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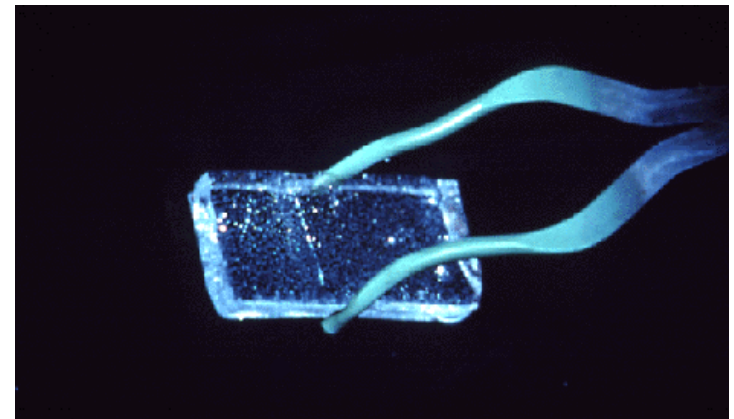
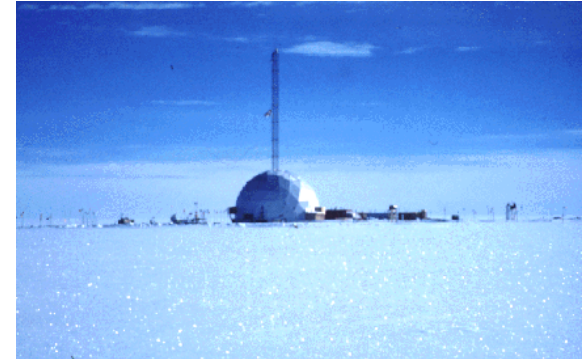
# **Global Warming: The Problem and Potential Solutions**

**Charles Christopher  
BP**

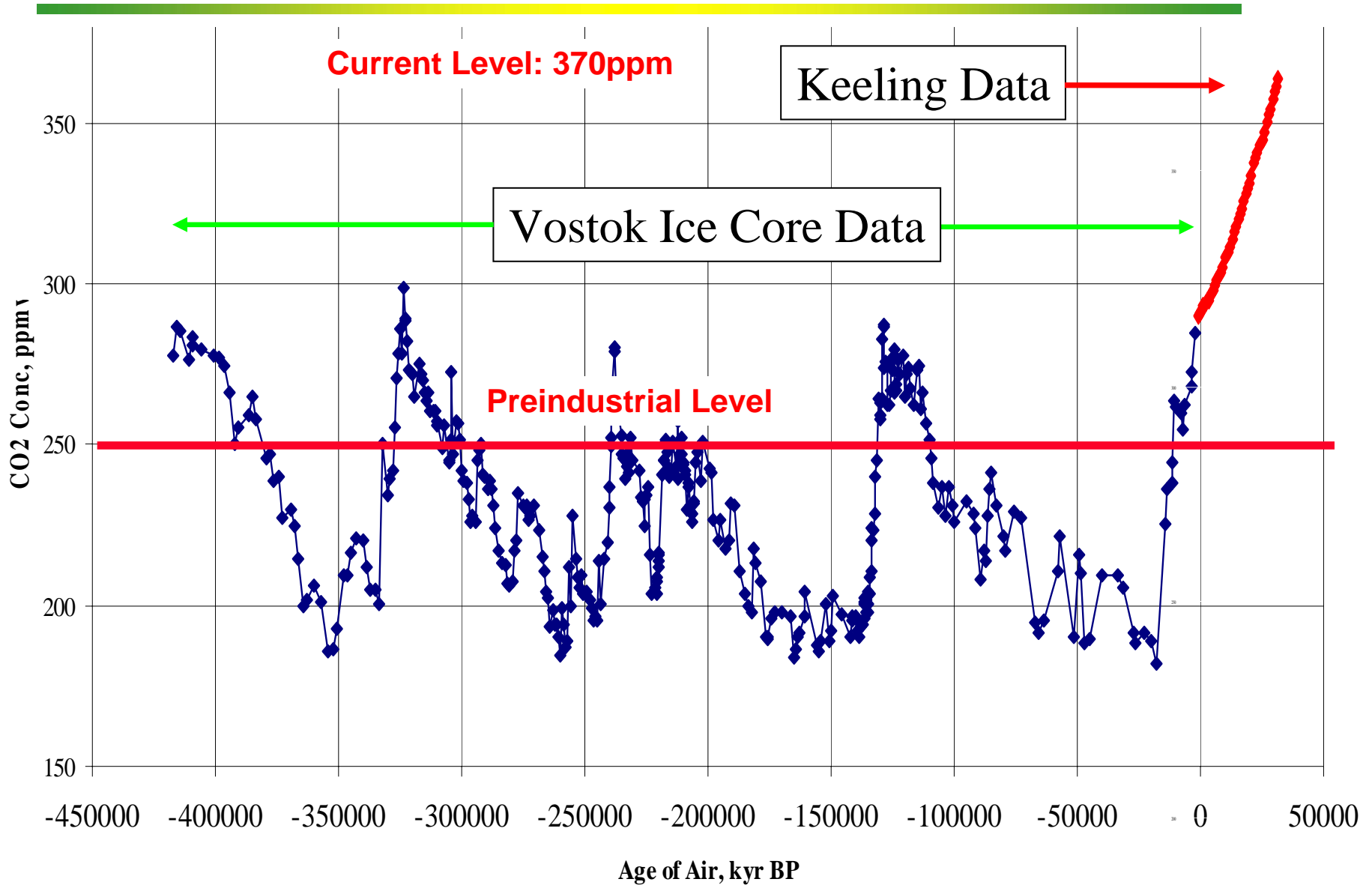
**Upstream Technology Group  
Houston**

# Ice Cores Capture Atmospheric History

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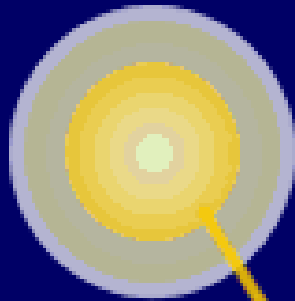


# Historical CO<sub>2</sub> Levels



# The Greenhouse Effect

## The natural Greenhouse Effect



Some of the sun's radiation is reflected back into space by the atmosphere, clouds and the earth. 51 % passes through the atmosphere and warms the earth's surface.

