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Macro and Micro: The Role for Carbon Dioxide Capture and Geologic Storage in Addressing Climate Change

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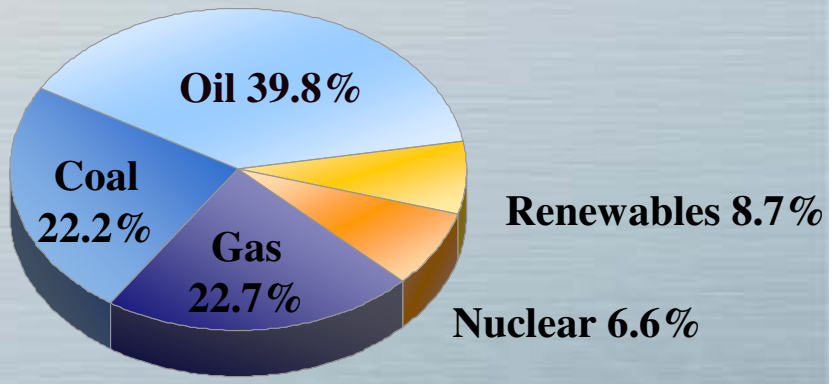
Outline

- The Carbon Management Challenge
  - What's the goal?
  - What are the technology implications?
- CO_2 Capture and Storage (CCS)
  - What is it?
  - What is the value of CCS deployment?
  - Is there enough geologic storage capacity?
  - How will CCS work within the US electric utility industry?
- Conclusions

About Energy
Facts

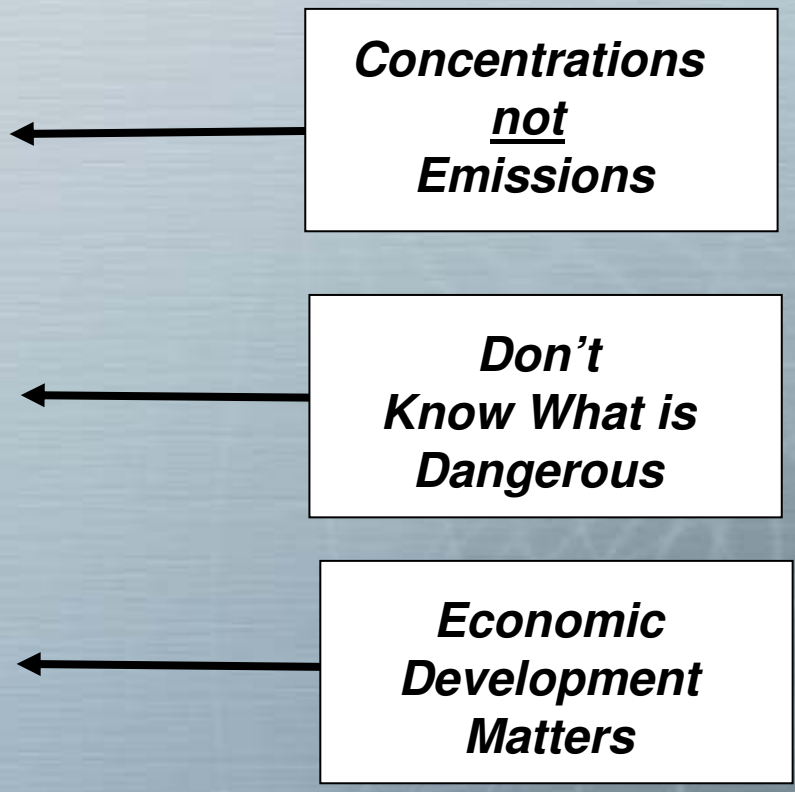
- Fossil fuels provide 85% of the world's energy
  - Affordable
  - Abundant
  - Extremely useful and valuable



- Global energy demand likely to increase 2x to 5x or more
  - 2.4 billion people with no access to commercial energy
  - Populations expected to expand

About UNFCCC
Facts

- UNFCCC has nearly 200 signatory countries and establishes as its "ultimate objective":
  - …the stabilization of greenhouse gas concentrations…
  - …at a level that would prevent dangerous…interference with the climate system…
  - …and to enable economic development to proceed in a sustainable manner.



About Emissions
Facts

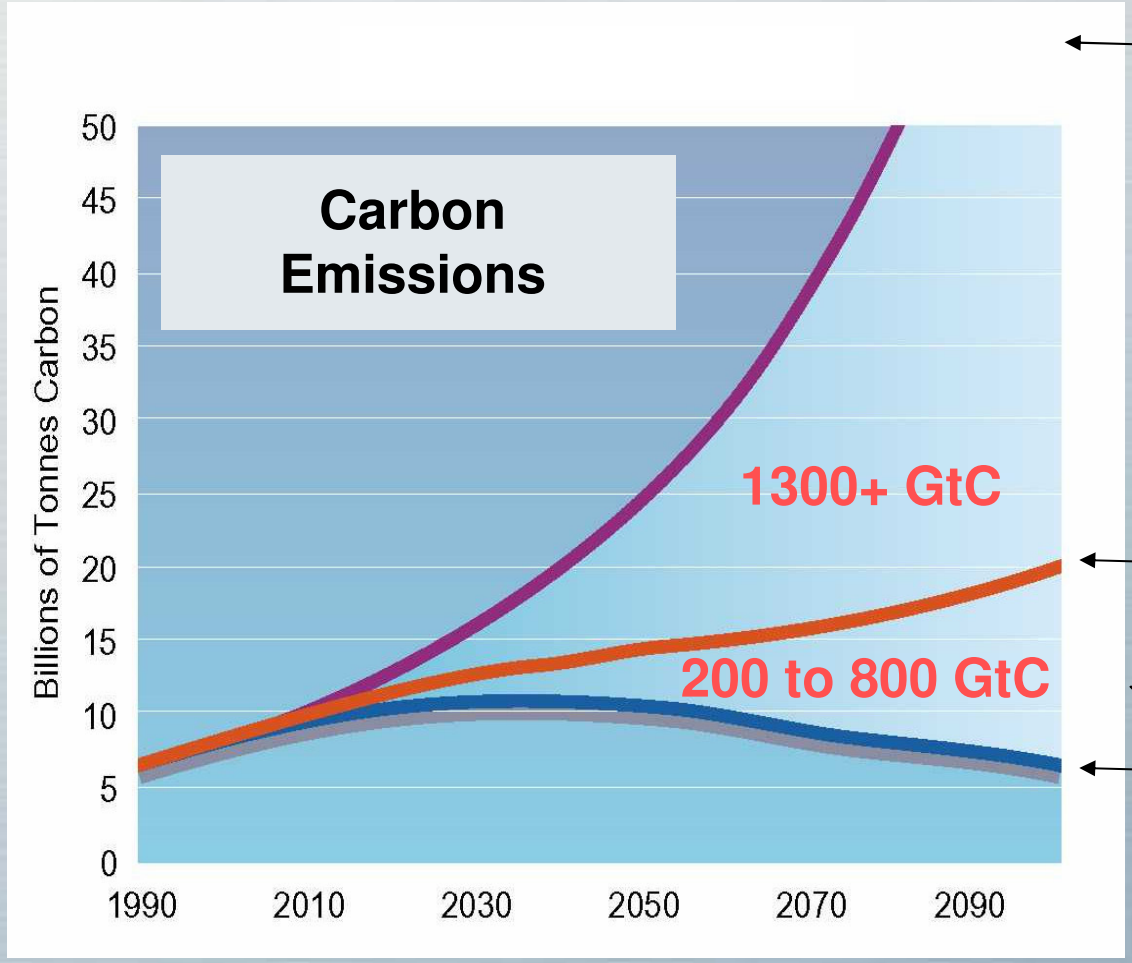
- Stabilization of greenhouse gas concentrations implies the need for a net “zero-emissions” world

- To satisfy the UNFCCC’s stabilization goal, global GHG emissions must peak and decline
  - Slow the growth
  - Peak
  - Decline (and decline, and decline, …)

- This then implies a *fundamental transformation* of the global energy system during this century.

