## Lec #22: Discuss Climate Change & Nuclear

F.F. 1. Supply, Extraction, Use (Chap 7)

- coal, gas, oil; what are they; how formed? where to find?
- hidden costs

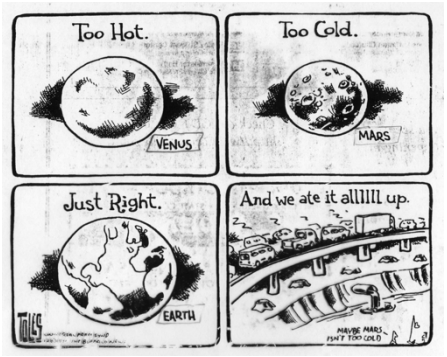
F.F. 2. Combustion of FF & The Byproducts (Chap 8)

- Combustion Process and Byproducts
- Pollutants
- Atmospheric Structure and Dynamics
- Pollution Control Technology and Techniques

F.F. 3. Global Environmental Impacts of FF Burning (Chap 9)

NEXT: Nuclear Power (Chaps 13-15)

## Goldilocks and the 3 Planets




see CofC's impact at www.cofc.edu/ghgas/

## Earth's Interactions & Cycles

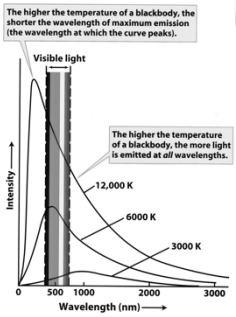
| | | |
|---|---|---|
| Interior | Biosphere | Atmosphere |
| Lithosphere | | Magnetosphere |
| Hydrosphere | | Heliosphere |

- Water Cycle
- Salt Cycle
- Carbon Cycle
- Climate Cycles
- Extinction Cycle?
- Impact Cycle?
- Geological Activity Cycle?

## The Greenhouse Effect

- ENERGY IN = ENERGY OUT
  - otherwise, Temperature changes
  - radiant energy only possible mechanism
- IN:
  - solar radiation (mostly visible)
- OUT:
  - reflected sunlight (visible)
  - thermal emission from surface and atmosphere (infrared, microwave)
  - Earth's interior cooling (infrared; 2700 times less)
- $H_2O$, $CO_2$, $CH_4$, etc. "absorb" infrared
  - block a fixed *fraction* from escaping
  - tiny changes in *composition* can change temperature

## "Blackbody Radiation": Electromagnetic Radiation emitted by a dense object in thermal equilibrium



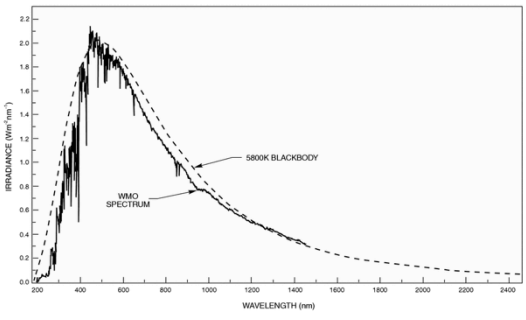

energy emitted at all wavelengths

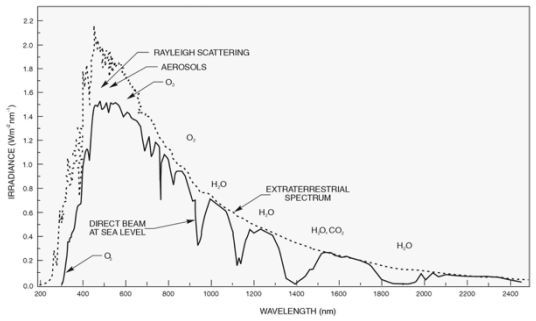
higher temperature emits more at all wavelengths

total energy emitted = (area) x $\sigma T^4$

peak wavelength proportional to temperature

[play with Spectrum Explorer]

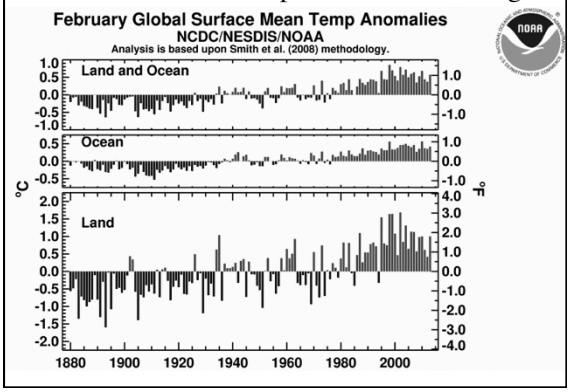





## Earth's Equilibrium Temperature

- Solar Luminosity $L_s = 4\pi R_s^2 \sigma T_s^4 = 10^{26}$ W
  - $T_s \sim 5800$ K
- Intensity of electromagnetic radiation decreases as square of distance
- "Flux" at Earth: $F = L_s/4\pi d^2 = 1356$ W/m$^2$
  - "albedo" = fraction not reflected ~ 0.5
- Radiant Energy IN = flux x albedo x $\pi R_E^2$
- Earth Luminosity $L_E = 4\pi R_E^2 \sigma T_E^4$
  - must equal energy IN
  - $T_E$ will adjust to make it so
- Without atmosphere, $T_E \sim 250$ K (brrr!!)
- With atmosphere, $T_E \sim 300$ K (mostly b/c $H_2O$)

