

Eighth Annual Conference on Carbon Capture & Sequestration

Policy/Regulatory Issues/Outreach

Evaluation of Tradeoffs between Carbon Capture and Storage Options and Carbon Trading

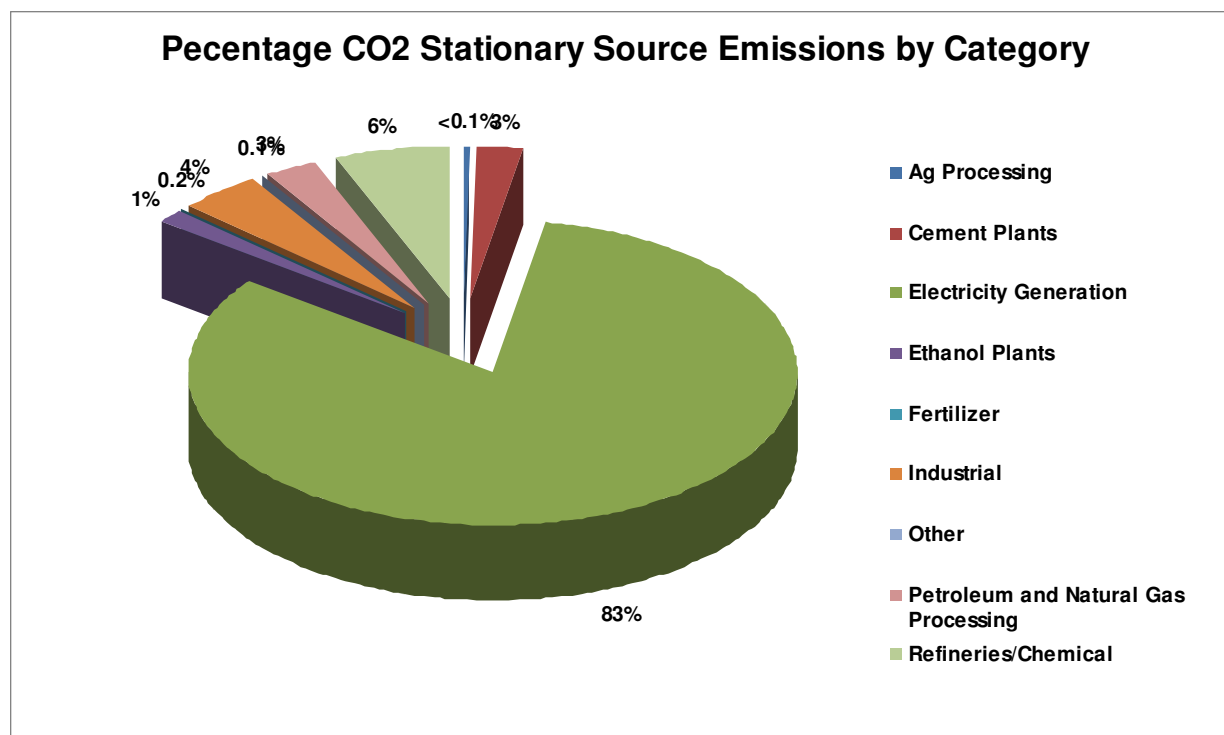
K. Summers, S. Roy, M. Unga, C. Munill, B. Mills, T. Grieb
Tetra Tech
Lafayette, California

May 4 -7, 2009 • Sheraton Station Square • Pittsburgh, Pennsylvania

Role of Carbon Capture and Storage

- Focus on Stationary CO₂ Sources
- Emissions and Proposed Future Reduction Goals
- Carbon Capture and Storage Options
 - Proximity of Sources to Potential Sites
 - Emission Allowances, Trading, Auctions, Offset Credits
 - How much CO₂ can be captured?
 - At what cost?