Carbon Management Challenge

Huge Technology Improvements Built-In to BAU



Today's Technology

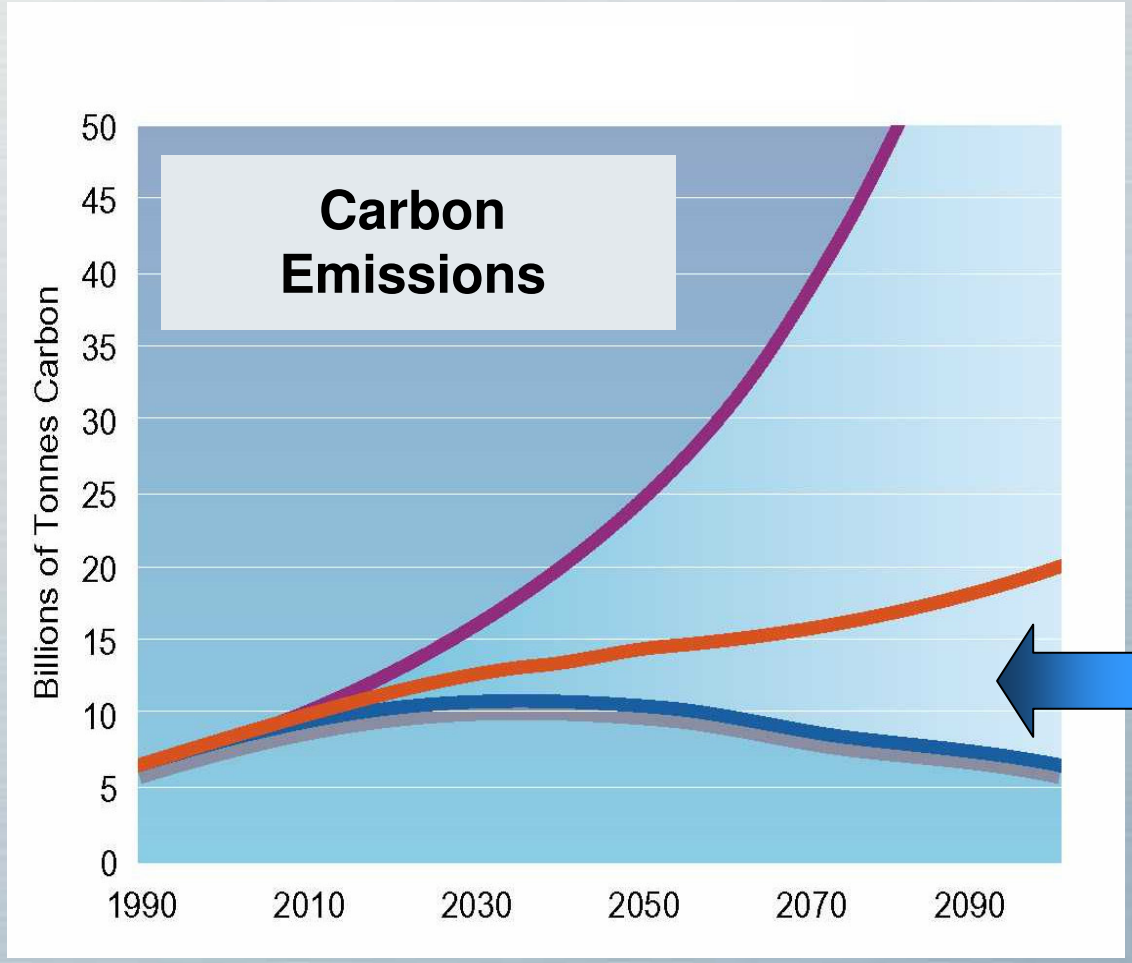
Solar/Wind
Nuclear
Efficient Fossil Electric
Advanced Transportation
End Use Efficiency

"Business As Usual"

One Possible Stabilization Trajectory

Carbon Management Challenge

Technology & Policy Fill the Gap and Control Costs



Filling the Stabilization Technology Gap

- Soil carbon sequestration
- Commercial Biomass
- CO_2 Capture and Storage
  - Central Power Production
  - H_2 Production
  - Synfuels Production
- And still more
  - Solar, wind, hydro
  - Nuclear
  - Conservation

Carbon Management Challenge
Take Home Points

- Addressing climate change will take continued progress on traditional energy R&D and carbon management R&D.

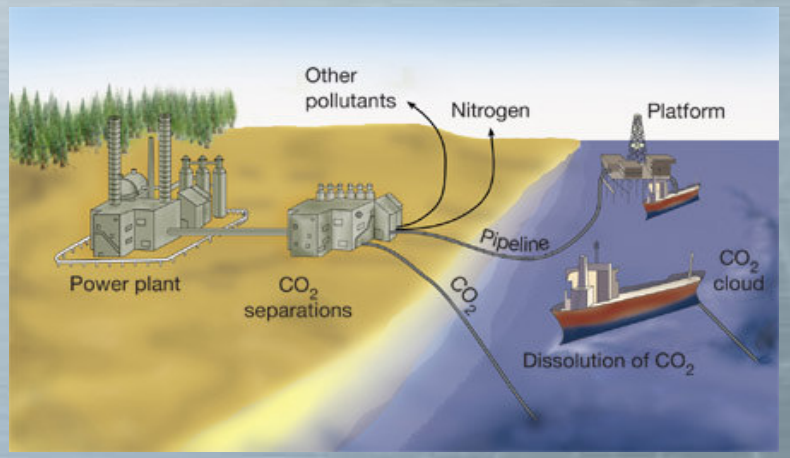
- Key Carbon Management Technologies that have to be ready for deployment by 2020 include:
  - Commercial Biomass
  - Soil Carbon Sequestration
  - CO_2 Capture and Storage
  - Advanced Gasification
  - Fuel Cells

- R&D programs need to be designed to lay the ground work for massive deployment. Near term field demonstrations need to be designed with this in mind.

What is carbon dioxide capture and storage (CCS)?

