


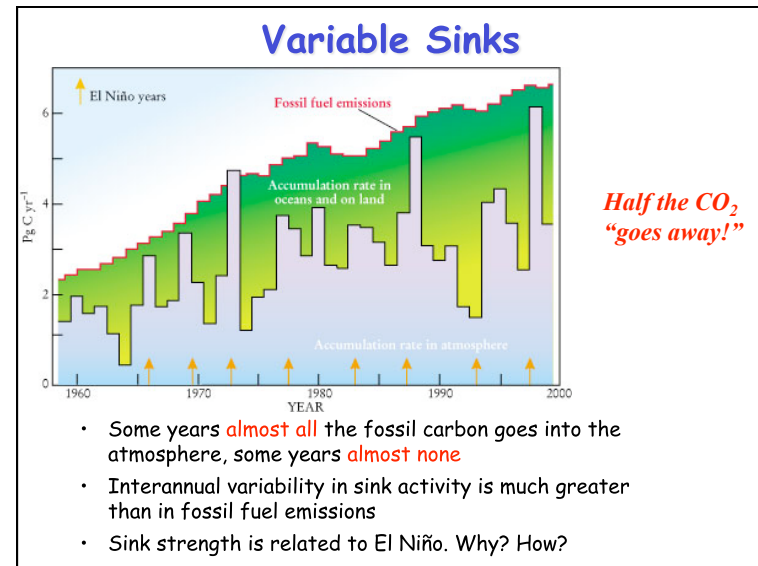
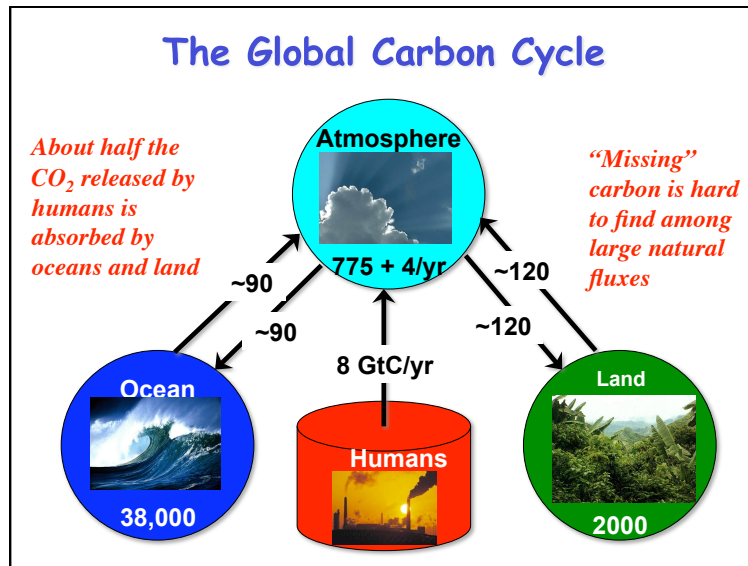
Mitigating Climate Change

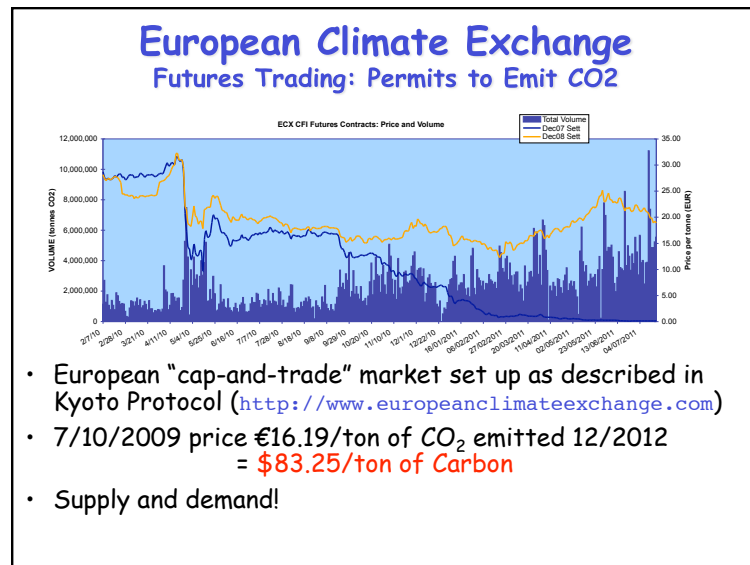
Sources and sinks of atmospheric CO₂
 Emissions trading
 Historical and projected CO₂ emissions
 Climate wedges
 Alternative energy