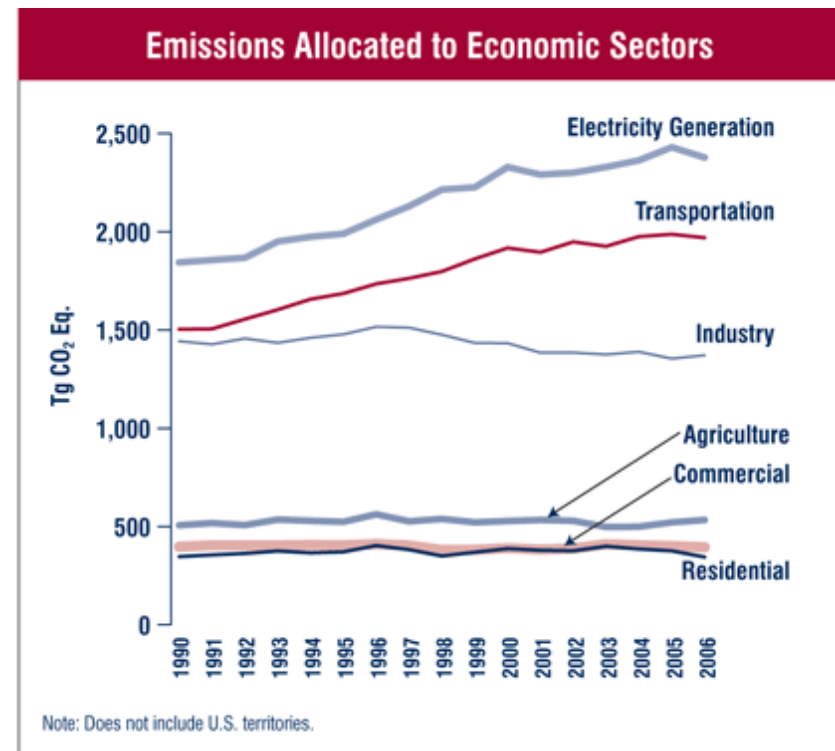
Summary of Stationary CO₂ Sources in US



Stationary Source Category	CO ₂ Emissions M Metric Ton/Year	Number of Sources
Ag Processing	6.3	140
Cement Plants	86.3	112
Electricity Generation	2,702.5	3,002
Ethanol Plants	41.3	163
Fertilizer	7.0	13
Industrial	141.9	665
Other	3.6	53
Petroleum and Natural Gas Processing	90.2	475
Refineries/Chemical	196.9	173
Totals	3,276.1	4,796

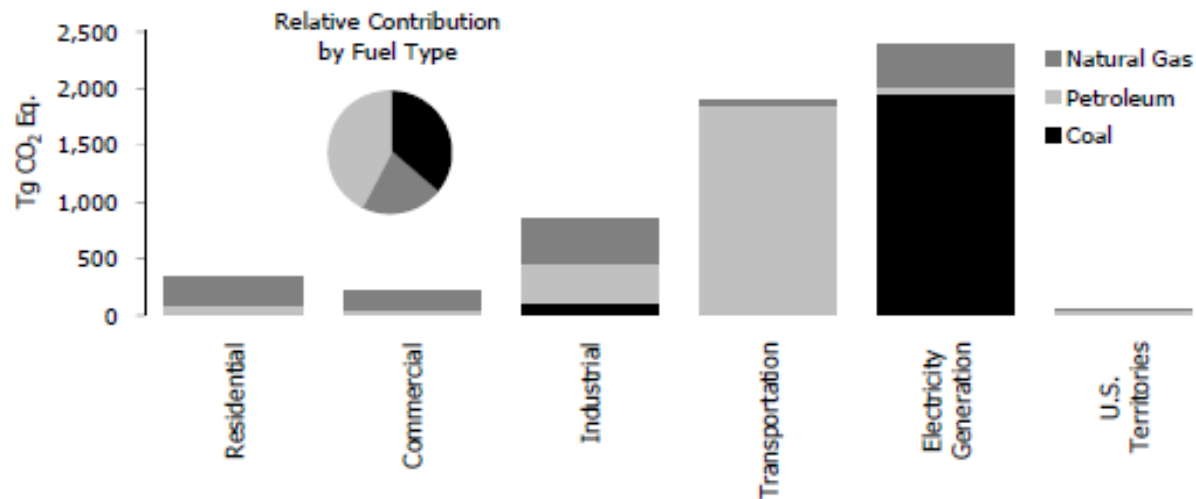
Changes in US Greenhouse Gas Emissions 1990-2006

- Emissions from Electricity and Transportation Sectors increased from 1990-2006
- Emissions from Industry decreased
- Agricultural, Commercial, and Residential Sectors largely unchanged
- In 2006, total CO₂ emissions:
 - 5,983.1 M Metric Tons
 - Electricity sector emitted 39.4% 2,360.6 M Metric Tons,
 - Industry sector emitted 16.4% 984.1 M Metric Tons,
- In 2005, total CO₂ emissions:
 - 6,074.3 M Metric Tons
 - Electricity sector emitted 39.7 % 2,412.3 M Metric Tons