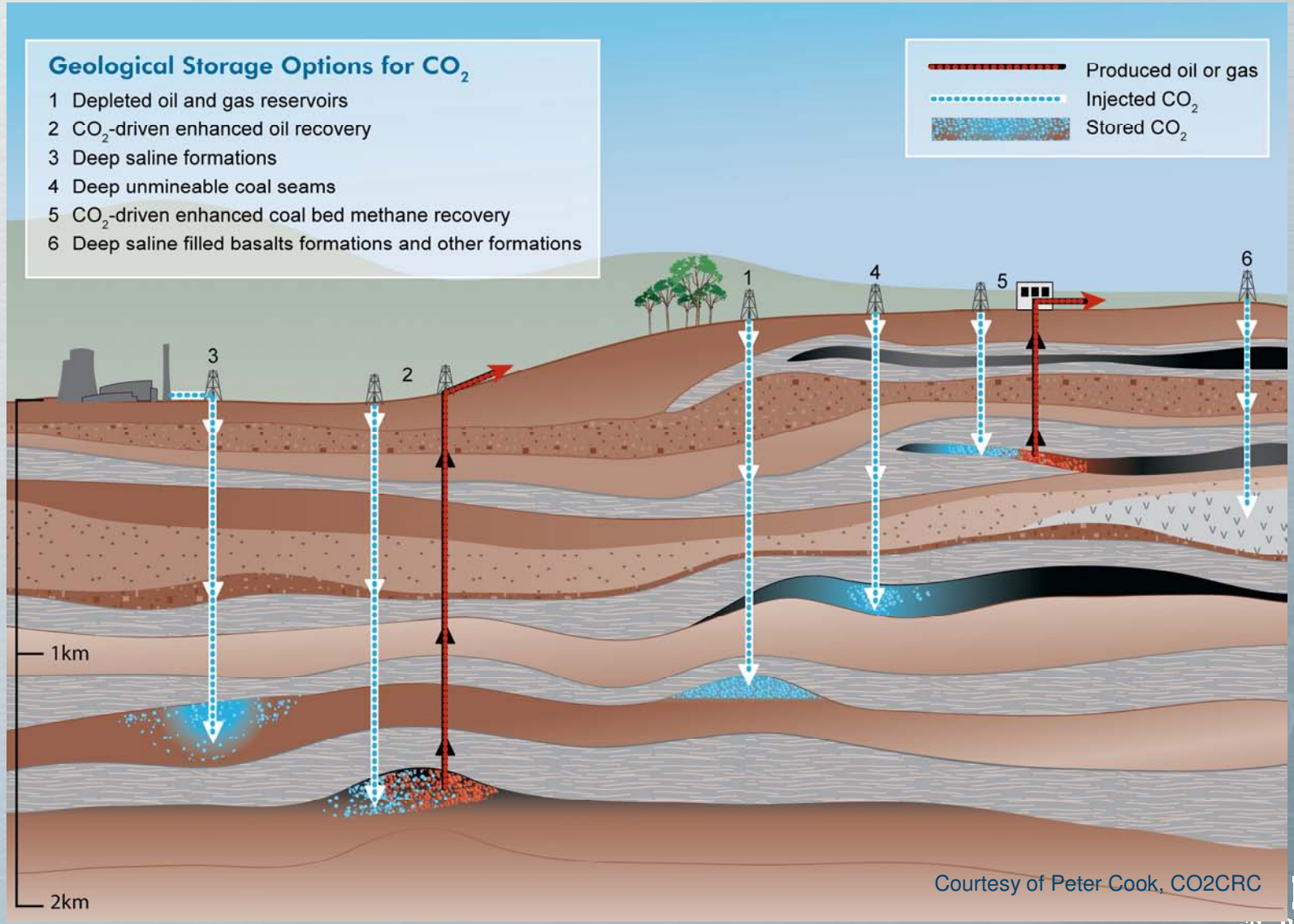
"Carbon Sequestration"
Different Types

- Terrestrial carbon sequestration
  - Agricultural Lands
  - Degraded/Eroded Lands
  - Abandoned Mine Lands
  - Forests
  - Pastures
  - Wetlands/Organic soils
  - Urban lands
- Ocean Sequestration
- Geologic Carbon Sequestration (a.k.a., carbon dioxide capture and storage)



Candidate Geologic CO_2 Storage Formations

Multiple Options

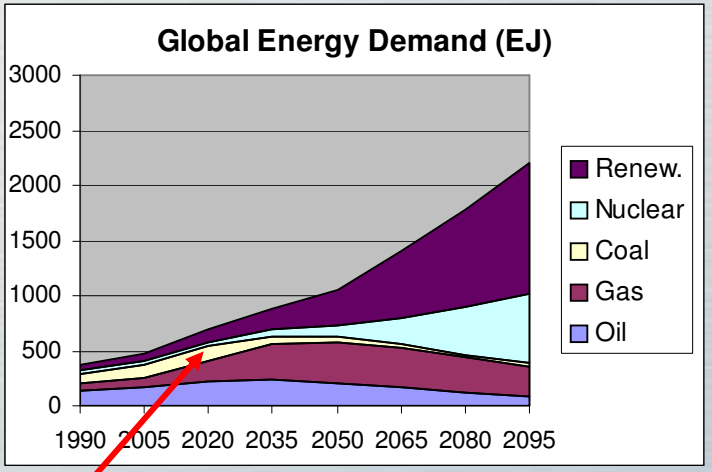


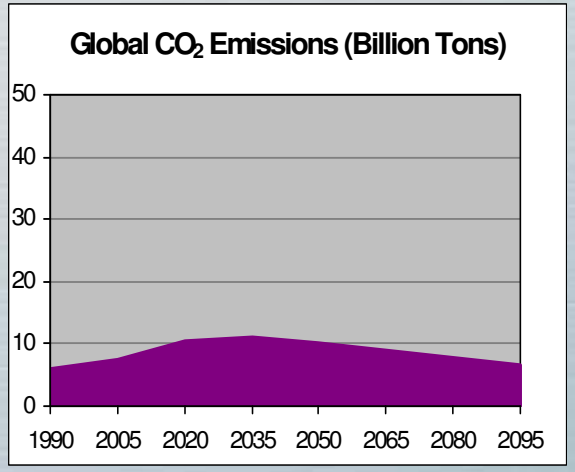
Courtesy of Peter Cook, CO2CRC

What is the economic value of CCS deployment?

Carbon-Constrained Future
With and Without Large-Scale CCS Deployment

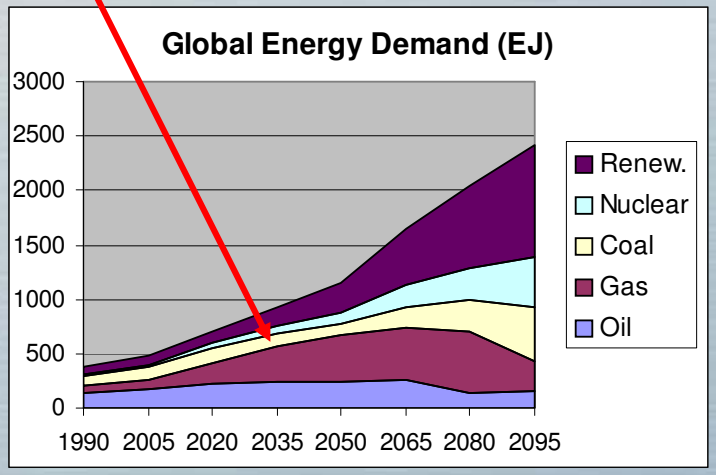
No CCS

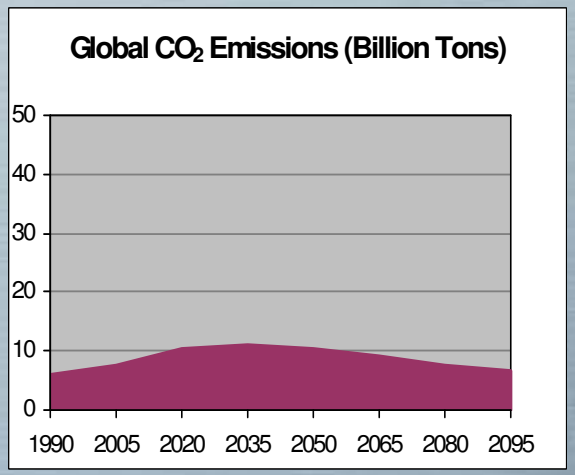




COAL

CCS Deployment





No CCS

- Economic forces push fossil fuels out of the market in the coming decades
- Higher energy prices

