



Battelle

The Business of Innovation

*Providing Low-Cost Energy in a
Carbon-Constrained World:*

The Role for Sequestration

Ken Humphreys
Carbon Management Solutions

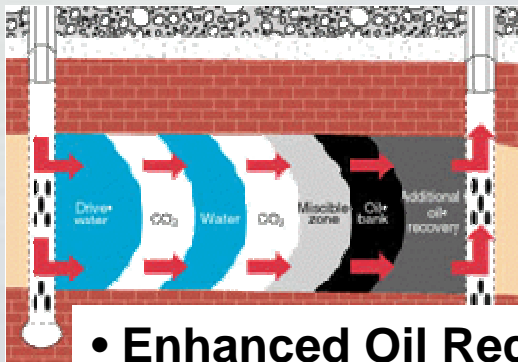
July 25, 2005

Key Messages

- **Sequestration is a necessary complement to, not a replacement for, other low-carbon energy technologies.**
- **Sequestration could reduce the cost of CO₂ management by \$100Bs to trillions.**
- **Terrestrial sequestration is low cost, deploys early, but available capacity is consumed early in the century.**
- **Capture of CO₂ and geologic storage is the “workhorse” sequestration technology**
- **Significant economic, regulatory, and public acceptance challenges remain before widespread acceptance of sequestration can be expected.**

Carbon Sequestration

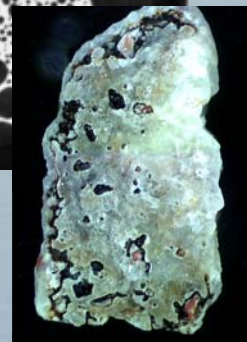
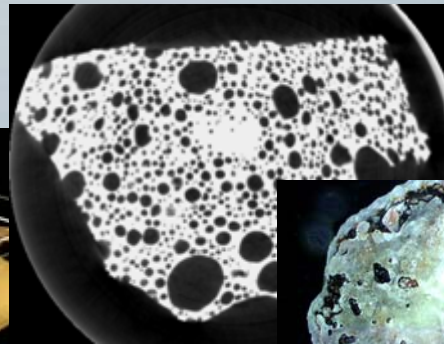
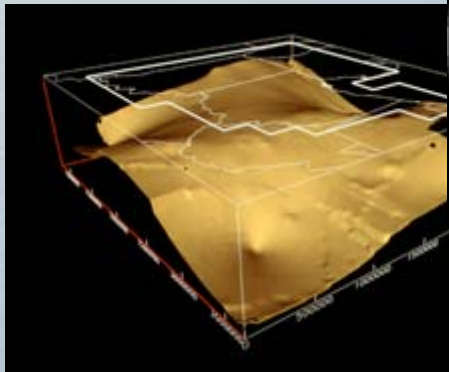
What is it?



- Enhanced Oil Recovery
- Enhanced Coal Bed Methane



- Terrestrial**
 - Forests
 - Soils
 - Other Ecosystems

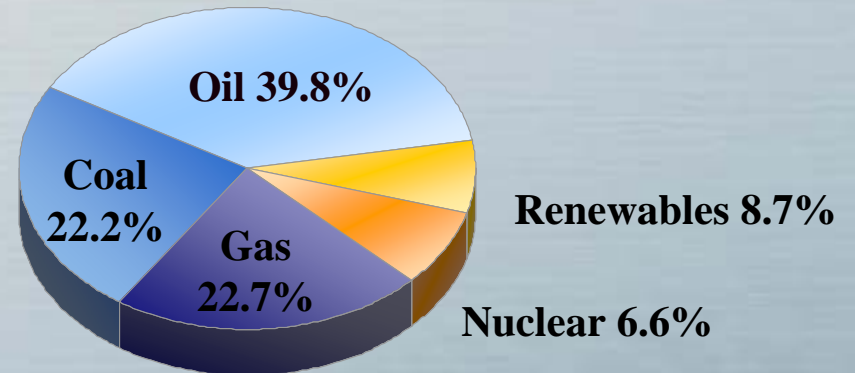


- Deep Saline Formations**
 - Sandstone
 - Carbonate
 - Basalt

About Energy

Facts

- Fossil fuels provide 85% of the world's energy
 - Affordable
 - Abundant



- Energy demand will likely increase
 - >1 billion people with no access to commercial energy
 - Populations expected to expand
- Many in the world are not willing to forgo the benefits of fossil fuels