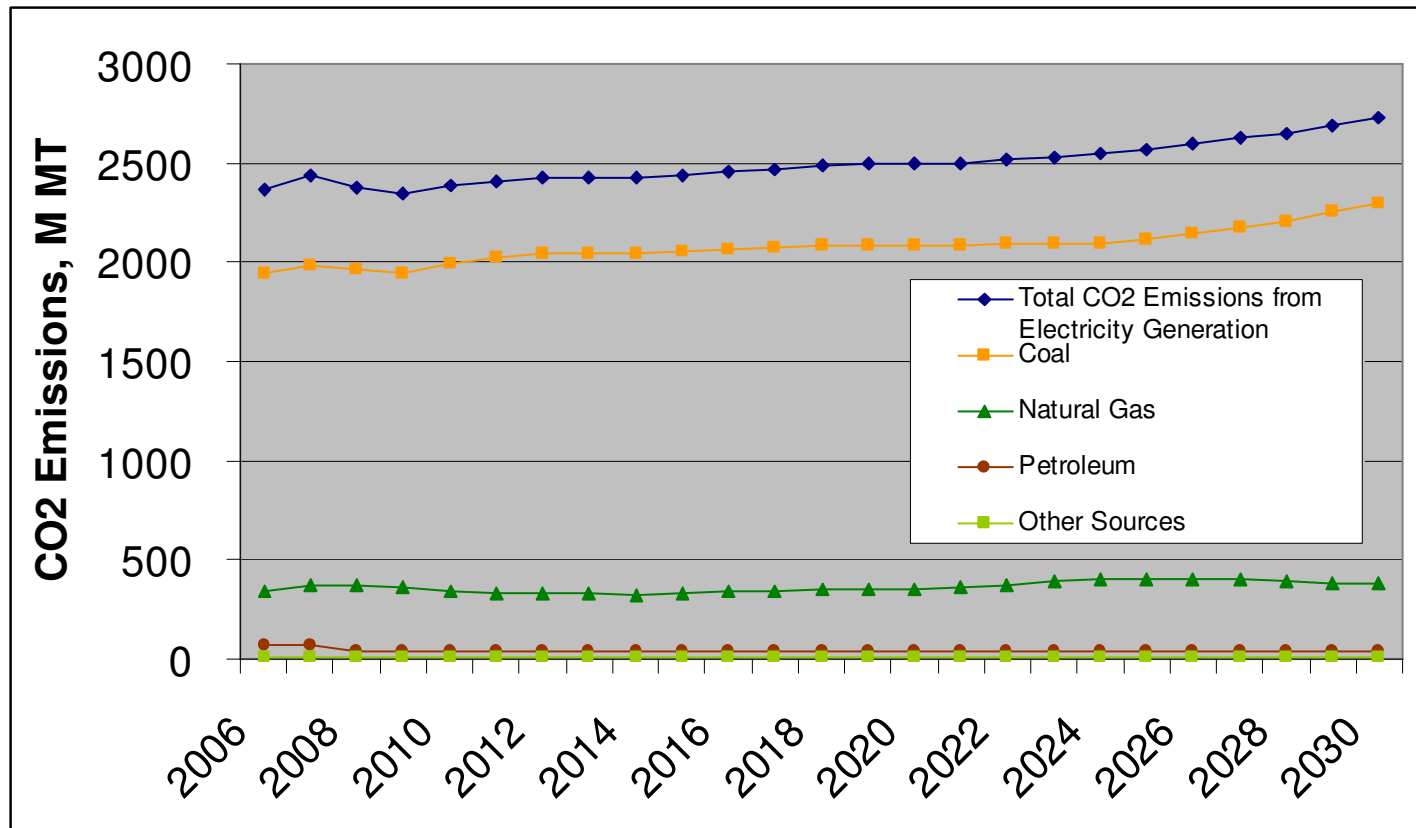
US EPA, 2008

2007 US Energy Sources & CO₂ Emissions



- Mix of US Energy Sources
 - Coal 22%
 - Natural Gas 22%
 - Petroleum 39%
 - Renewables 7%
 - Nuclear 8%