## Earth's Surface Temperature is Increasing




## Why Is Any Of This Controversial?

- Rio, Kyoto, IPCC
  - very little disagreement on facts
- Scientists are their own worst enemies
  - focus on *uncertainties* and on *what we don't know*
- Non-scientists misinterpret this focus AS uncertainty and ignorance
- Hindsight does not necessarily lead to foresight. Understanding components in a complex system doesn't necessarily lead to *predictability*.
- Waiting is *not always* counterproductive (but it is in this case)

## What Can, Should, Must We Do?

- Nothing? Mother Earth will find a way to protect us from our own behavior. (will it?)
- Research? Wait 'til there's no uncertainty?
- Develop alternatives to replace fossil fuels?
  - eventually, we have to do this anyway
- Drive Economic Changes? (cost accounting)
- Political Action?
- "Manage" the Earth? (introduce counter-effects)

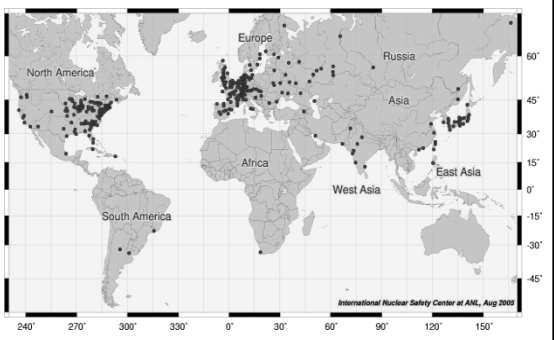
## Summary

- fossil fuels are our primary energy source
- burning them produces $CO_2$ & pollutants
- we breathe the pollutants
- $CO_2$ --> global warming
- fossil fuel supply is finite
- Pick your favorite reason; We've got to change our ways. (and soon!)
- How?
  - Thermal Energy w/out burning (solar, geothermal, nuclear)
  - Mechanical Energy directly (wind, water, tides)
  - Radiant Energy (direct, or convert to TE or ME)

## Nuclear Power Today

- Worldwide:
  - 33 countries, 443 power plants, 367 GW capacity
  - 38 under construction
  - 18 countries have higher reliance on nuclear than US
  - France gets over 80% of electricity from nuclear
- In US:
  - 104 power plants; 99 GW total capacity
  - 20% of US electrical generation capacity
- South Carolina:
  - 7 nuclear plants
  - Savannah River Site

**World Nuclear Energy Facilities**

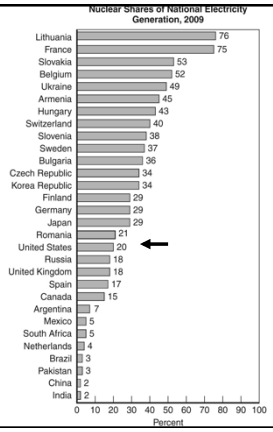



**Over 440 commercial nuclear power reactors operating in 30 countries**

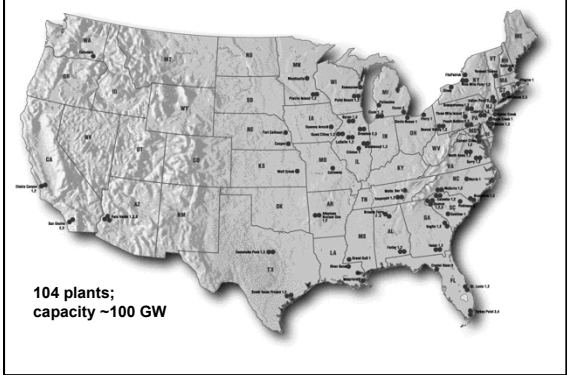
Table 14.1 WORLD NUCLEAR POWER 2004

| Country | In Operation: Number of Units | In Operation: Total Net MWe | Under Construction: Number of Units |
|---|---|---|---|
| Argentina | 2 | 935 | 1 |
| Armenia | 1 | 376 | |
| Belgium | 7 | 5,527 | |
| Brazil | 2 | 1,900 | 1 |
| Bulgaria | 4 | 2,722 | |
| Canada | 22 | 15,200 | |
| China | 9 | 6,587 | 4 |
| Czech Republic | 4 | 3,548 | 2 |
| Finland | 4 | 2,756 | |
| France | 59 | 63,368 | 1 |
| Germany | 18 | 20,643 | |
| Hungary | 4 | 1,755 | |
| India | 14 | 2,550 | 8 |
| Iran | | | 2 |
| Japan | 53 | 45,220 | 4 |
| Korea, North | | | 2 |
| Korea, South | 18 | 14,900 | 6 |
| Lithuania | 2 | 2,370 | |
| Mexico | 2 | 1,310 | |
| Netherlands | 1 | 450 | |
| Pakistan | 2 | 425 | 1 |
| Romania | 1 | 630 | |
| Russia | 30 | 20,793 | 3 |
| Slovakia | 6 | 2,442 | 1 |
| Slovenia | 1 | 660 | |
| South Africa | 2 | 1,842 | |
| Spain | 9 | 7,588 | |
| Sweden | 11 | 9,451 | |
| Switzerland | 5 | 3,220 | |
| Taiwan | 6 | 5,144 | |
| Ukraine | 13 | 11,207 | 2 |
| United Kingdom | 27 | 12,052 | |
| United States | 104 | 98,975 | |
| **World Total** | **443** | **366,546** | **38** |