Climate Change

Administration Commitments

- Short-term commitment:
 - Reduce emissions/GDP by 18% by 2012.
- Long-term commitment:
 - “I reaffirm America's commitment to the United Nations Framework Convention and it's central goal, to stabilize atmospheric greenhouse gas concentrations at a level that will prevent dangerous human interference with the climate.”
 - —President George W. Bush

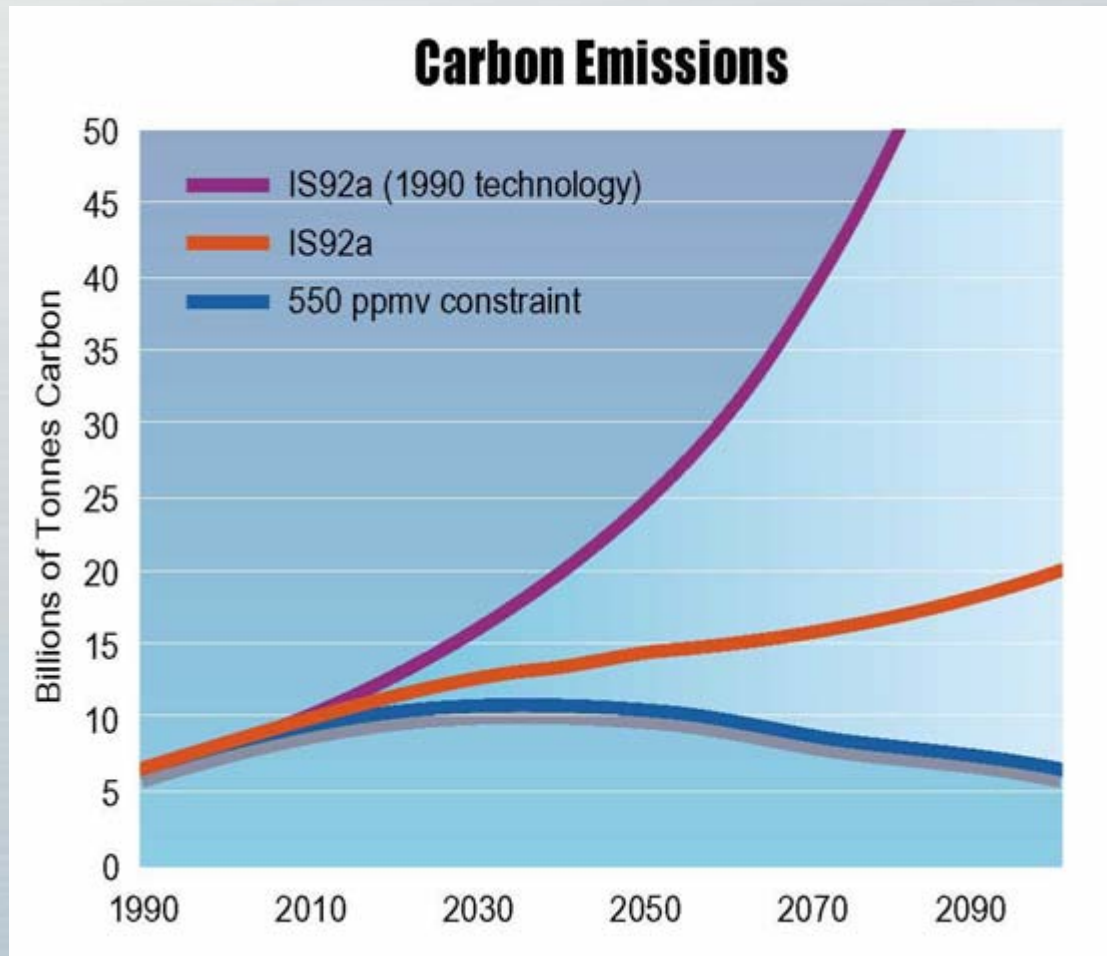
About Emissions

Facts

- Stabilization of greenhouse gas concentrations implies the need for a net “zero-emissions” world
 - Fundamental transformation of the global energy system
- Must peak and decline
 - Slow the growth
 - Peak
 - Decline
- Energy Demand will likely increase
 - 2X to 5X+ this century

Future of Global Emissions

Huge Technology Improvements Built-In to BAU



Today's Technology



**Solar/Wind
Nuclear
Efficient Fossil Electric
Advanced Transportation
End Use Efficiency**

"Business As Usual"



*One Possible
Stabilization Trajectory*

Carbon Management Challenge

A gigaton is...