Projected CO₂ Emissions by Fuel Type in US



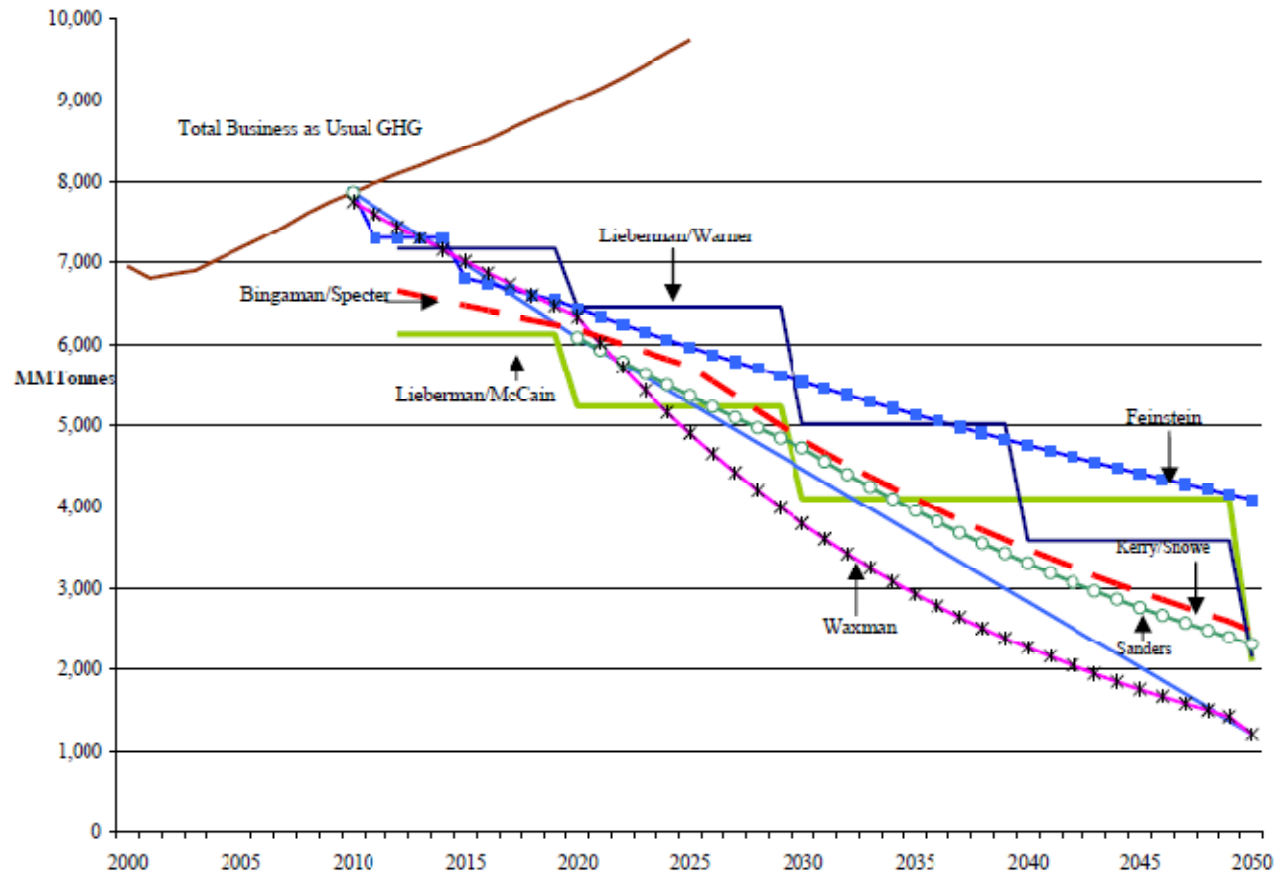
Key Drivers for Future US Projections

Less near-term use of coal, but new plants to meet power needs after 2020

Increased renewables from 8% in 2007 to 14% in 2030

Decreased emission growth rate from 0.8%/yr (1980-2007) to 0.3%/yr

Example: Proposed US GHG Emission Targets



Targets are expressed as CO₂ equivalents

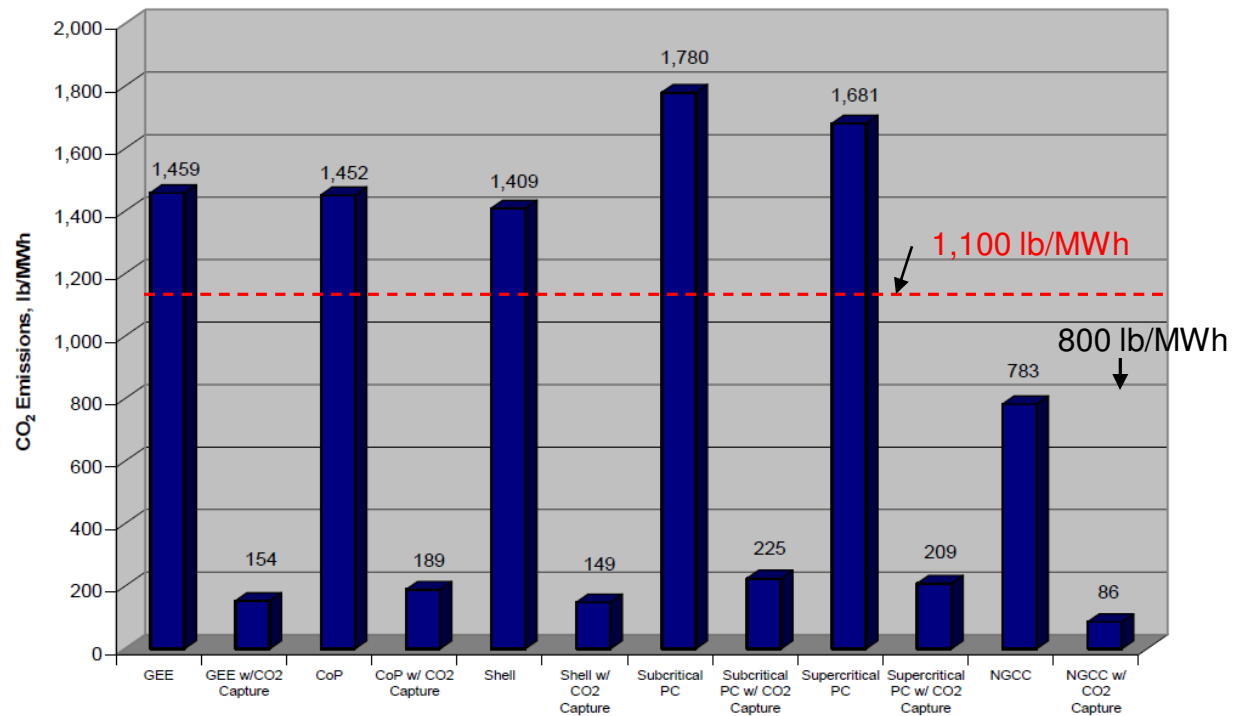
ICF, 2009

Potential for Carbon Sequestration

- What percent of large coal-fired plants overlie or are near (within 50 miles) deep saline aquifers or oil and gas reservoirs?
- What percent of CO₂ emissions could be captured by these plants?
- What percent of CO₂ emissions from other industrial sources are located within reservoirs and could be captured?
- How does this compare to proposed reduction goals?