“Scientists are necessary, but not sufficient to solve the climate problem”

Dr. Ralph Cicerone,
 President of the National Academy of Science, November 2007





Present Value of Carbon Sinks

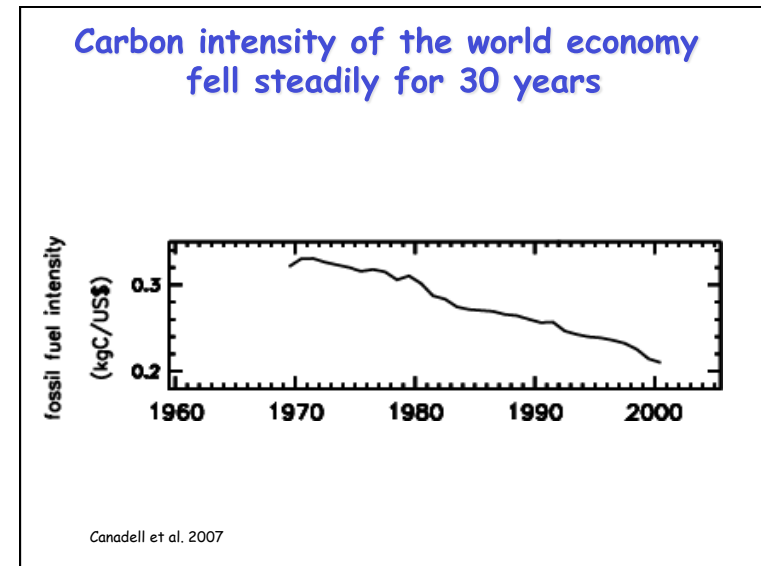
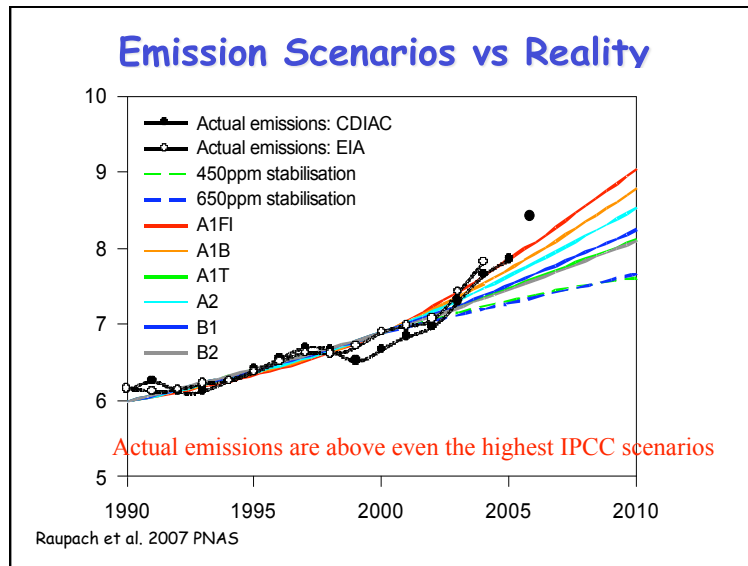
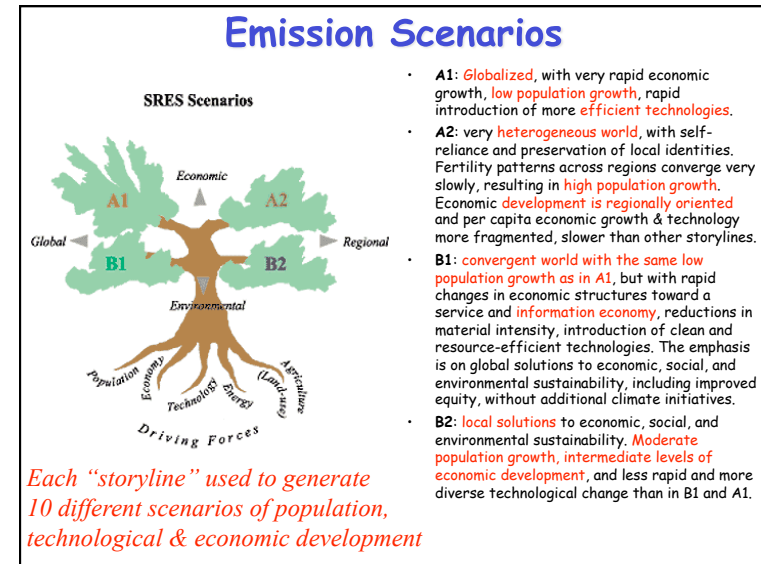
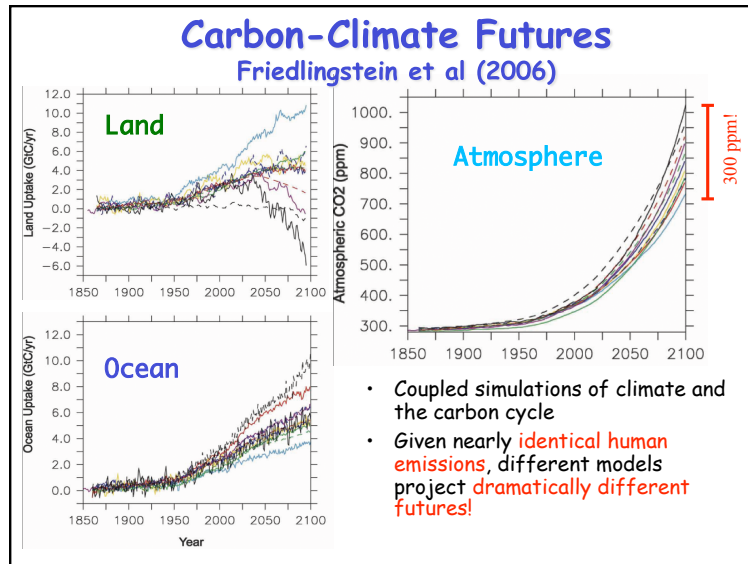
- Terrestrial and marine exchanges currently **remove more than 4 GtC per year from the atmosphere**
- This free service provided by the planet constitutes an **effective 50% emissions reduction, worth about \$325 Billion per year** at today's price on the ECX!
- Carbon cycle science is currently **unable to quantitatively account for**
 - The **locations** at which these sinks operate
 - The **mechanisms** involved
 - How long the carbon will **remain stored**
 - How long the sinks will **continue to operate**
 - Whether there is **anything we can do** to make them work better or for a longer time