CCS Allowed to Deploy to Its Full Potential

- Preserves economic and energy security benefits of fossil fuels
- **Lowers the cost of energy relative to "no CCS" scenario**
- A portfolio of energy technologies achieves stabilization goal
- **Reduces the cost of stabilization by up to trillions of dollars.**

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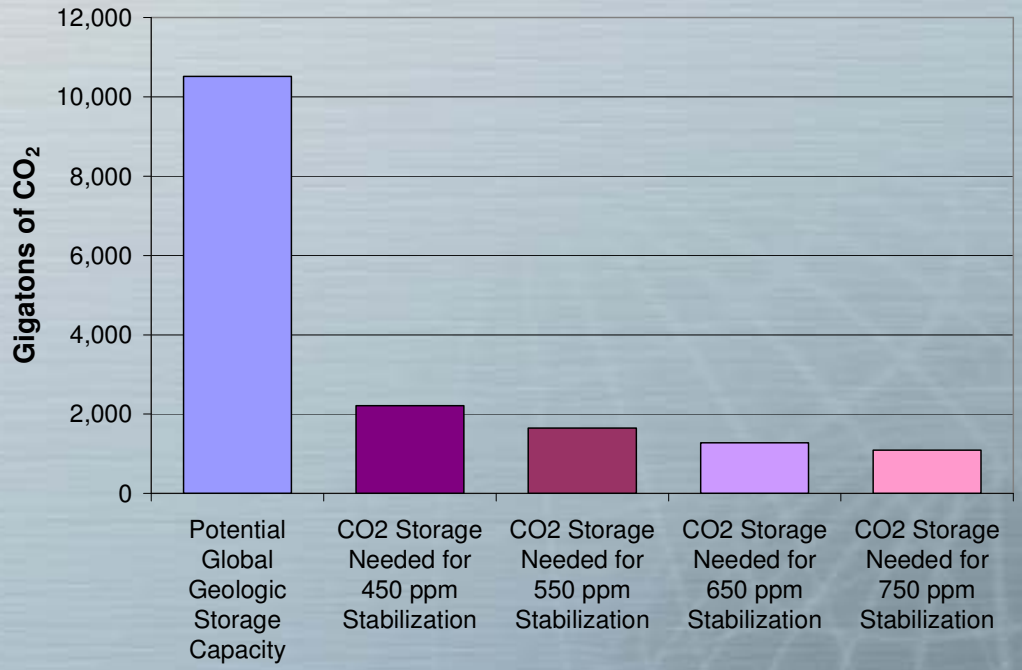
Is there enough CO_2 storage capacity in the world?

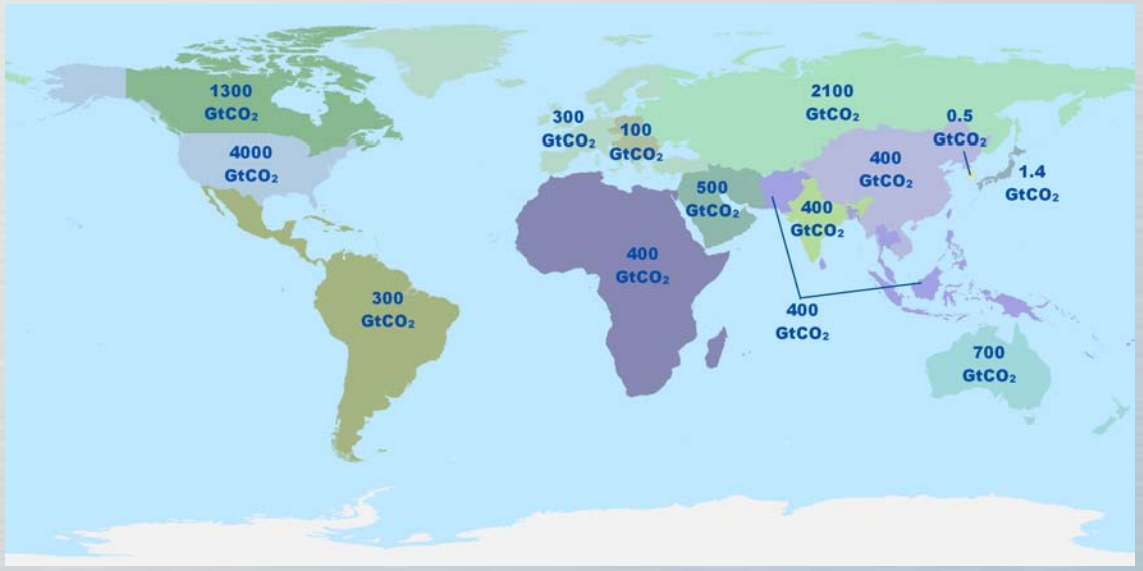
Is it "in the right places"?

Projection of CO_2 Storage Demand
Global 2000-2100

- For stabilization scenarios from 450-750ppmv, most integrated assessment models show a demand for no more than 600 GtC (2,220 $GtCO_2$) storage over the course of this century.
- Published estimates of potential storage capacity place the potential global geologic CO_2 storage capacity at approximately 3,000 GtC (11,000 $GtCO_2$).
- A broad portfolio of carbon management technologies will be needed to fulfill the UNFCCC stabilization goal.