Some of this warmth escapes as infrared radiation. Gases in the atmosphere, like water vapour, Carbon Dioxide, Methane, Chlorofluorocarbons, Halons and Nitrous Oxide absorb and re-emit some of the infra-red, effectively warming the lower atmosphere and earth by about 35°.

**The Enhanced Greenhouse Effect** ▶ An increase in the quantity of Greenhouse gases as a result of human activity, may increase temperatures.

# The Greenhouse Gases

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- Water vapor – responsible for some 60% of the GH effect
- Global Warming Potential
  - Carbon Dioxide -  $\text{CO}_2$  – 1
  - Methane –  $\text{CH}_4$  – 21
  - Nitrous Oxide -  $\text{N}_2\text{O}$  - 310
  - Freon 23 -  $\text{CHF}_3$  – 11,700
  - Sulfur Hexafluoride -  $\text{SF}_6$  – 23,900

# Future BAU Emissions Trends

(IS92a “**B**usiness **A**s **U**sual” Scenario of IPCC)

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- Increase in global energy use/capita, 1997-2100:
  - For primary energy up 2.0X
  - For electricity up 2.6X
  - For “fuels used directly” up 1.4X
- Annual global CO<sub>2</sub> emissions (not/capita):
  - Total: 22.7 Gt CO<sub>2</sub>, 1997(37% coal) → 73 Gt CO<sub>2</sub>, 2100 (88% coal)
  - From electricity: 7 Gt CO<sub>2</sub>, 1997 → 18 Gt CO<sub>2</sub>, 2100
  - From fuels used directly: 16 Gt CO<sub>2</sub>, 1997 → 55 Gt CO<sub>2</sub>, 2100
- Cumulative emissions, 1990-2100: 5,500 Gt CO<sub>2</sub>  
(about the volume of Lake Michigan)

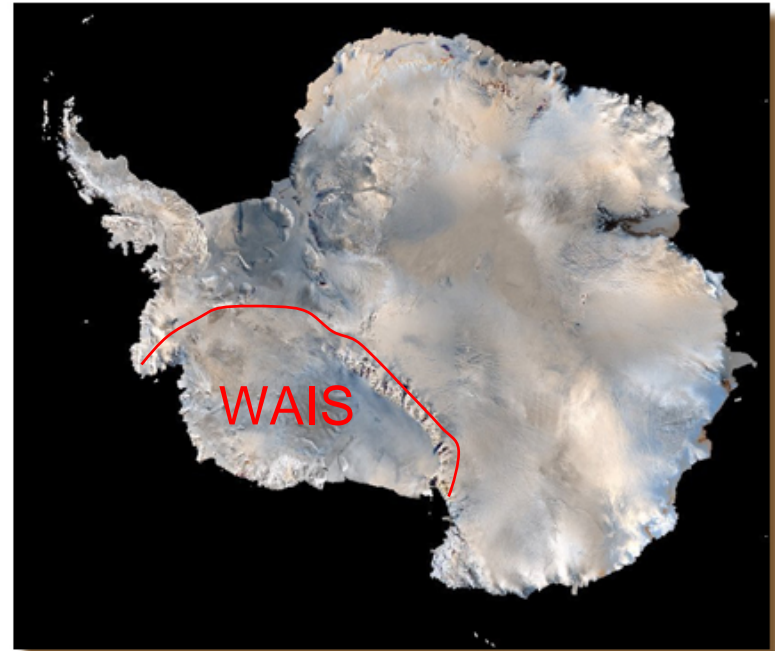
Mt Pinatubo, 1991 eruption = 42 M tonnes CO<sub>2</sub>

# Potential Consequences of BAU

## Business As Usual

- **Sea Level Rise – West Antarctic Ice Sheet, Greenland**
- Thermohaline Circulation Belt
- Peats in Northern Latitudes
- Methane Hydrates
- Severe weather patterns