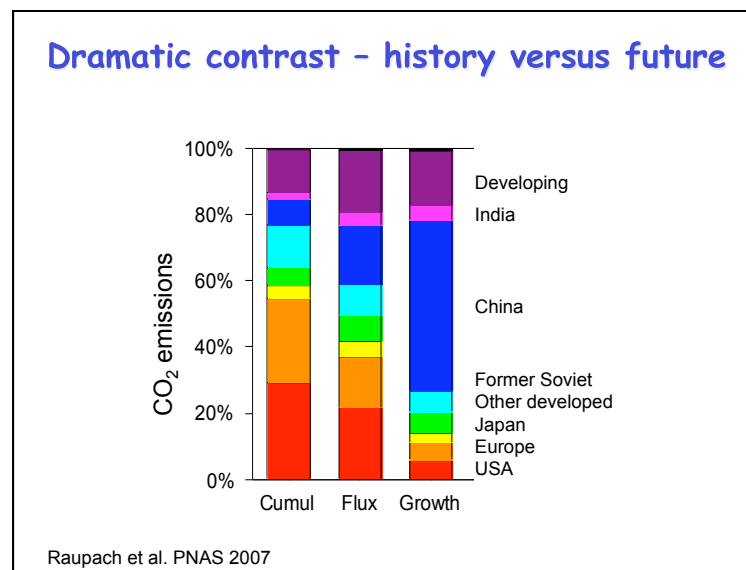
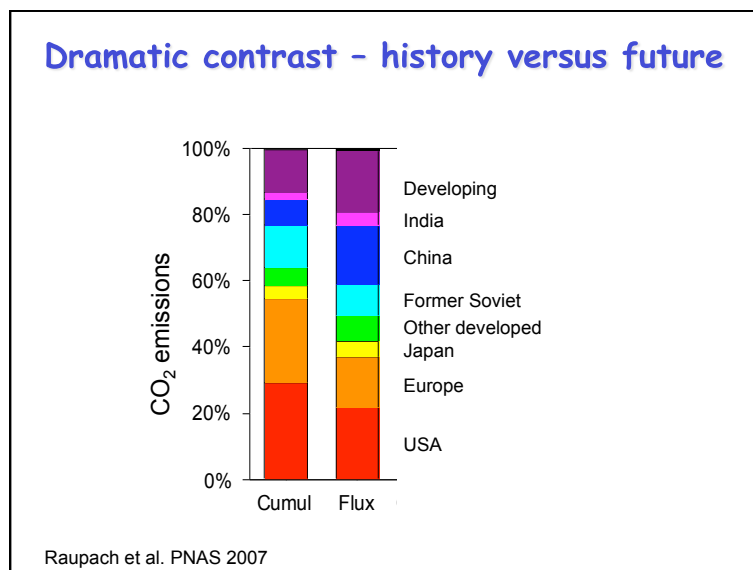
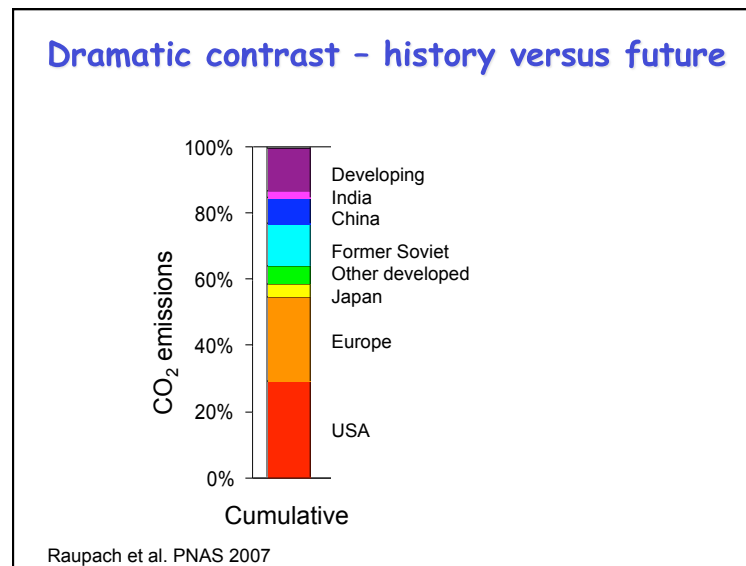
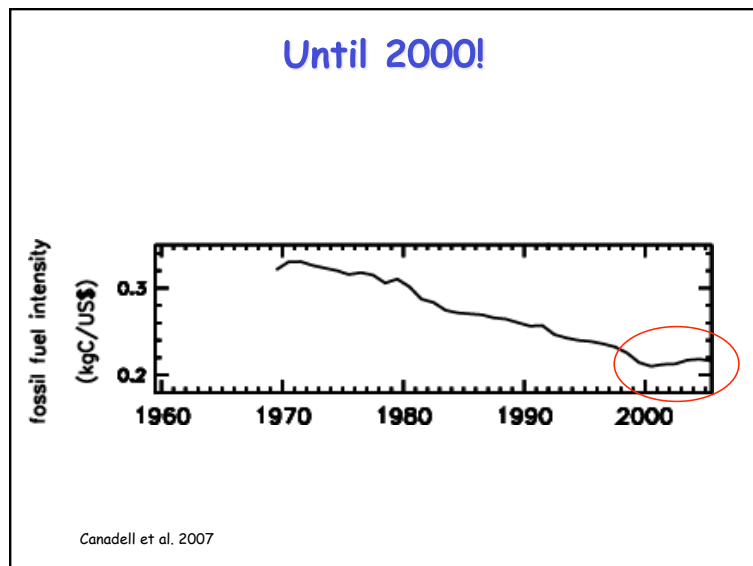
Where Has All the Carbon Gone?