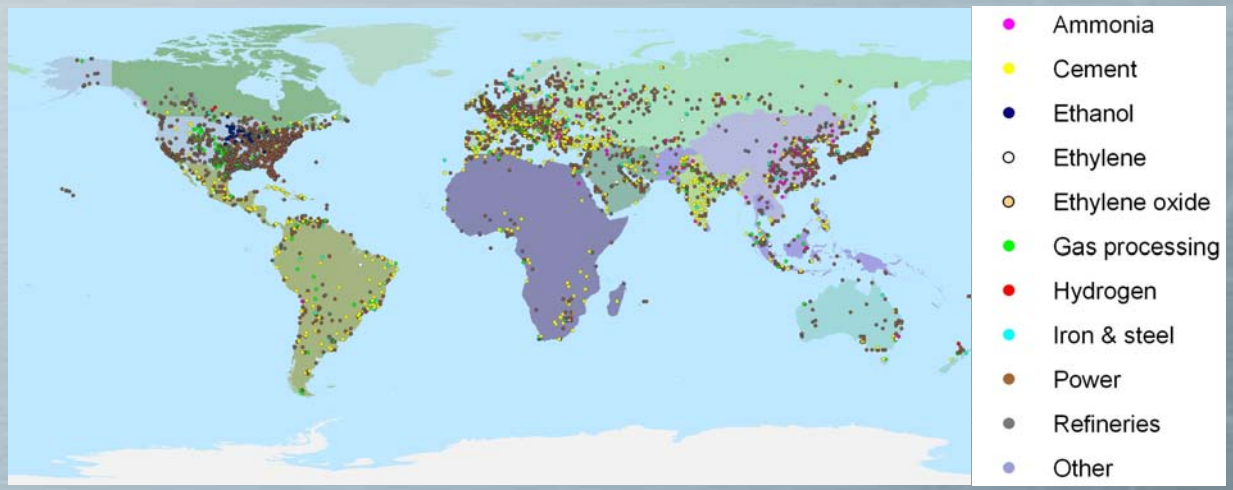


Global CO_2 Storage Capacity
A Very Heterogeneous Natural Resource

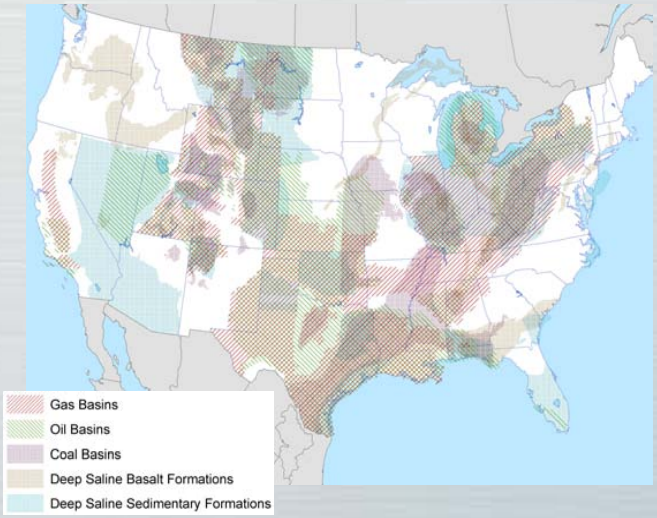


- Potentially 11,000 GtCO2 of available storage capacity
- US, Canada and Australia likely have sufficient CO2 storage capacity for this century
- Japan and Korea's ability to continue using fossil fuels likely constrained by relatively small domestic storage reservoir capacity

- ~8100 Large CO_2 Point Sources
- 14.9 $GtCO_2$/year
- >60% of all global anthropogenic CO_2 emissions

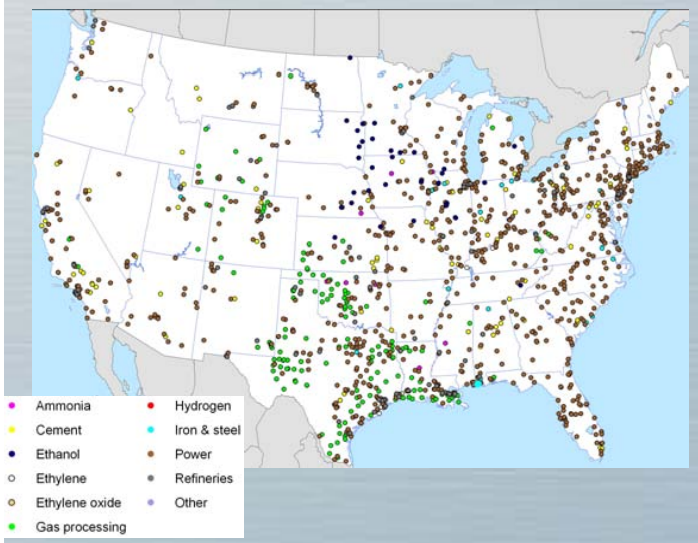


Large Scale CCS Deployment Potential
Diverse Set of Sources and Sinks



3,900+ $GtCO_2$ Capacity within 230 Candidate Geologic CO_2 Storage Reservoirs

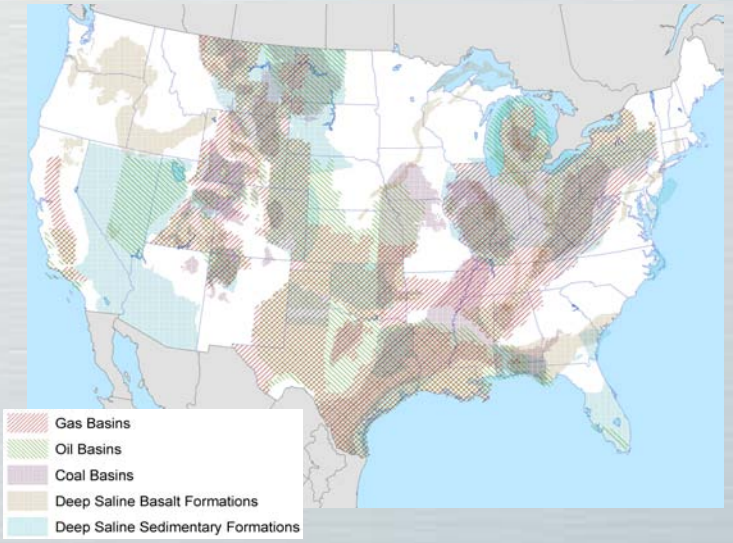
- 2,730 $GtCO_2$ in deep saline formations (DSF) with perhaps close to another 900 $GtCO_2$ in offshore DSFs
- 240 Gt CO2 in on-shore saline filled basalt formations
- 35 $GtCO_2$ in depleted gas fields
- 30 $GtCO_2$ in deep unmineable coal seams with potential for enhanced coalbed methane (ECBM) recovery
- 12 $GtCO_2$ in depleted oil fields with potential for enhanced oil recovery (EOR)