CO₂ Emissions by Advanced Plant Types

- Waxman-Markey Bill proposes standards for CO₂ emissions from new coal-fired power plants
- After Jan 2015, 1,100 lbs/MWh
- After Jan 2020, 800 lbs/MWh
- Could require some units with CO₂ capture



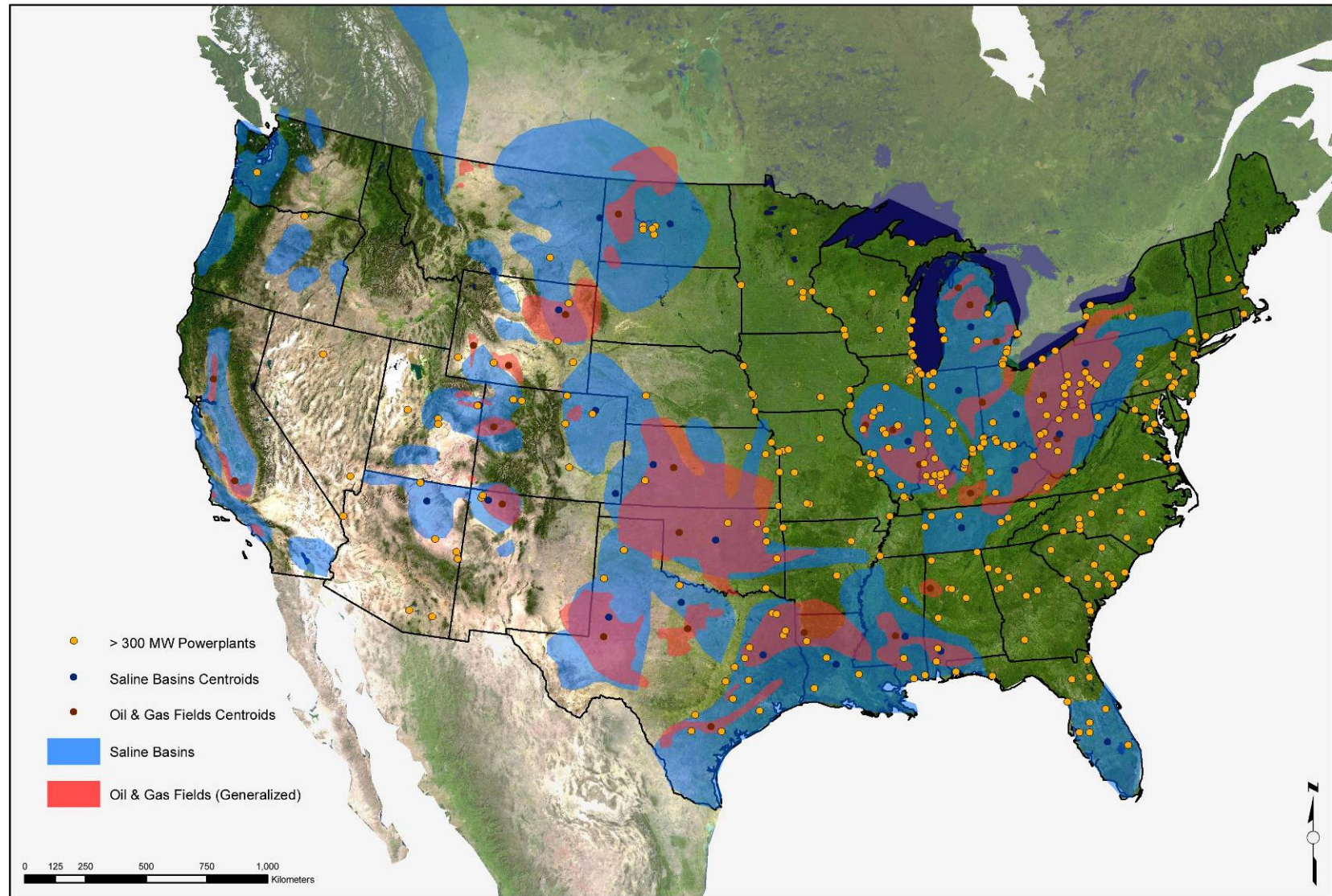
Existing plants: Coal-fired 1583 to 3694 lbs/MWh
Natural gas 823 to 2894 lbs/MWh

DOE, 2007

Example: Emission Control Reduction Options

- **Emission Allowances for GHGs** (Waxman-Markley Bill discussion draft)
 - 2012 4,770 M allowances; 1 allowance = 1 ton of CO₂ emitted
 - 2050 1,035 M allowances
 - Electric utilities >250 MW need 1 allowance per ton of CO₂ eq emitted after 2012
- **Trading Options**
 - Allowances can be traded; 2-year rolling compliance period
 - Banking and Borrowing allowed over 2-5 years with limits
 - First auction in 2012
 - Strategic reserve of allowances
- **Offset Credits**
 - Requires 5 credits for 4 tons of emissions
 - Total Limit of 2B tons for offsets; 1B domestic, 1B international
- Offset Credits allowed for permanent sequestration
 - Geologic sequestration in certified sites would be allowed

Coal-Fired Power Plants (>300 MW)