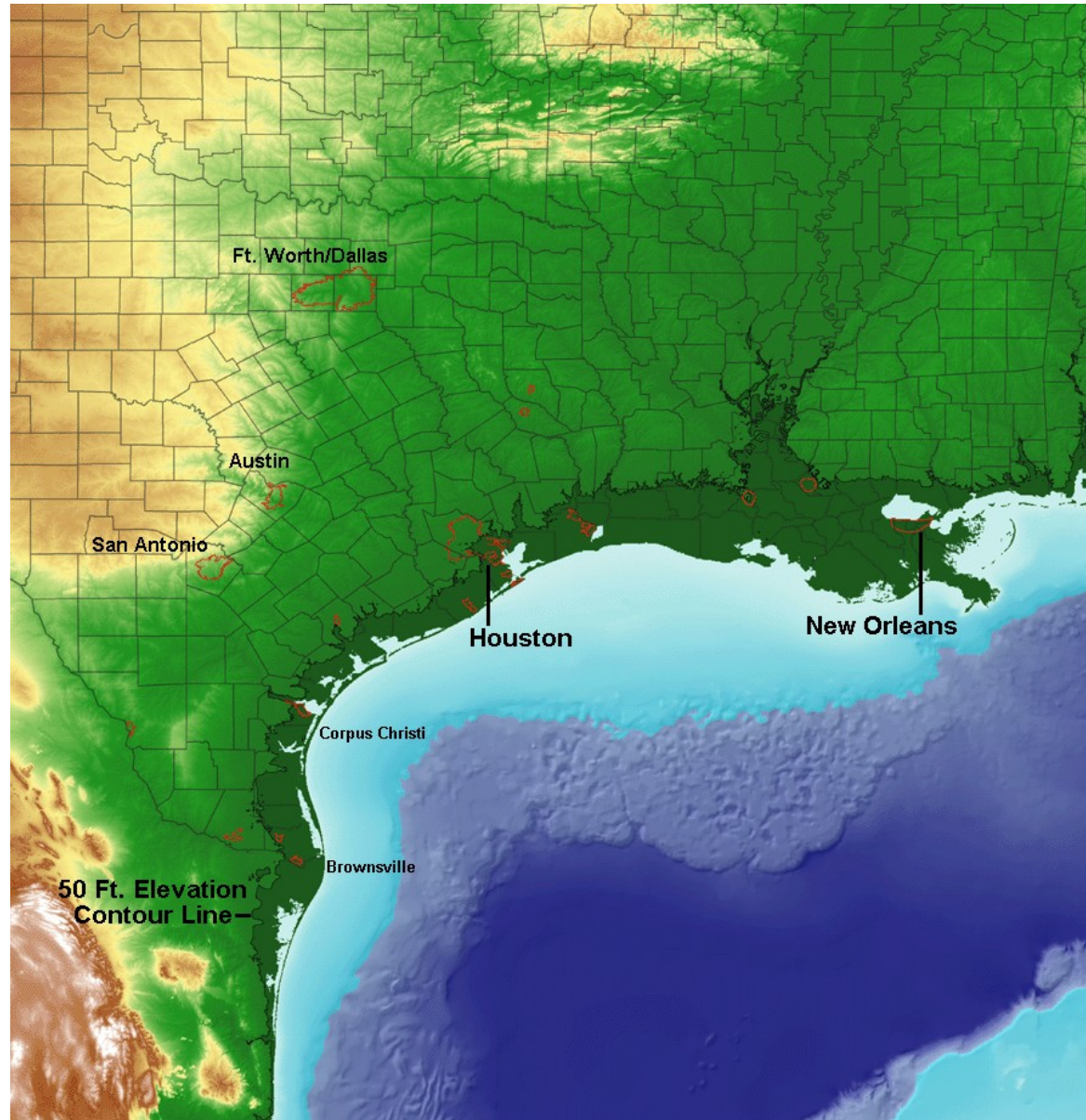
Antarctica



This ice is 90 percent of all Earth's ice and 70 percent of all its fresh water, amounting to about 6 million cubic miles. if it were returned to the oceans, it would raise global sea level about 200 feet.

# Potential Consequences of BAU

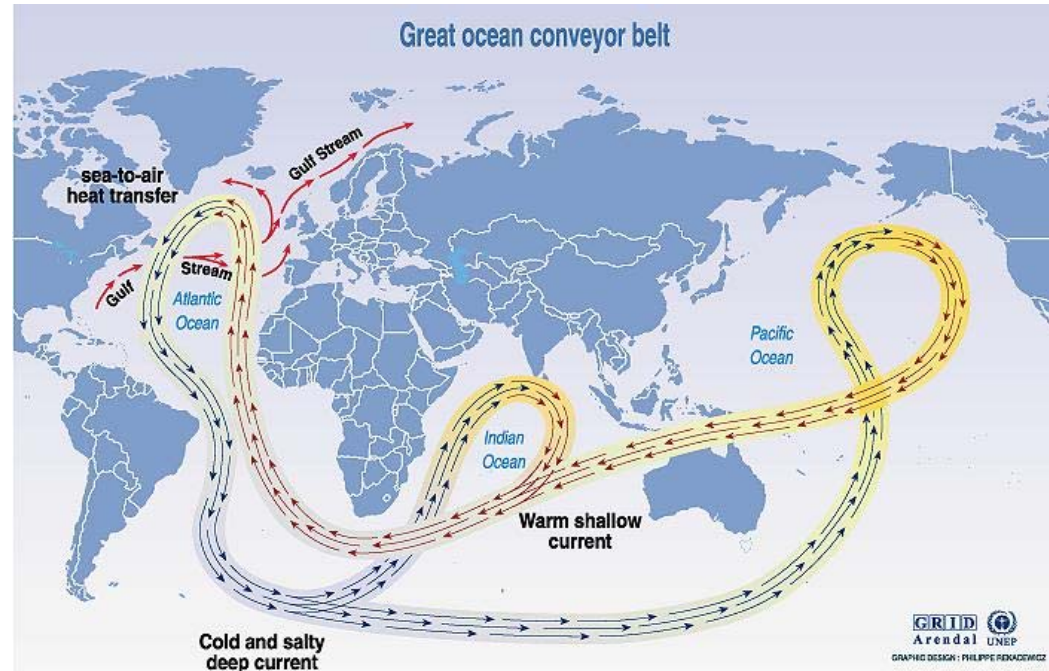
- **Sea Level Rise –**
- **West Antarctic Ice Sheet, Greenland**
- Thermohaline Circulation Belt
- Peats in Northern Latitudes
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- Severe weather patterns