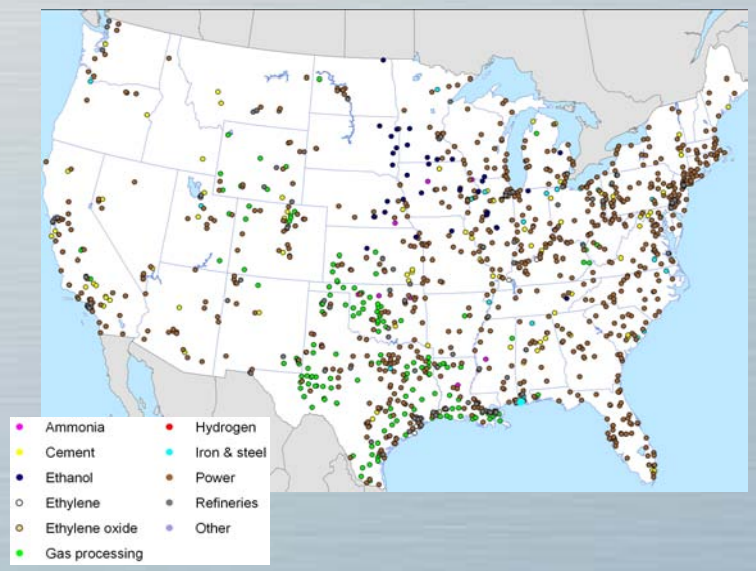


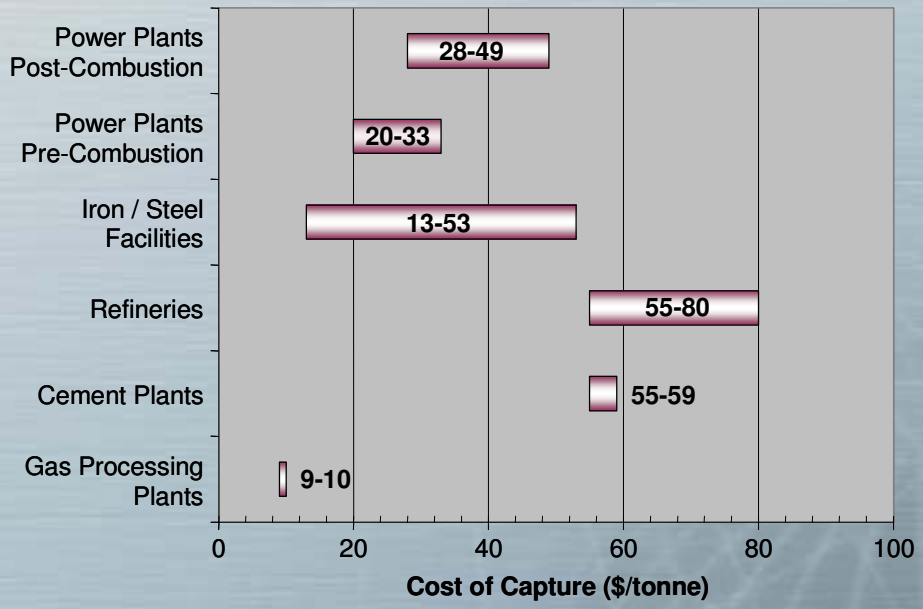
1,715 Large Sources (100+ $ktCO_2/yr$) with Total Annual Emissions = 2.9 $GtCO_2$

- 1,053 electric power plants
- 259 natural gas processing facilities
- 126 petroleum refineries
- 44 iron & steel foundries
- 105 cement kilns
- 38 ethylene plants
- 30 hydrogen production
- 19 ammonia refineries
- 34 ethanol production plants
- 7 ethylene oxide plants

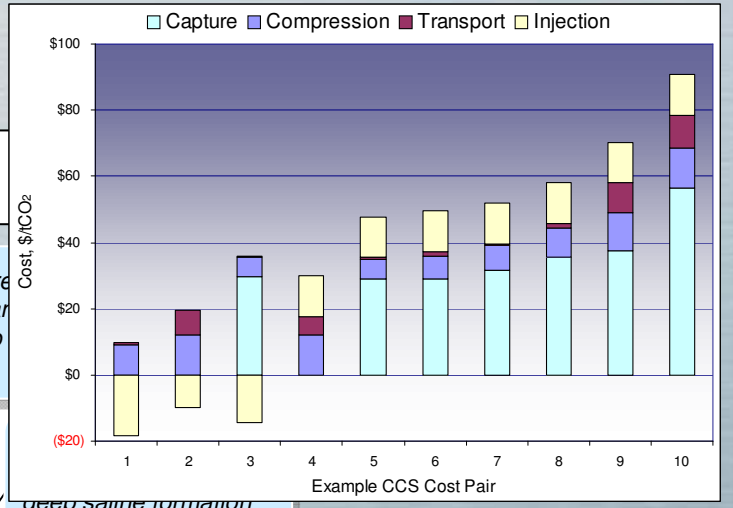
“CCS” not one homogeneous technology and not a homogenous market



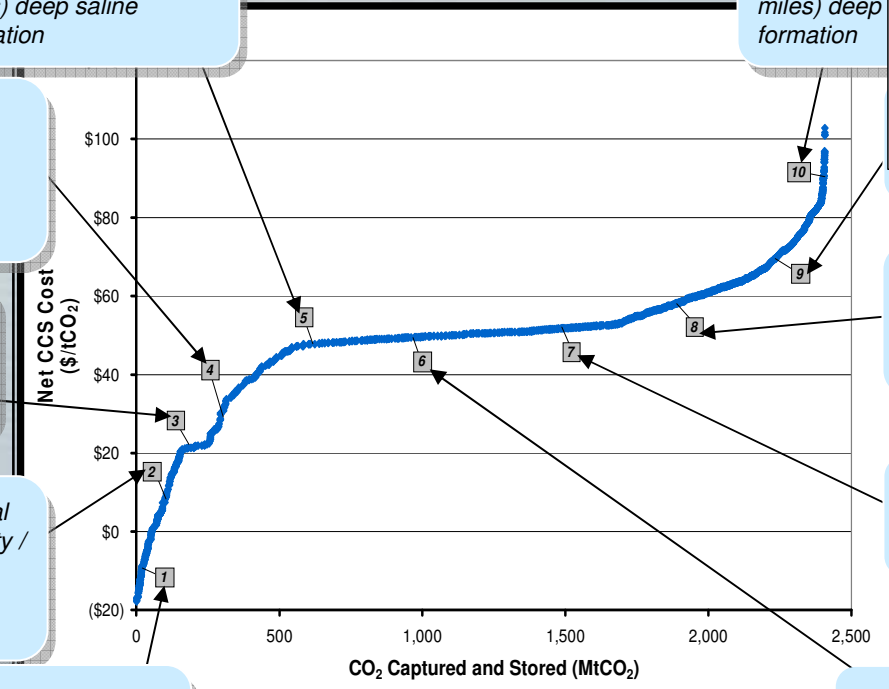




"CCS" not one homogeneous technology and not a homogenous market



The Net Cost of Employing CCS within the United States - Current Sources and Technology



(5) Large, coal-fired power plant / nearby (<25 miles) deep saline formation

(10) Gas-fire plant / distar miles) deep formation

(4) High purity hydrogen production facility / nearby (<25 miles) depleted gas field

(3) Large, coal-fired power plant / nearby (<10 miles) ECBM opportunity

(8) Smaller coal-fired power plant / nearby (<25 miles) deep saline basalt formation

(2) High purity natural gas processing facility / moderately distant (~50 miles) EOR opportunity