CO₂ Emissions for Large Coal-fired Plants Near Potential Sequestration Sites

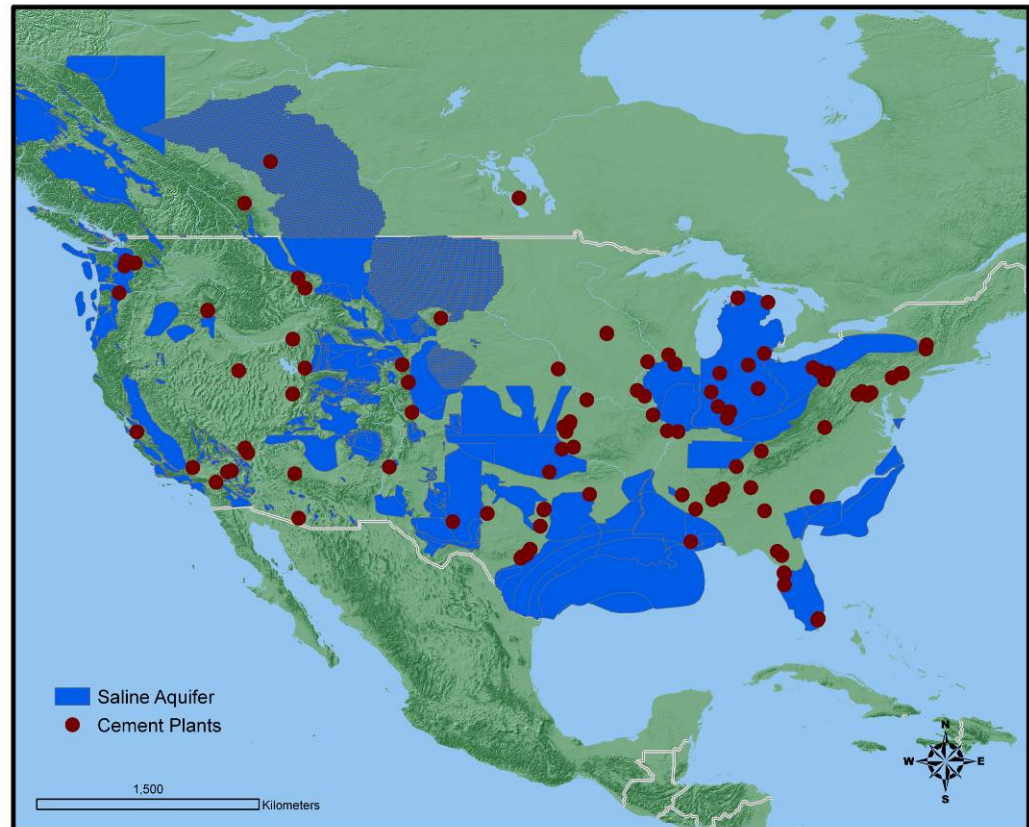
- Coal-fired power plants >300 MW located over potential sequestration reservoirs emitted 964 M Metric tons CO₂ in 2005
- Plants within 50 miles of reservoirs emitted 386.6 M Metric tons CO₂
- Total CO₂ is 1,350.6 M Metric tons or 56 % of all CO₂ emissions by electricity sector
- Additional 19 plants >250 MW have total CO₂ emissions of 37.9 M Metric tons
- Proposed economy-wide reduction target in draft Waxman-Markey Bill based on 2005 emissions of 7,206 M Metric tons CO₂ eq :
 - 2012 <97% 216 M Metric tons
 - 2020 <80% 1,441 M Metric tons
 - 2050 <17% 5,981 M Metric tons
- To meet 2020 economy-wide target would require other sources to capture CO₂

Detailed Example: Emission Allowances

- Total Allowances: 4,770 M in 2012, decreasing thereafter
- 2012 Reduction Goal: 216.2 M Me T
 - Typical 500 MW coal-fired plant emits about 2.72 M Metric Tons CO₂
 - 80 plants required for reduction
- Alternative using Large Plants
 - 147 >300 MW plants within potential saline reservoir footprints
 - 14 largest plants needed to meet goal
 - Estimated capital cost of carbon capture and storage per plant: \$1B to \$1.4B
 - Estimated combined cost: \$17-22B
- Cost for >300 MW Plant near reservoir
 - Estimated capital cost for CO₂ capture & storage, \$0.8B for 10 M Metric Tons CO₂
 - 50 mile CO₂ pipeline, \$37 -90M using range of estimates for 22-inch diameter pipe
 - Price of allowance to offset cost, \$5 per ton when annualized over a 40 year period; if capital cost recovered in one year would need to be greater than \$79-84 per ton
 - RGGI trading of carbon offsets in last six months \$3.05-3.51 per ton
- Future Years would require reductions by other types of CO₂ sources