Source: International Atomic Energy Agency



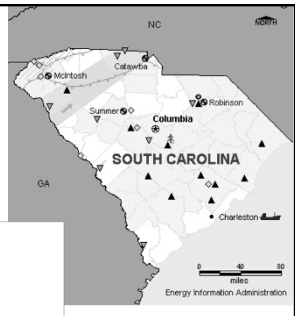

**US Nuclear Energy Facilities**

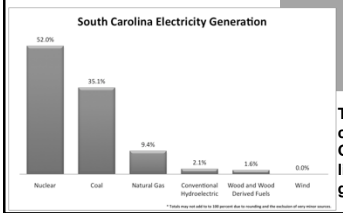


**104 plants; capacity ~100 GW**

**Nuclear Energy Facilities in South Carolina**

**South Carolina's four nuclear power plants typically supply about one-half of the State's electricity generation**

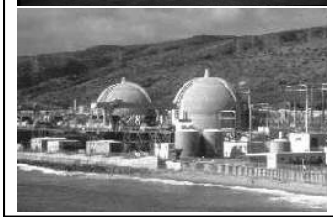



**Two new nuclear reactors could come online in South Carolina by 2016, if licensing and construction go as planned.**

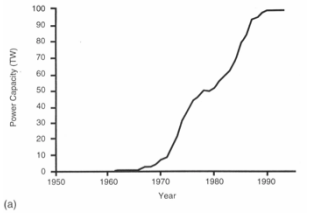
Oconee

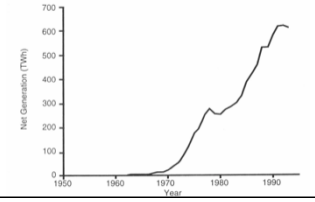
(near Clemson, SC)



San Onofre

(near Camp Pendelton)




TRENDS:

rapid buildup of nuclear power plants in 70's and 80's

no new plants ordered after 1979 (until very recently)

few under construction

many getting old

capacity has leveled off

Three Mile Island (near Harrisburg, PA)

## Nuclear v. Fossil Fuels

- No combustion byproducts!
  - no air pollution
  - no greenhouse gases
- Tiny solid waste stream!
  - coal: 100 train cars each day in; up to 10 cars of waste out
  - nuclear: 1 train car enough fuel for 3 years (in and out)
- Nuclear is proven technology
  - large scale electrical power plants
  - smaller scale for ship propulsion
- Fuel can be **reprocessed** until all fissile material is used
- Some reactors can "**breed**" more fuel than they use!

Average Operating Expense of Electricity Generation for Major U.S. Investor-Owned Electric Utilities, 2002-2006
In Cents Per Kilowatt Hour

| Year | Nuclear | Fossil Steam | Hydroelectric | Gas Turbine |
|---|---|---|---|---|
| 2002 | 1.82 | 2.13 | 0.87 | 3.69 |
| 2003 | 1.87 | 2.26 | 0.75 | 4.89 |
| 2004 | 1.83 | 2.39 | 0.87 | 5.01 |
| 2005 | 1.82 | 2.77 | 0.89 | 5.89 |
| 2006 | 1.95 | 2.96 | 0.85 | 5.78 |

Note: Excludes capital costs, a major expense for nuclear electricity.
*Source: U.S. Energy Information Administration.*

**PROS**
**•Emit relatively low amounts of carbon dioxide ($CO_2$).**
**•Large amount of electrical energy can be generated in one single plant.**

**CONS**
**•Pollution during mining and processing. Radioactive waste.**
**•Safety Issues. Although considered safe, accidents can still happen.**
**•Uranium is scarce, its supply is estimated to last only for about 50 years**
**•Nuclear Terrorism**

## Some Disadvantages

- Still relies on mining and "consuming" natural resources, but the impact is far less than coal and the geopolitics is not as unfavorable as petroleum.
- Uranium ore is a finite resource; maybe only ~50 years!
  - but it can go a long way with reprocessing a/o breeding
  - there might be more; we never really got serious
- Initial processing of fuel is very expensive and energy intensive (but infrastructure is already developed)
- Some radioactive waste release to environment is inevitable (though it's less than that from coal burning)
- High-level radioactive waste must be dealt with
  - spent fuel
  - power plant itself