# Potential Consequences of BAU

- Sea Level Rise – West Antarctic Ice Sheet, Greenland
- **Thermohaline Circulation Belt - THC**
- Peats in Northern Latitudes
- Methane Hydrates
- Severe weather patterns

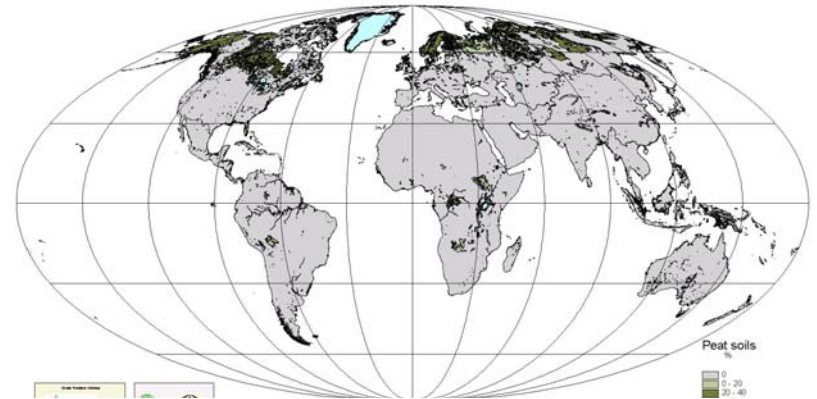


Source: Broecker, 1991, in *Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.*

**In addition to large effects on weather, upwelling may be responsible for 70% of the oceans' biological productivity.**