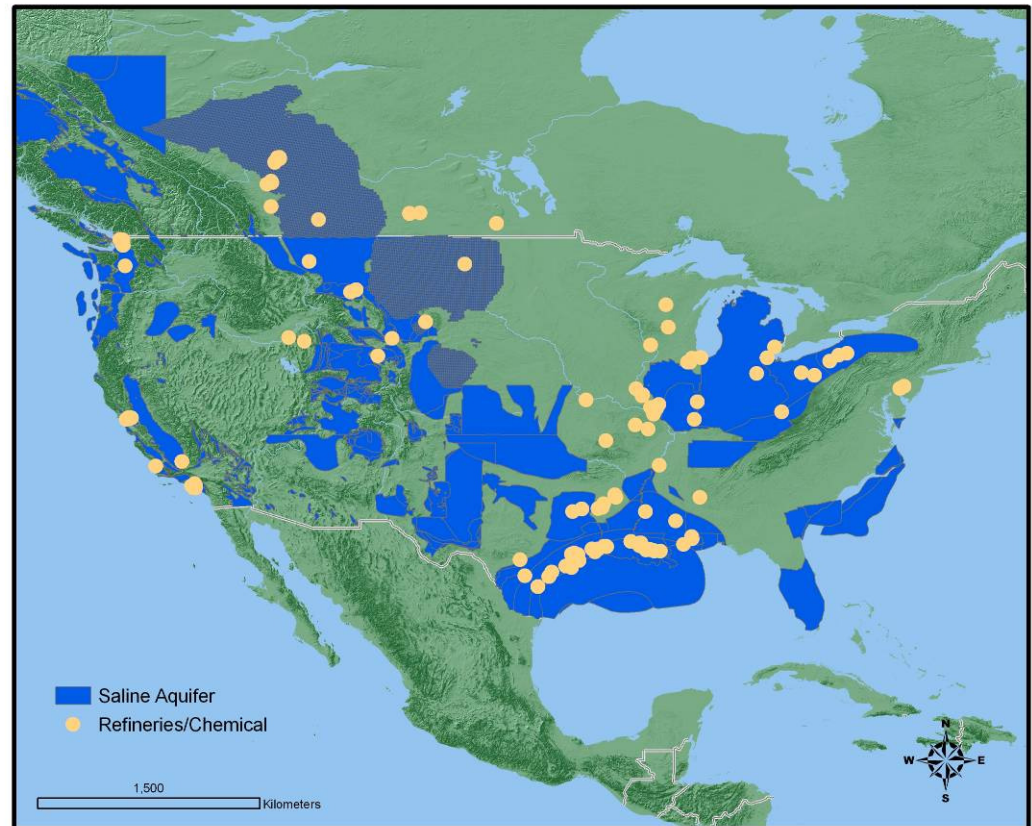
Cement Plants within Reservoirs

- 37 US Plants within Reservoirs
- Total CO₂ emissions, 24.54 M Metric Tons/yr; representing 34 plants and 28.4% of emissions
- Annual CO₂ emissions,
 - 6 plants >1 MMT
 - 33 plants >0.25 MMT
 - 3 plants had no data
- 33 plants subject to emission limits



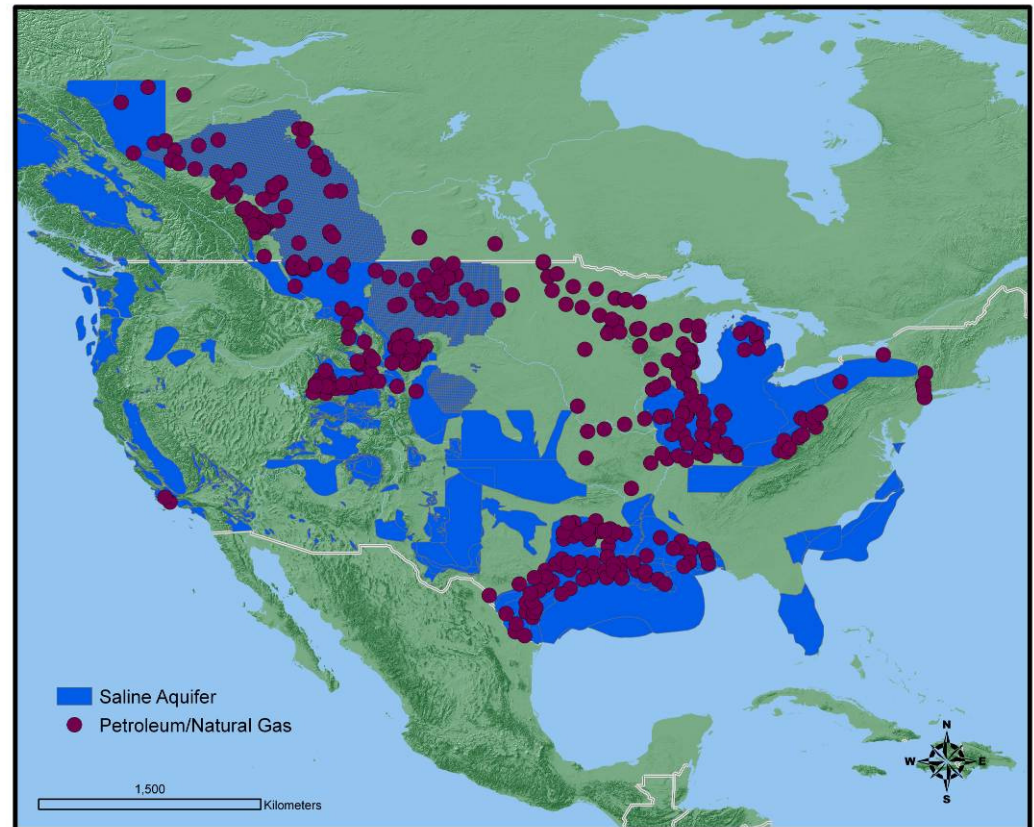
Refineries/Chemical Plants within Reservoirs

- 118 US Plants within Reservoirs
- Total CO₂ emissions, 164.02 M Metric Tons/yr; representing 118 plants and 83.3% of emissions
- Annual CO₂ emissions,
 - 58 plants >1 MMT
 - 88 plants >0.25 MMT
- 88 plants subject to emission limits