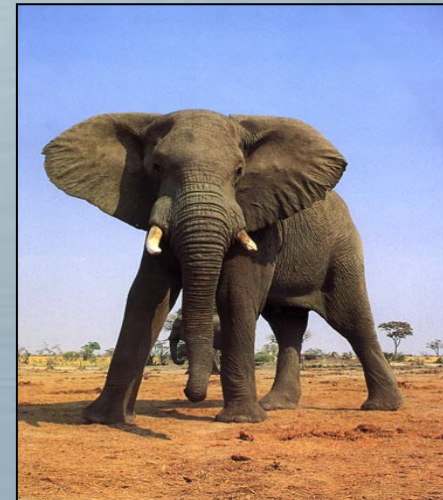
247,450 US Capitol Domes



2740 Empire State Buildings



142,857,142 African elephants



Need to think on a megascale!

A Gigatonne of Mitigation Is...

Technology	1 Gigaton Carbon / year (1 billion tons C / year)
Nuclear	500 new 1GW nuclear plants
Efficiency	1 billion cars operating at 40 mpg instead of 20 mpg
Sequestration	3,700 Sliepner Projects
Solar	10,000 x current US solar generation
Coal	1000 new 500 MWe “zero-emission” coal plants
Biomass	Convert a barren area ~15 times the size of Iowa’s farmland to 100% biomass production

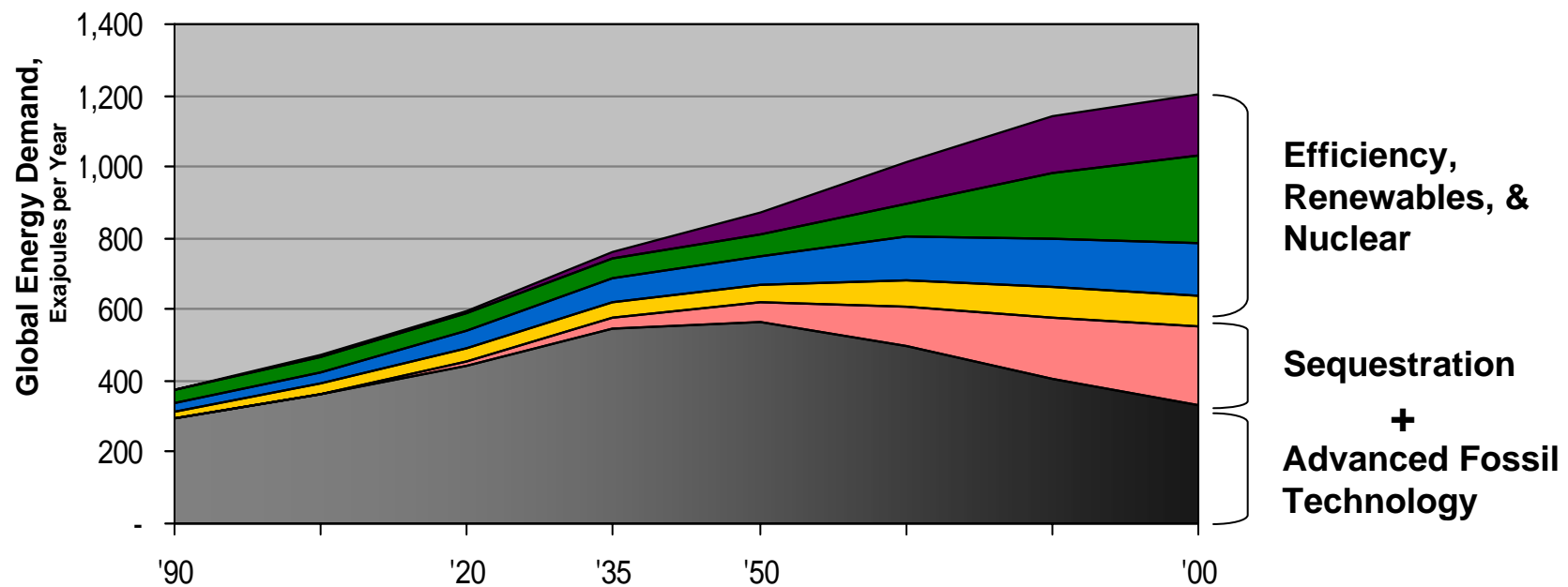
Need to boldly advance technology—more productive, more cost-effective!