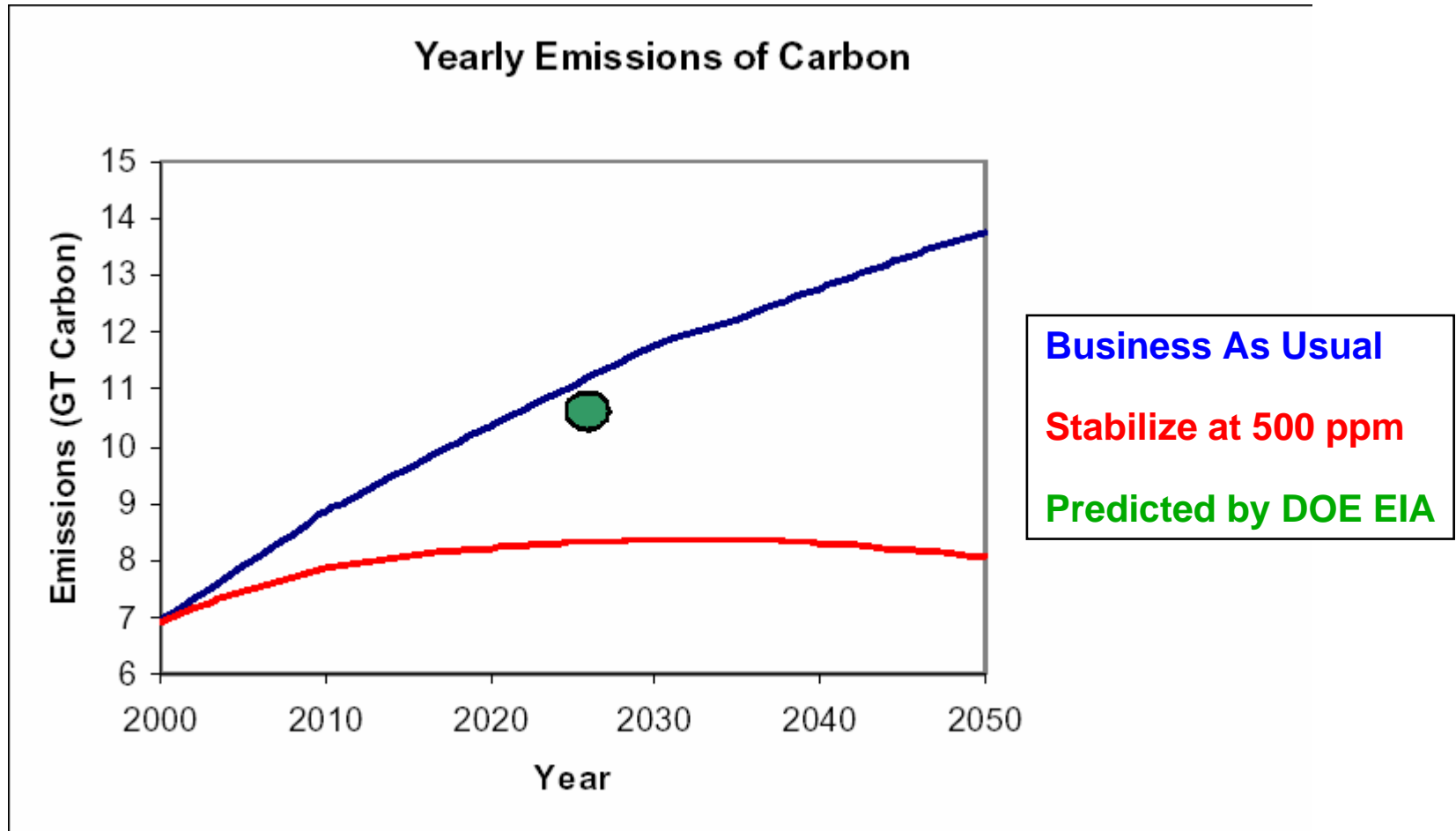
# Potential Consequences of BAU

- Sea Level Rise – West Antarctic Ice Sheet, Greenland
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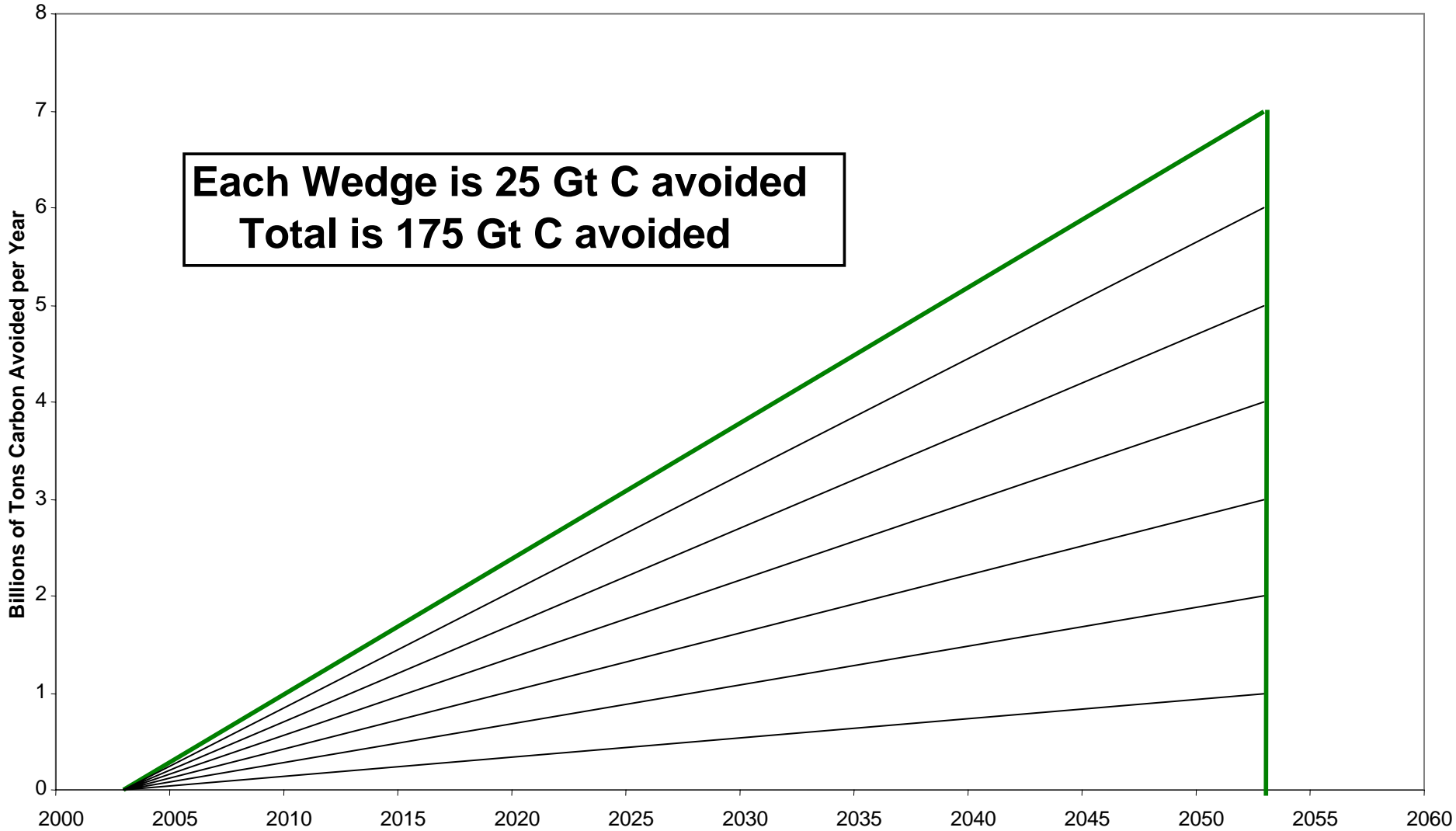
**Russia and Canada alone have more than 2.7 million Km<sup>2</sup> = 67million acres of peat.**

# Business As Usual?



Emissions reductions required are the differences between the curves

# Seven Slices of the Stabilization Wedge



After Pacala 2003

# What Is Required to Achieve a Slice?

Category	Global Annual Increment	Total Capacity in 2050
Fuel shifting to replace coal	1) Build 28 GW of gas-fueled plants	1400 GW fueled by gas instead of coal (12% of current total)
Increased energy efficiency	2) Double efficiency of 40 million gas/diesel cars	2 billion gas/diesel cars at 60 mpg rather than 30 mpg
Displace Fossil Fuel in Electricity Gen	3) Wind 1.4x current	70x current
	4) Solar 20x current	1000x current; $12 \times 10^6$ acres
	5) Nuclear 4% current capacity	700 1 GW plants; 2x current cap
Substitute Renewables	6) Biomass 10 million acres	$500 \times 10^6$ acres = all US cropland
	7) Hydrogen from nuclear 20 1GW plants	1000 1GW plants
Forest and soil seq.	8) 35 million acres	1,500 million acres = total area of lower 48