(7) Iron & steel plant / nearby (<10 miles) deep saline formation

(1) High purity ammonia plant / nearby (<10 miles) EOR opportunity

(6) Coal-fired power plant / moderately distant (<50 miles) depleted gas field

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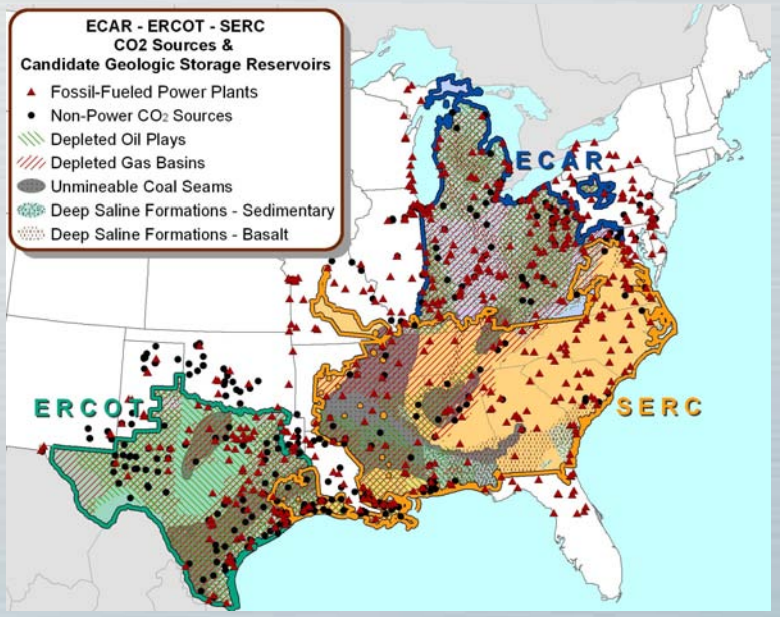
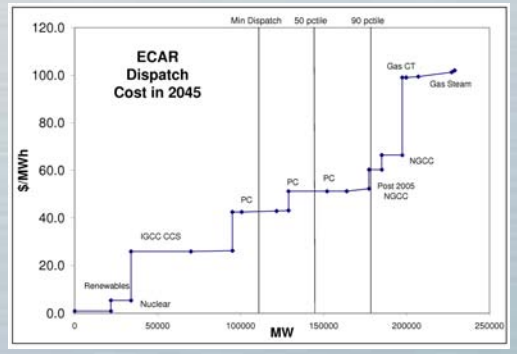
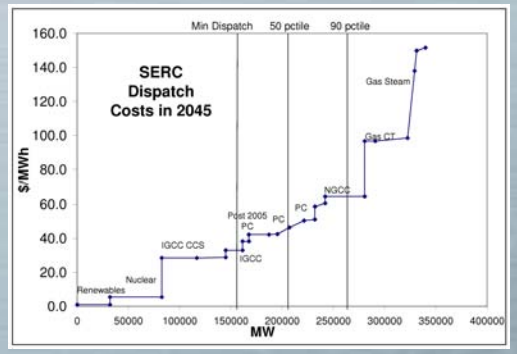
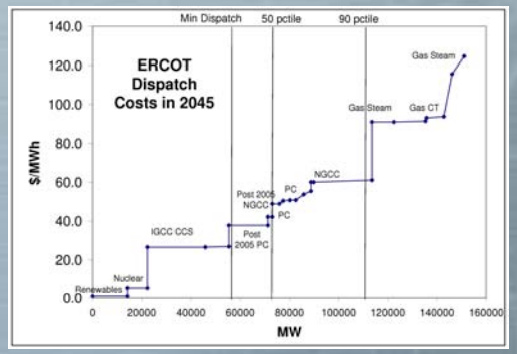
CCS and the U.S. Electric Power Industry

CCS Dispatch Modeling
Carbon-Constrained World



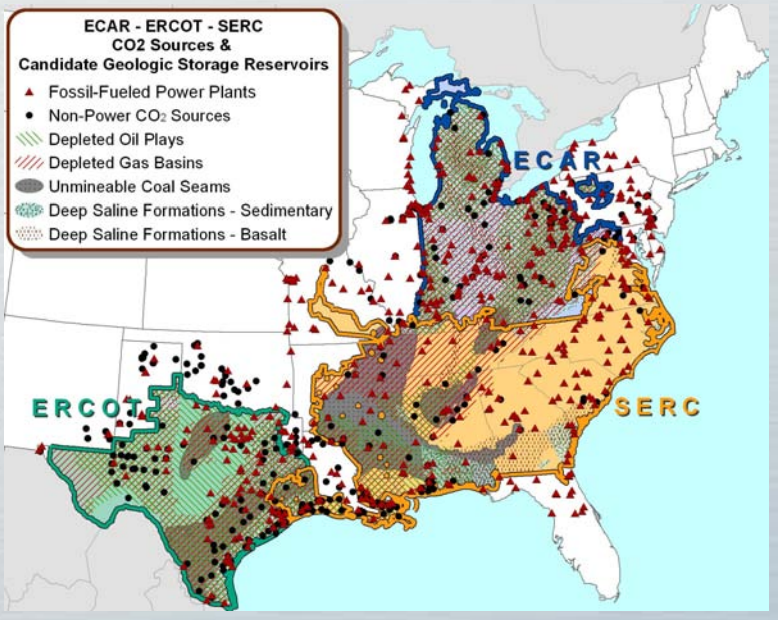




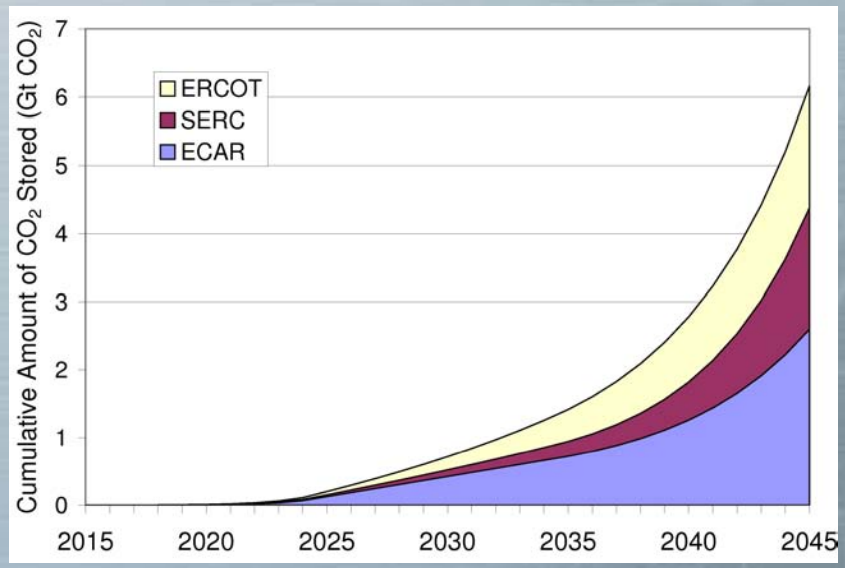


Hypothetical CO_2 emissions control policy starts with a carbon tax of $12/tonCO2 in 2015 and the price of carbon permits escalates at 2.5% per year thereafter.

CCS Dispatch Modeling
Carbon-Constrained World



- By 2045
  - ~150 large IGCC+CCS plants are operational
  - ~900 $MtCO_2$ stored each year
  - >6 $GtCO_2$ cumulatively stored in regional storage formations



CCS Deployment

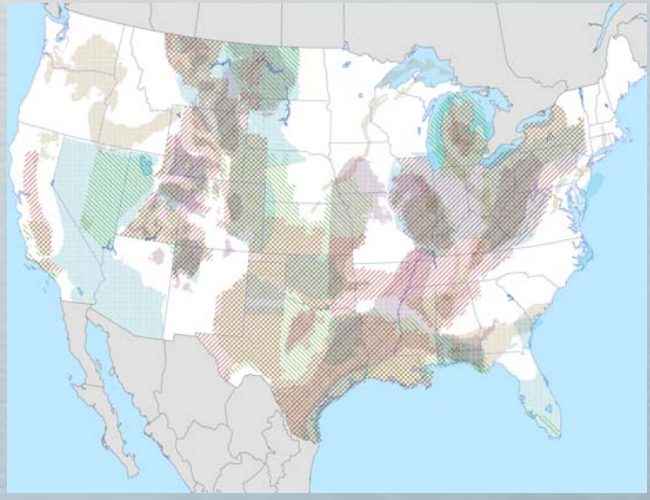
Today and 2050 (on 550 ppmv path)

