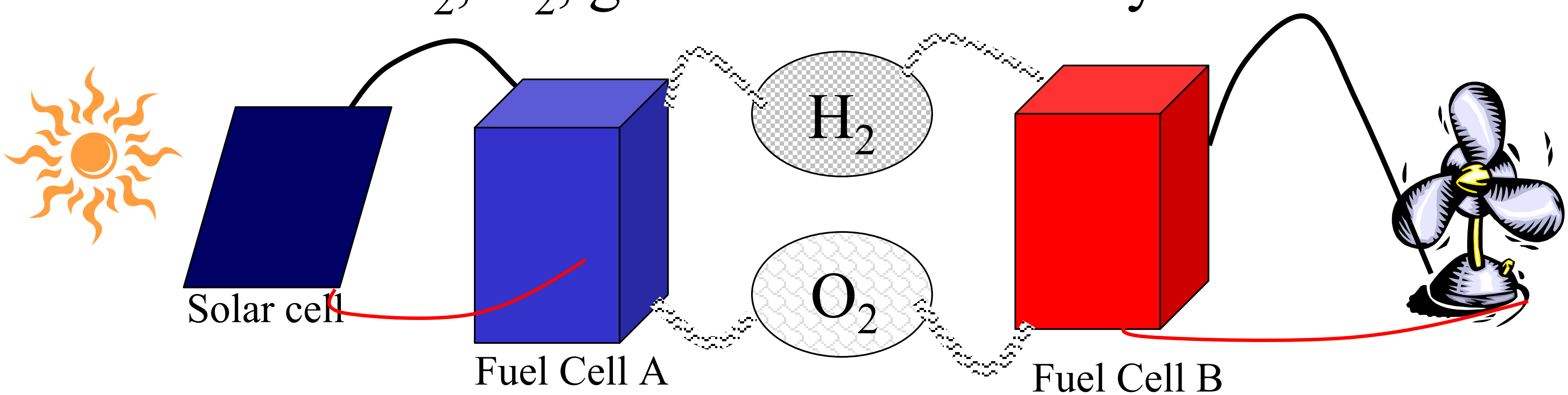
**Hindenburg burns over Lakehurst NJ May 6 1937**

# Demonstrations

1. Solar Cell:




2. Solar Cell output makes $H_2$, $O_2$, at **Fuel Cell A**, and the $H_2$, $O_2$, gases make electricity at **Fuel Cell B**.



# Conclusion

- Fossil fuels have been great. Have enabled mass of humanity to move beyond subsistence living.
  → But we really need to figure out how to live without them.

- Carbon loading of the atmosphere is reaching terrifying levels.
  → Scientific consensus on global warming.

- Clean alternatives like solar, wind, etc. have problems of rate, efficiency.
  → Hydrogen is abundant. Problems of storage, distribution, etc. can be solved.