**2003 US Fleet Average = 20.8 mpg**  
**World average 15 cars/1000 pop => 50/1000 by 2020**

# What Is Required to Achieve a Slice?

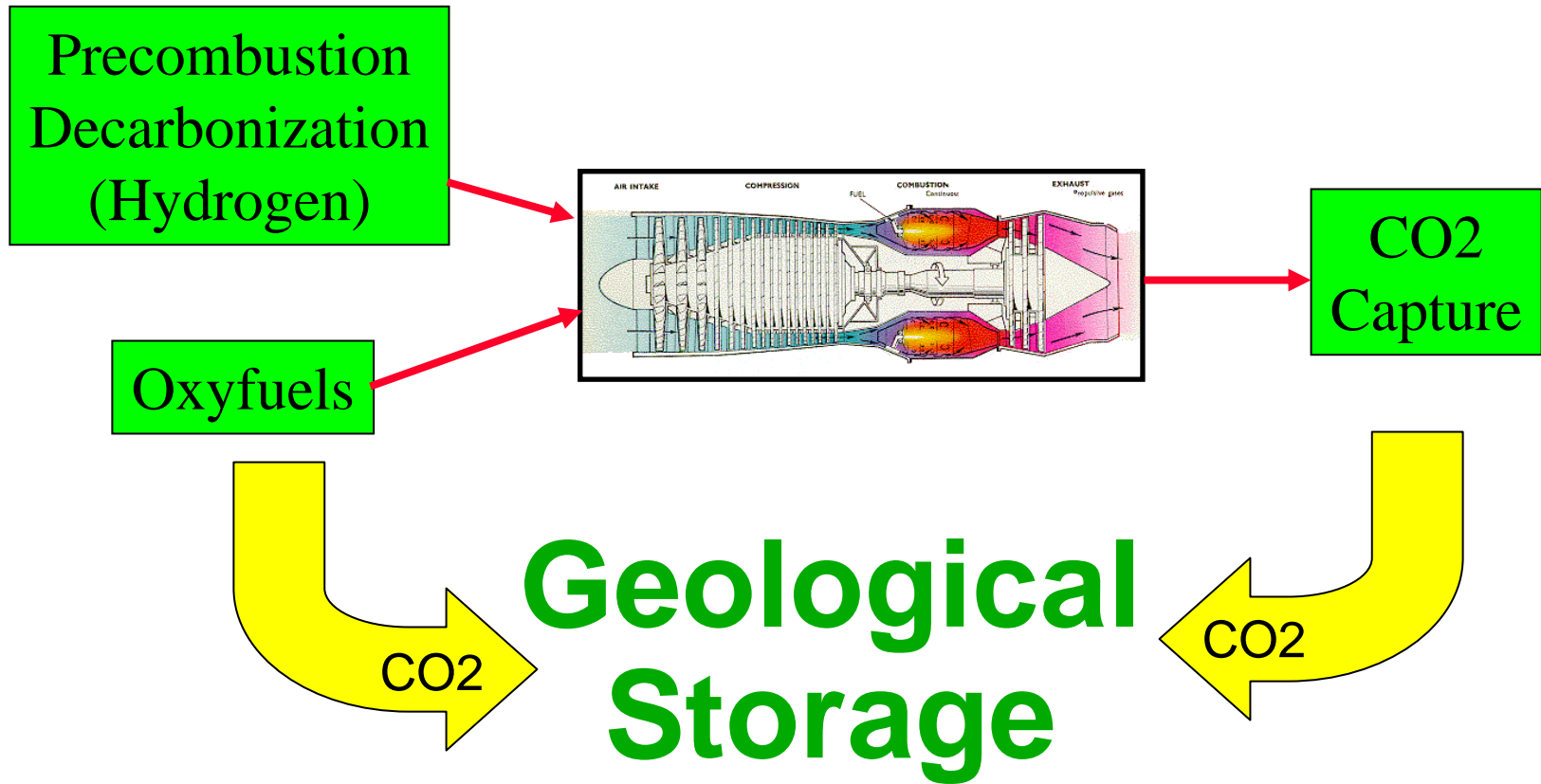
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Category	Global Annual Increment	Total Capacity in 2050
Carbon Capture and Storage	9) Equip 14 coal plants with CCS	700 1 GW coal plants
	10) 70 Sleipners or Weyburns	3,500 Sleipners at 1 Mt CO <sub>2</sub> /yr
	11) Displace 20 million gas/diesel cars with H <sub>2</sub> (CO <sub>2</sub> free)	1 billion H <sub>2</sub> cars (CO <sub>2</sub> free) displace 1 billion 30 mpg gas/diesel cars