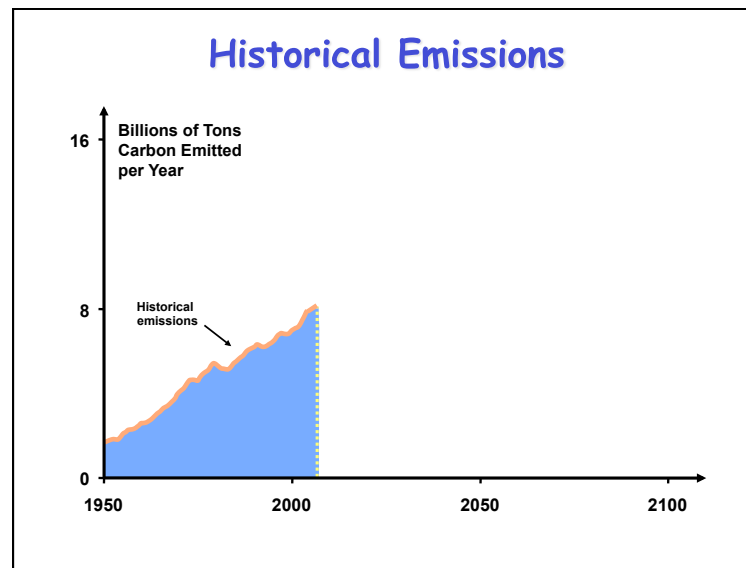
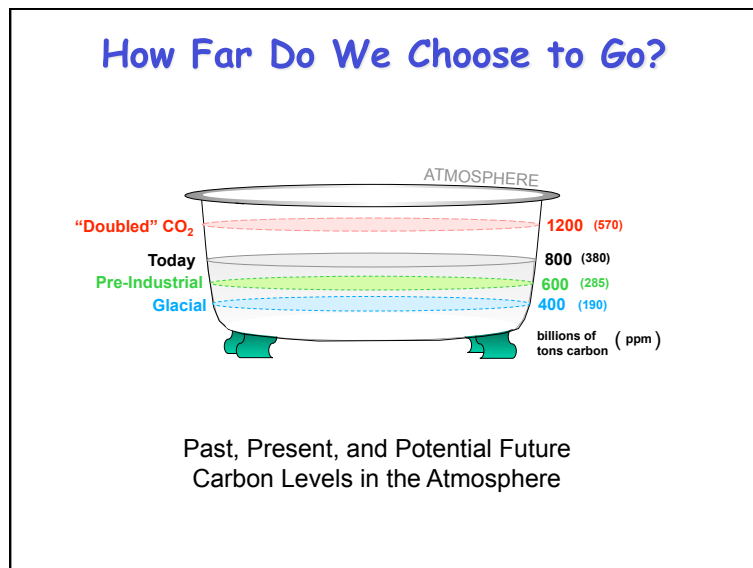
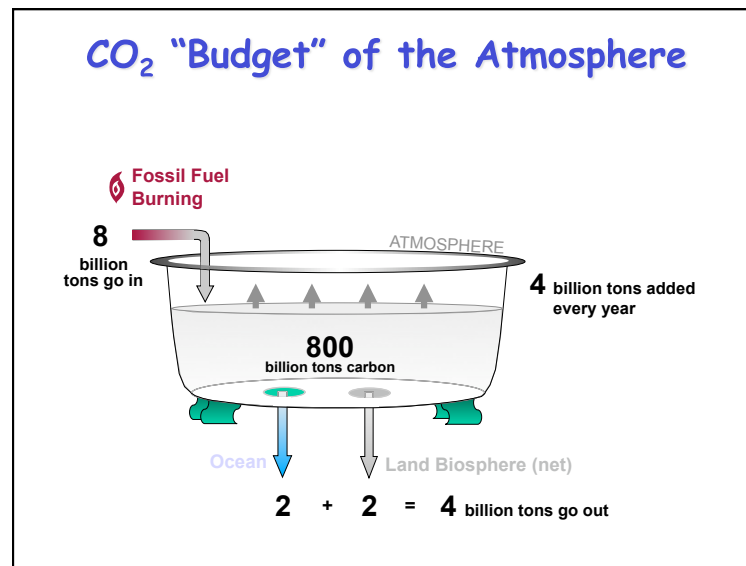
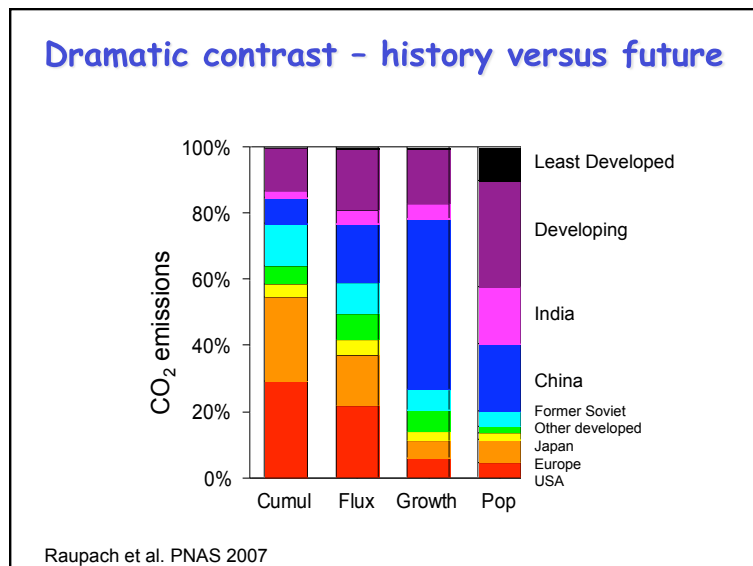
- Into the **oceans**
 - **Solubility pump** (CO₂ very soluble in cold water, but rates are limited by slow physical mixing)
 - **Biological pump** (slow “rain” of organic debris)
- Into the **land**
 - **CO₂ Fertilization** (plants eat CO₂ ... is more better?)
 - **Nutrient fertilization** (N-deposition and fertilizers)
 - **Land-use change** (forest regrowth, fire suppression, woody encroachment ... but what about Wal-Mart's?)
 - Response to **changing climate** (e.g., Boreal warming)