One Possible Energy Future

With Near-Zero Emission Coal Technology

Global Energy Demand

Mid-Range Economic/Energy Growth
One Possible Carbon Constraint



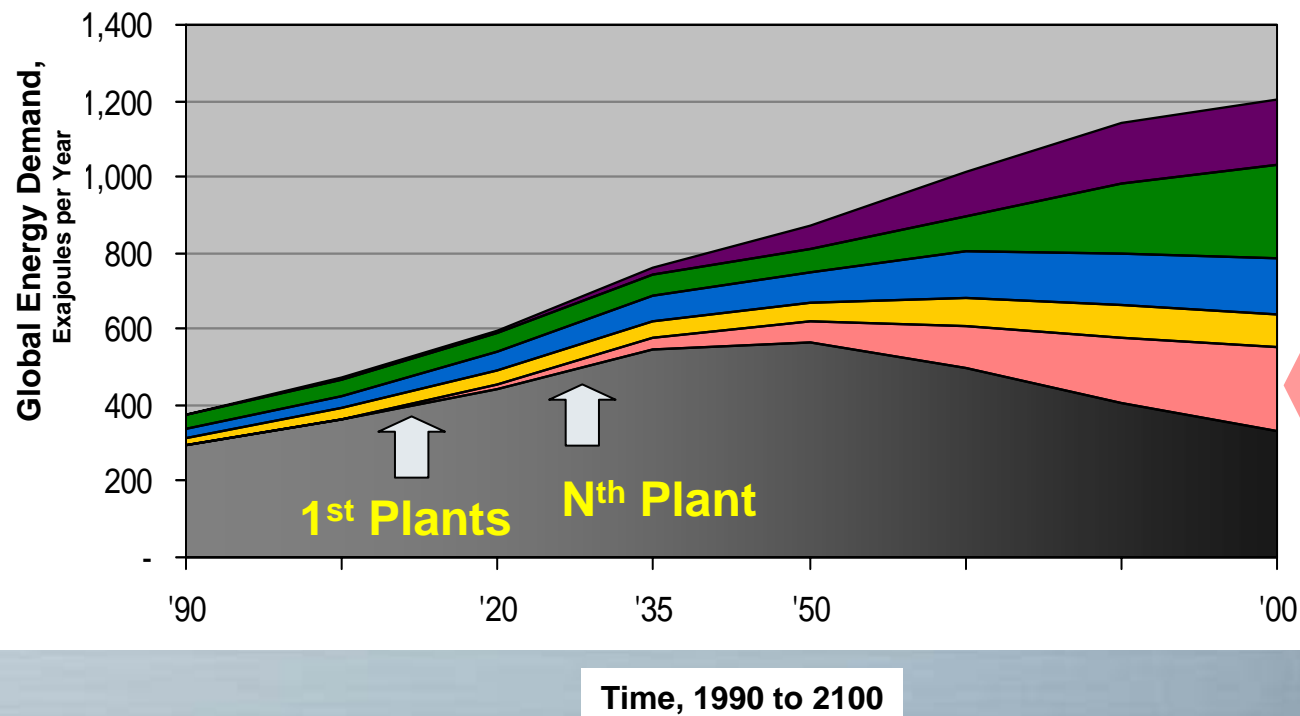
Time, 1990 to 2100

One Possible Energy Future

With Near-Zero Emission Coal Technology

Global Energy Demand

Mid-Range Economic/Energy Growth
One Possible Carbon Constraint



Benefits of Proving-out Near-Zero Emission Coal

- More stable energy prices
- Reduces the cost of addressing carbon emissions by trillions of dollars

FutureGen

A Bold Technology Initiative



One billion dollar, 10-year project to create the world's first, coal-based, zero-emission electricity and hydrogen plant with sequestration

President Bush, February 27, 2003

Large Scale Deployment Potential

Technical, economic, and social challenges remain



3,800+ GtCO₂ Capacity within 330 US and Canadian Candidate Geologic CO₂ Storage Reservoirs