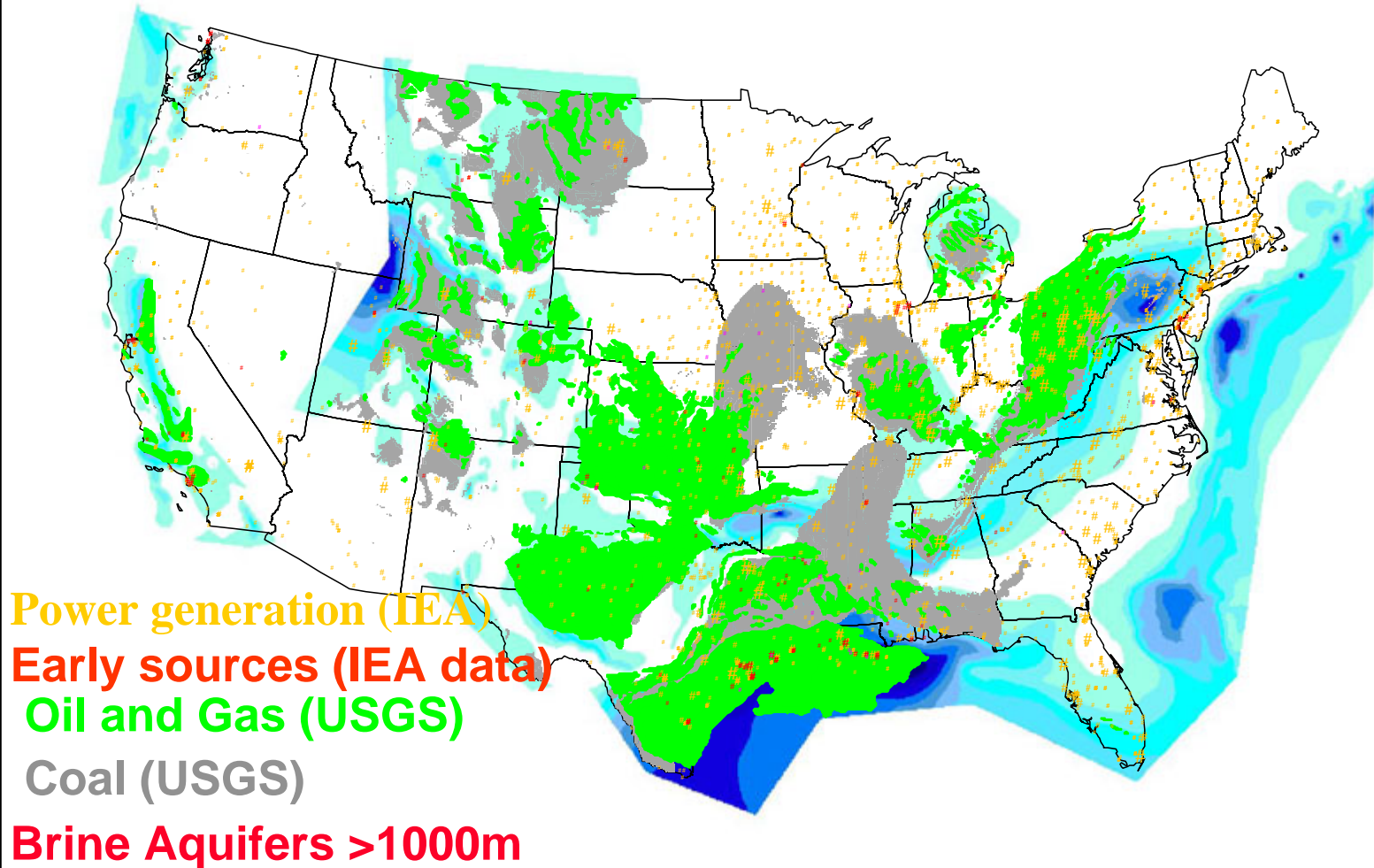
**But these are with the gas options!**

# CO<sub>2</sub> – How to Get It, What to Do With It

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# U.S. Geologic Storage Potential





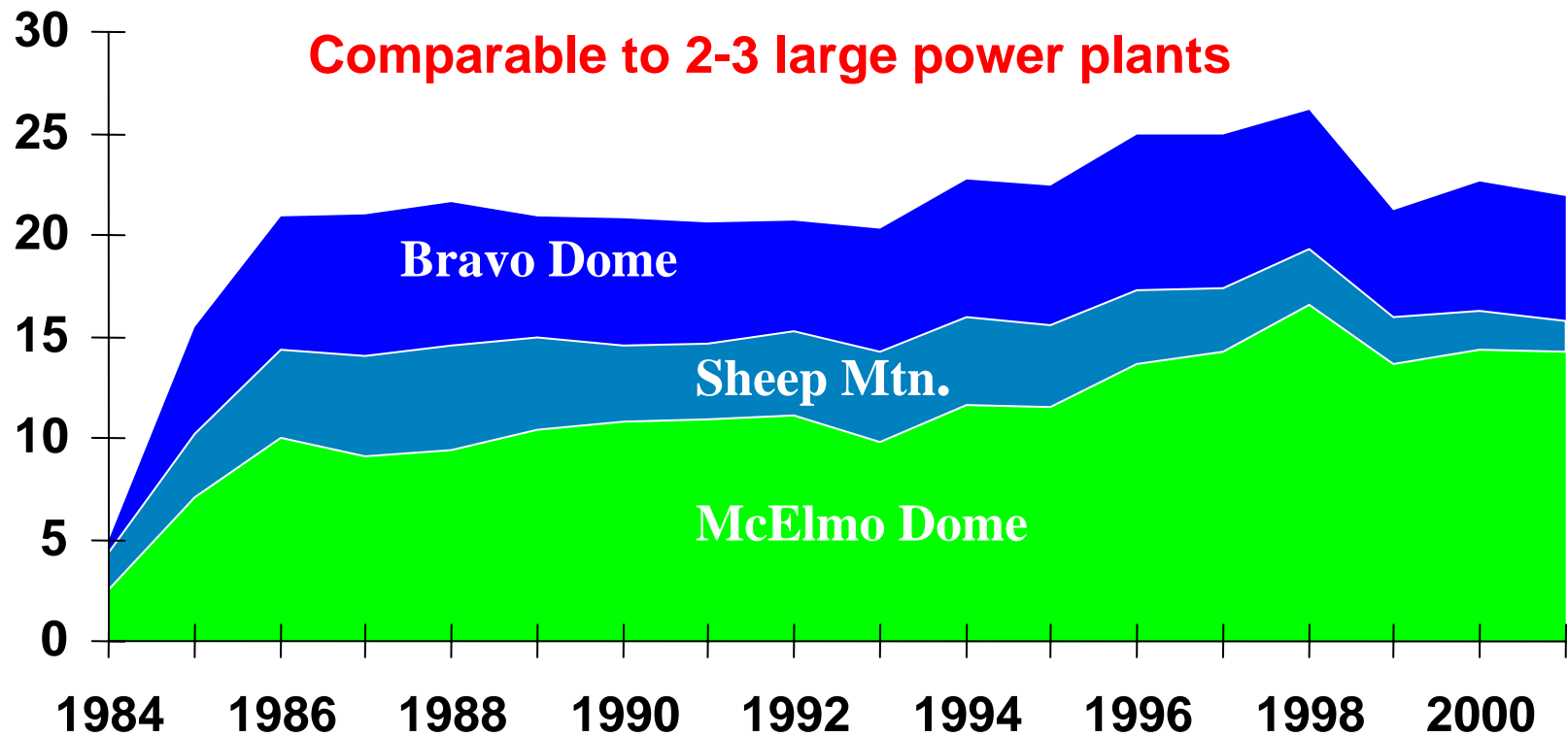
# CURRENT US CO<sub>2</sub> SOURCES and PIPELINES