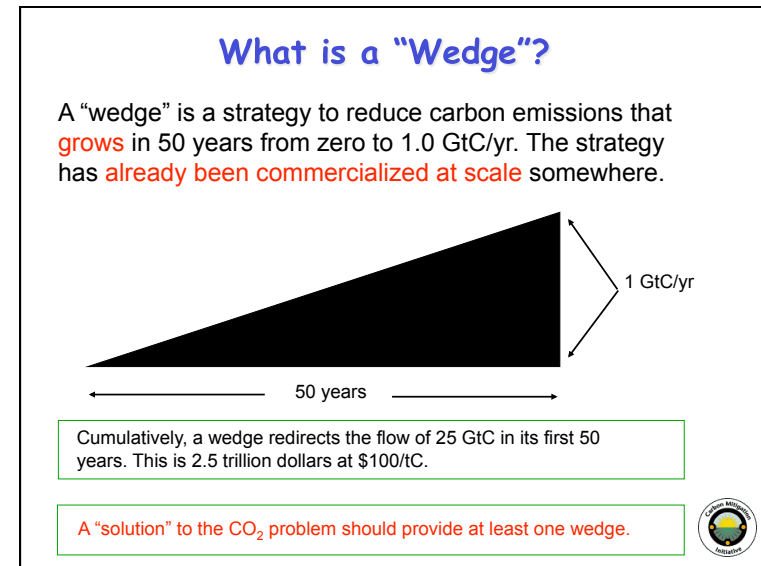
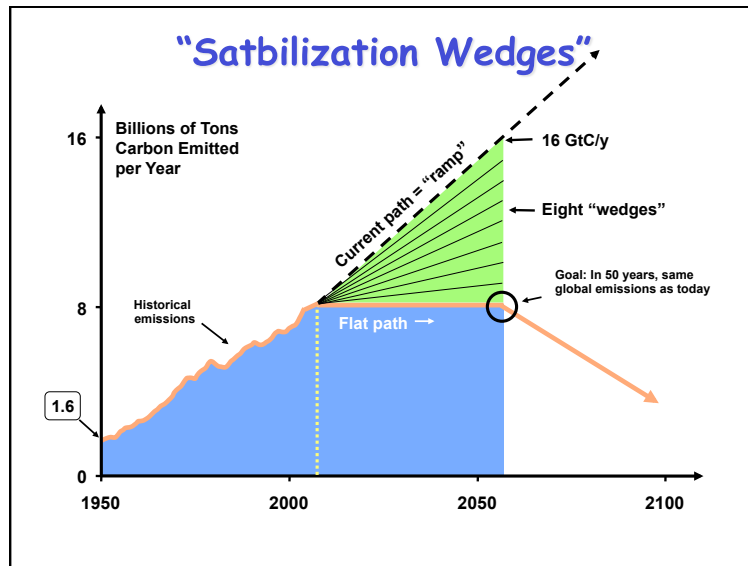
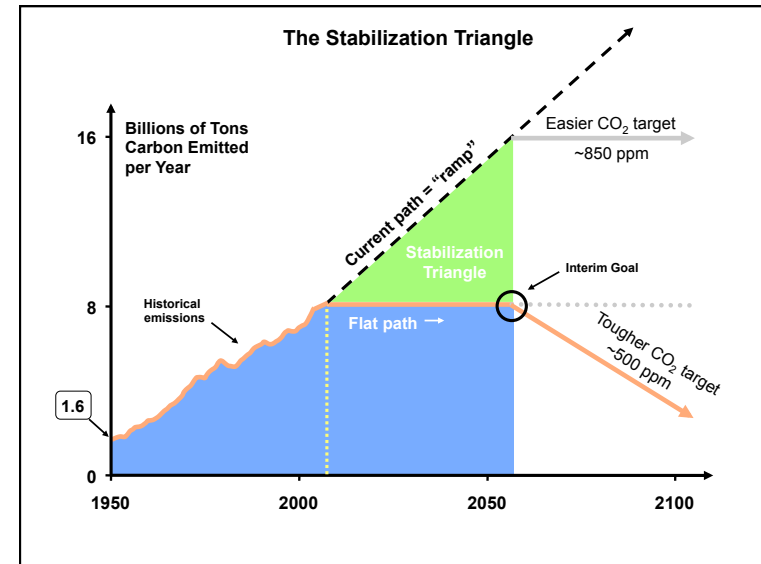
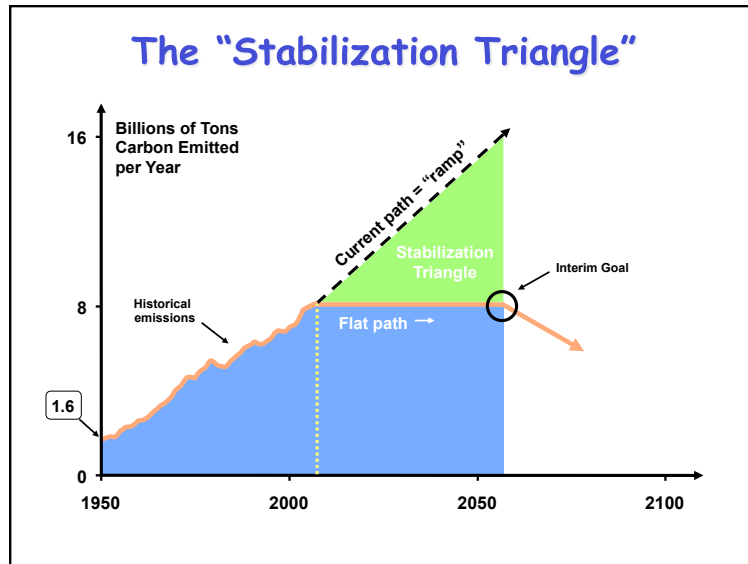
Coupled Carbon-Climate Modeling