- 3,730 GtCO₂ in deep saline formations (DSF)
- 65 GtCO₂ in deep unmineable coal seams with potential for enhanced coalbed methane (ECBM) recovery
- 40 GtCO₂ in depleted gas fields
- 13 GtCO₂ in depleted oil fields with potential for enhanced oil recovery (EOR)



2,082 Large Sources (100+ ktCO₂/yr) with Total Annual Emissions = 3,800 MtCO₂/yr

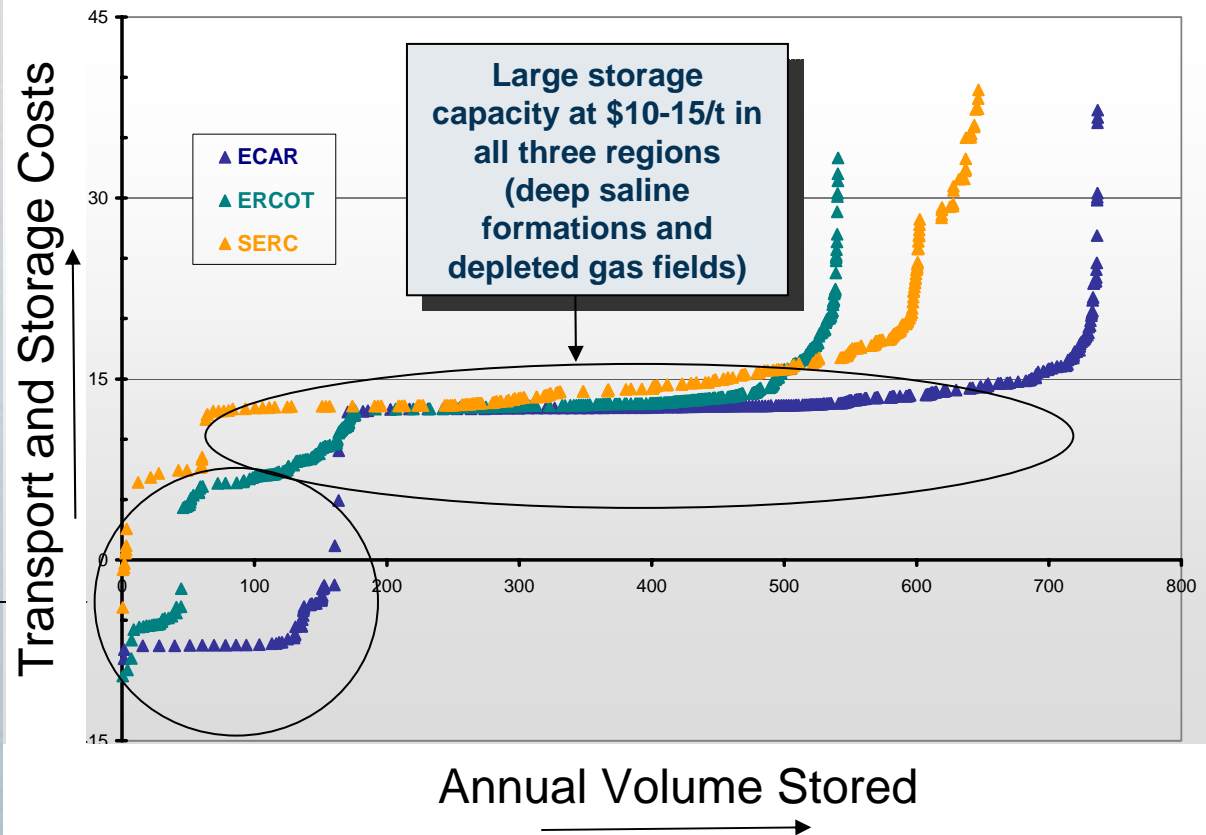
- 1,185 electric power plants
- 447 natural gas processing facilities
- 154 petroleum refineries
- 53 iron & steel foundries
- 124 cement kilns
- 43 ethylene plants
- 9 oil sands production areas
- 40 hydrogen production
- 25 ammonia refineries
- 47 ethanol production plants
- 8 ethylene oxide plants

Different regions have different endowments of low cost storage capacity

CO2 Transport and Storage Costs in Three NERC Regions (USA)



Different levels of low cost / value added storage capacity (EOR and ECBM)



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