## Industry knows how to handle CO<sub>2</sub>

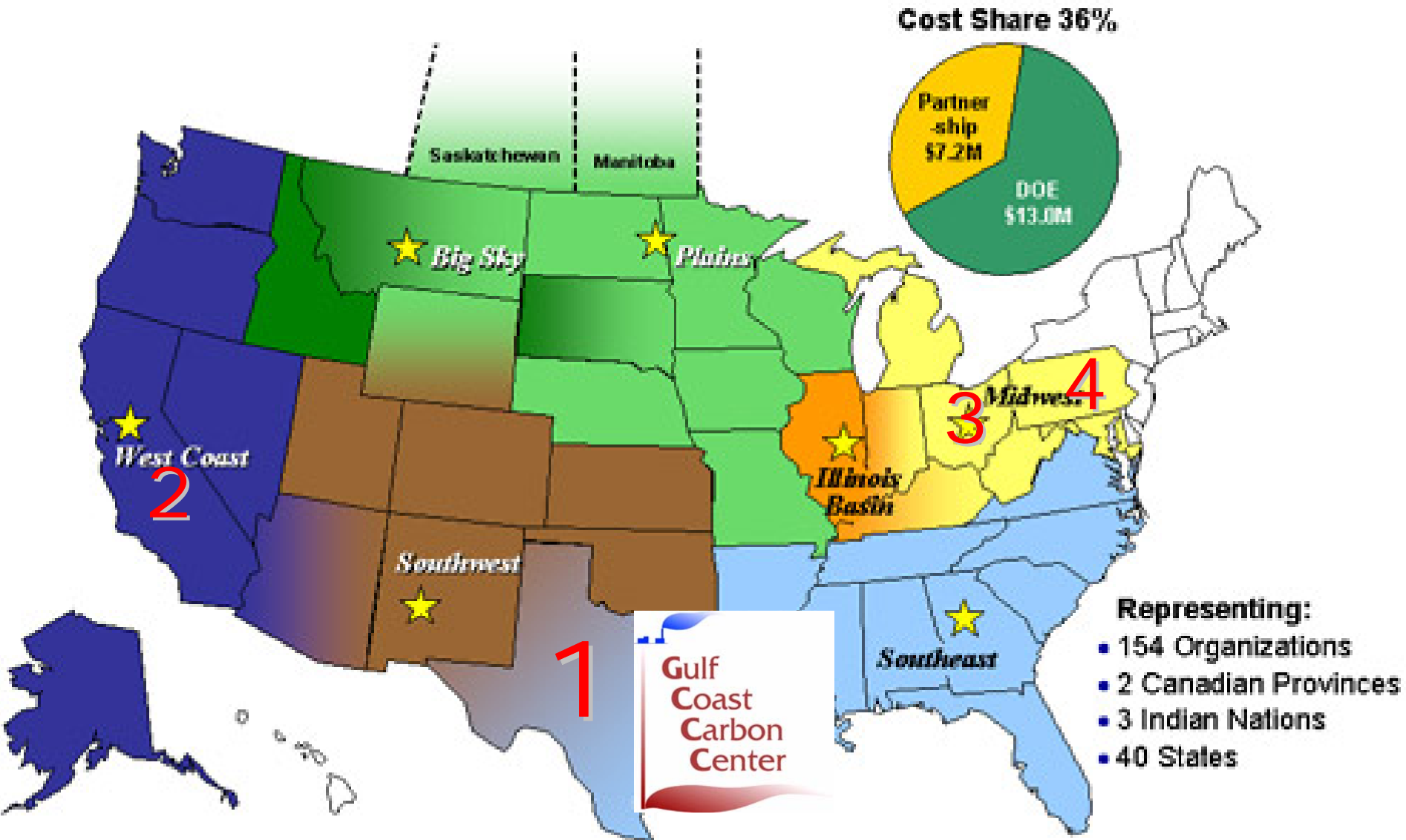


# Permian Basin CO<sub>2</sub> Purchased for EOR

Million Tonnes per Year



# Dept of Energy Regional CO<sub>2</sub> Partnerships



# The Business Case

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- If public perceives this problem to be high priority, governments will act
- There will be a value for CO<sub>2</sub> at some point due to caps
- Current caps in Europe will affect multinationals in the US and elsewhere
- Those who plan for a carbon constrained future will benefit

# Summary

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- The scientific evidence is compelling that there is a link between CO<sub>2</sub> emissions and global warming.
- There are potentially very serious consequences if the BAU path is followed.
- There is no silver bullet - In order to meaningfully reduce CO<sub>2</sub> emissions, every means available, including capture and storage will be required.
- Industry has long experience handling CO<sub>2</sub>.
- Regulatory caps will need to be in place to make it happen.

[www.co2captureproject.com](http://www.co2captureproject.com)  
[www.princeton.edu/~cmi/](http://www.princeton.edu/~cmi/)  
[www.fe.doe.gov/programs/sequestration/](http://www.fe.doe.gov/programs/sequestration/)