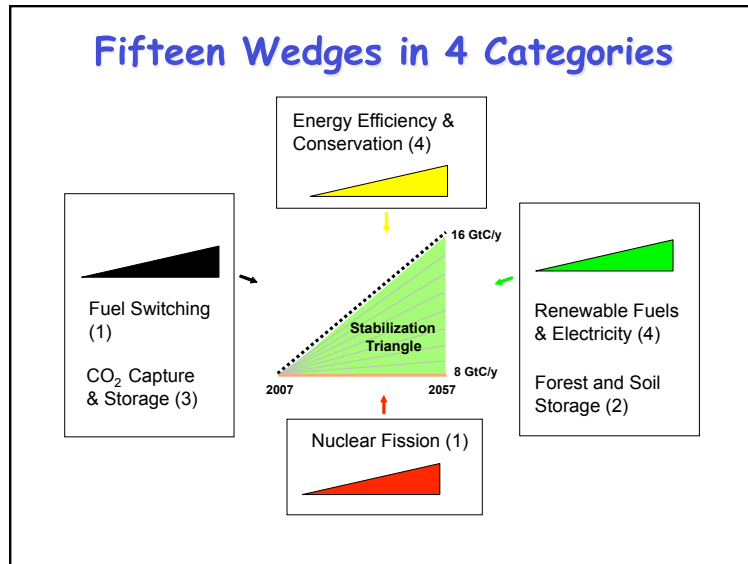
- “Earth System” Climate Models
 - **Atmospheric GCM**
 - **Ocean GCM** with biology and chemistry
 - **Land** biophysics, biogeochemistry, biogeography
- Prescribe fossil fuel **emissions, rather than CO₂ concentration** as usually done
- Integrate model from 1850-2100, **predicting both CO₂ and climate** as they evolve
- Oceans, plants, and soils exchange CO₂ with model atmosphere
- **Climate affects ocean circulation and terrestrial biology, thus feeds back to carbon cycle**