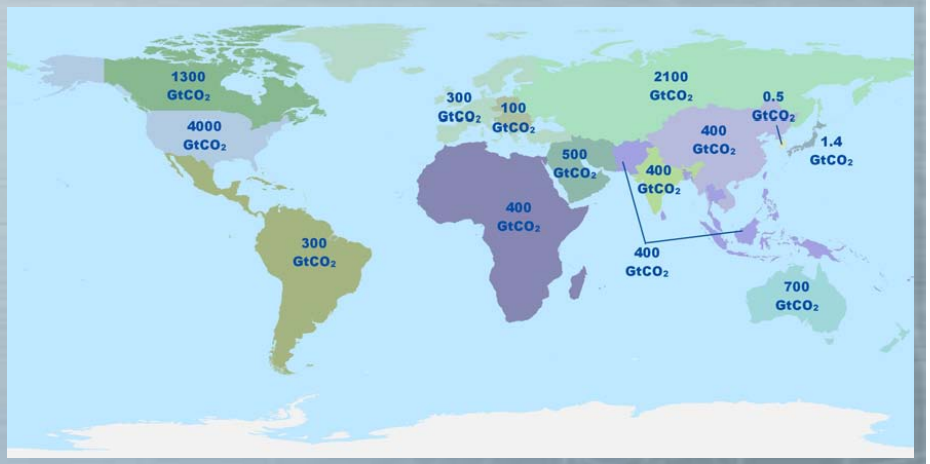
Cumulative Global 2005-2050 CCS Deployment 30,000 $MtCO_2$

Cumulative USA (2005-2050) CCS Deployment 8,000 $MtCO_2$

Take Home Messages
CCS

- Geologic CO_2 storage reservoirs, like many other natural resources, are not homogenous in quality nor in their distribution across the USA and around the world.
  - Some regions will be able to use CCS for a very long time and likely with fairly constant and possibly declining costs.
  - In other regions, CCS appears to be more of a transition technology.





- A near-term high priority research task is to survey candidate CO_2 reservoirs as the availability of this resource directly impacts the likely evolution of a region's future energy infrastructure.

Take Home Messages
CCS

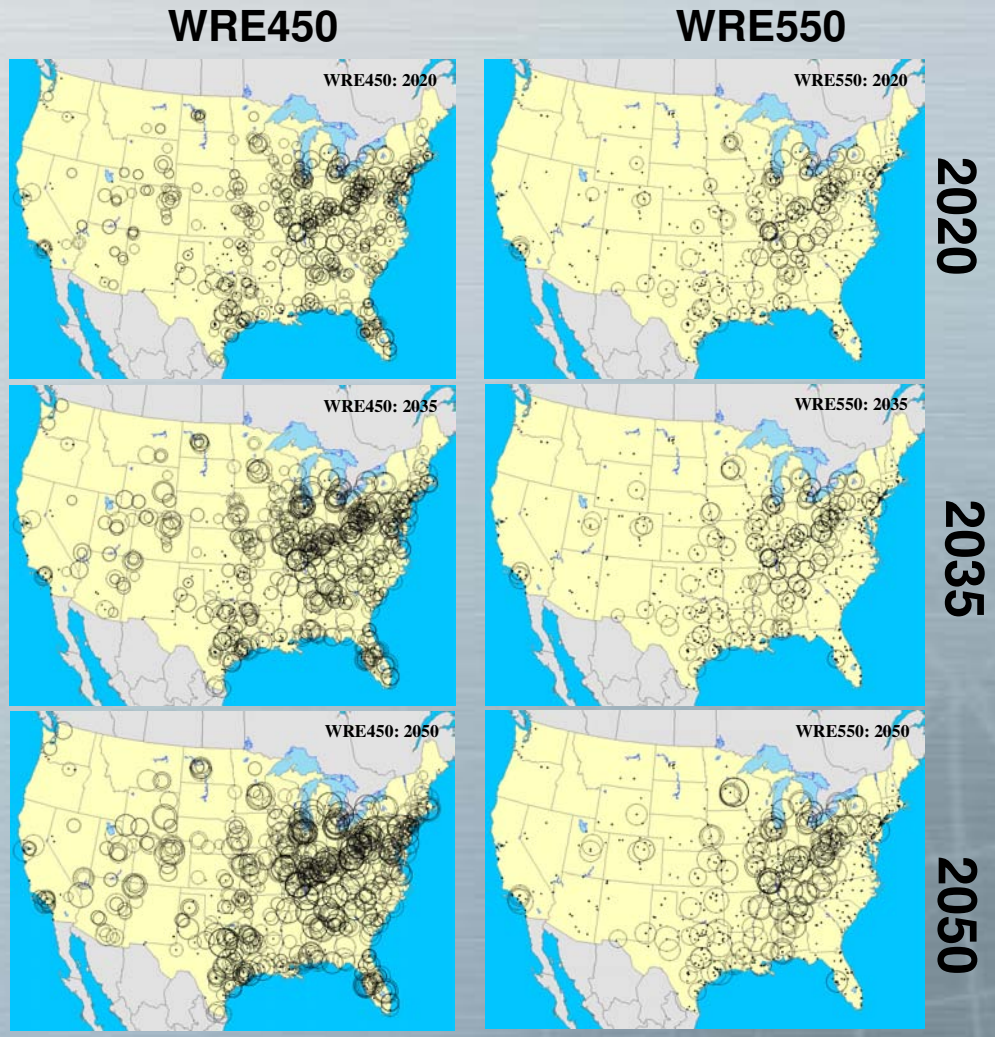
- The overwhelming criteria for siting a CCS-enabled power plant will relate to things like injectivities and total reservoir capacity and not whether there is "buyer for CO_2"
- Deep saline formations will be the workhorse for the USA and many other countries.
- Within the utility sector, CCS is about baseload power.
- While CCS technologies are likely to deploy first in non-power markets first, if CCS is to make a large contribution to addressing climate change it must be effectively integrated with large coal-fired electricity and H_2 production.
- Multiple large-scale field experiments, on different sinks and sources, need to go forward now (FutureGen is just ONE and not enough).

Take Home Messages
CCS

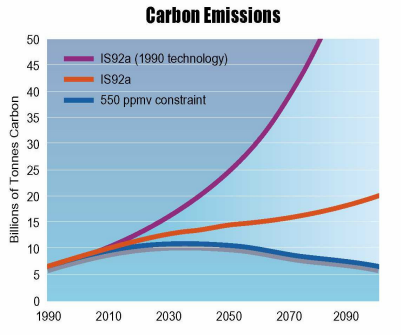
- The cost of capturing CO_2 is **not** the single biggest obstacle standing in the way of CCS deployment.
- No one has ever attempted to determine what it means to store 100% of a large power plant's emissions for 50+ years.
  - How many injector wells will be needed? How close can they be to each other?
  - Can the same injector wells be used for 50+ years?
  - What measurement, monitoring and verification (MMV) "technology suites" should be used and does the suite vary with time?
  - How long should post injection monitoring last?
  - Who will regulate CO_2 storage on a day-to-day basis? What criteria and metrics will this regulator use?

Take Home Messages
CCS

- The potential deployment of CCS technologies could be truly massive. The potential deployment of CCS in the US could entail:
  - 1,000s of power plants and industrial facilities capturing CO_2, 24-7-365.
  - 1,000s of miles of dedicated CO_2 pipelines.
  - 100s of millions of tons of CO_2 being injected into the subsurface annually.
  - The deployment will be so large that it is hard to imagine how positive prices for CO_2 (i.e., buyers willing to pay for pipeline quality CO_2) can be sustained.



Summary



- The UNFCCC goal:
  - speaks to protecting the environment and fulfilling other societal needs
  - speaks to stabilizing concentrations and not emissions
  - demands that we acknowledge that there is no silver bullet technology
- CCS could the reduce the cost of stabilization by hundreds of billions to trillions of dollars.
- Different CO_2 storage solutions will be appropriate for different countries, at different points in time, and have different stakeholder issues. Again there's no silver bullet.
- There are many strategies for managing the risks posed by climate change. It is collectively up to us to put the best possible strategy on the table.