Efficiency

Photos courtesy of Ford Motor Co., DOE, EPA

Double the fuel efficiency of the world's cars **or** halve miles traveled

There are about 600 million cars today, with 2 billion projected for 2055

Produce today's electric capacity with double today's efficiency

Average coal plant efficiency is 32% today

Use best efficiency practices in all residential and commercial buildings

Replacing all the world's incandescent bulbs with CFL's would provide 1/4 of one wedge

E, T, H / \$

Sector s affected:
E = Electricity, T = Transport, H = Heat

Cost based on scale of \$ to \$\$\$

Fuel Switching

Substitute 1400 natural gas electric plants for an equal number of coal-fired facilities

Photo by J.C. Willett (U.S. Geological Survey).

A wedge requires an amount of natural gas equal to that used for all purposes today

E, H / \$

Carbon Capture & Storage

Implement CCS at

- 800 GW coal electric plants **or**
- 1600 GW natural gas electric plants **or**
- 180 coal synfuels plants **or**
- 10 times today's capacity of hydrogen plants

Graphic courtesy of Alberta Geological Survey

There are currently three storage projects that each inject 1 million tons of CO₂ per year – by 2055 need 3500.

E, T, H / \$\$

Nuclear Electricity

Triple the world's nuclear electricity capacity by 2055



Graphic courtesy of NRC

The rate of installation required for a wedge from electricity is equal to the global rate of nuclear expansion from 1975-1990.

E/ \$\$



Wind Electricity



Photo courtesy of DOE

Install 1 million 2 MW windmills to replace coal-based electricity,

OR

Use 2 million windmills to produce hydrogen fuel

A wedge worth of wind electricity will require increasing current capacity by a factor of 30

E, T, H / \$-\$\$



Solar Electricity

Install 20,000 square kilometers for dedicated use by 2054



Photos courtesy of DOE Photovoltaics Program

A wedge of solar electricity would mean increasing current capacity 700 times

E / \$\$\$



Imagine it's 1800, and you're in charge ...

Somebody presents you with a grand idea for transforming the world economy:

- ✓ Dig 8 billion tons of carbon out of the ground every year
- ✓ Build a system of pipelines, supertankers, railroads, highways, and trucks to deliver it to every street corner on the planet
- ✓ Build millions of cars every year, and millions of miles of roads to drive them on
- ✓ Generate and pipe enough electricity to every house to power lights & stereos & plasma TVs

... *"and here's the itemized bill ..."*

Thinking about Costs

- Our global society built that very system
- We didn't go broke building it ...
- We got rich beyond the avarice of kings!
- Now we have to do it again!
- How?

Putting a Price on Carbon Emissions

- A **new industrial revolution** won't happen because people want to "do the right thing"
- The government **can't just pass a law** and create a new global energy economy, any more than they could 200 years ago
- If low-carbon-footprint goods and services cost less than "dirtier" ones, **people will buy them**
- The role of policy is to provide incentives, to **put a price on carbon!**

A Policy Spectrum

"command and control"

"market capitalism"

direct
subsidy

"cap and trade"

"tax and rebate"

Conclusions

- Rising levels of CO_2 will cause **significant climate change** in the 21st century and far beyond
- The only way to mitigate these changes is to **stop burning coal, oil, and gas**
- This can **feasibly be done using today's technology**, but requires tremendous will
- Solving the climate problem will lead to a **new industrial revolution**, and huge wealth creation
- Dealing with this problem will be a **major theme of history** for centuries to come



We choose to do these things not because they are easy, but because they're hard!

President John F. Kennedy
Rice University
September 12, 1962