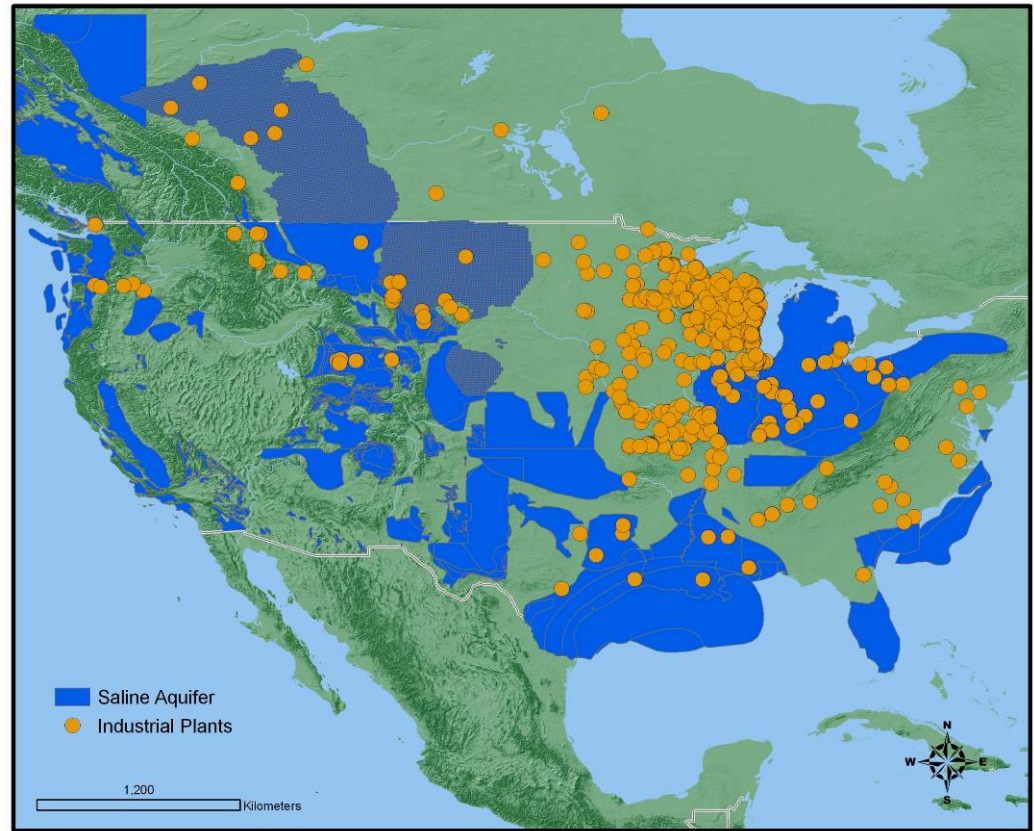
Petroleum/Natural Gas Processing Plants within Reservoirs

- 316 US Plants within Reservoirs
- Total CO₂ emissions, 24.02 M Metric Tons/yr; representing 299 plants and 26.6% of emissions
- Annual CO₂ emissions,
 - 1 plant >1 MMT
 - 123 plants >0.25 MMT
 - 17 plants had no data
- 123 plants subject to emission limits



Other Industrial Sources within Reservoirs

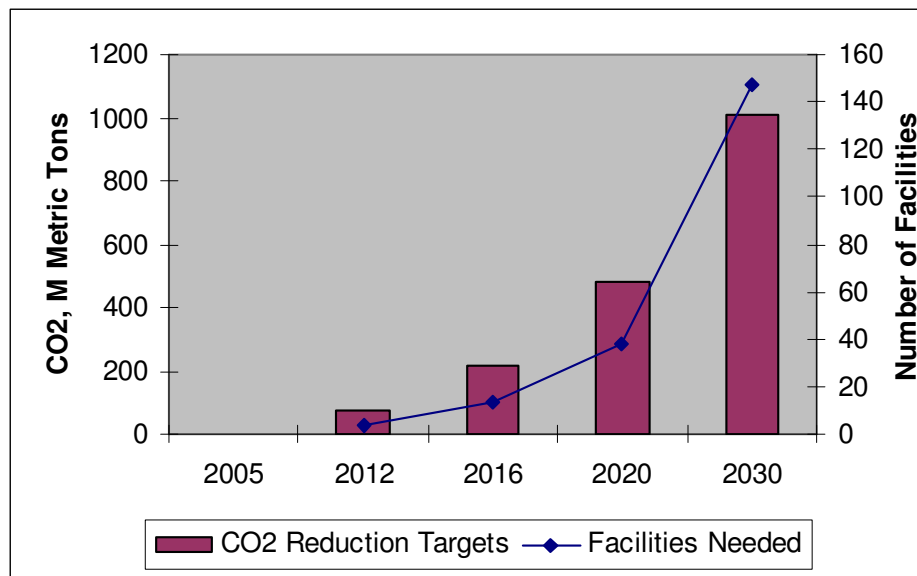
- 83 US Plants within Reservoirs
- Total CO₂ emissions, 72.63 M Metric Tons/yr, representing 78 plants and 51.2% of emissions
- Annual CO₂ emissions,
 - 16 plants >1 MMT
 - 29 plants >0.25 MMT
 - 5 plants had no data
 - 14 largest, iron & steel
- 29 plants subject to emission limits



Evaluation of Non-coal Sources

- Other sources small compared to coal-fired power plants
- Given the required investment to develop and implement capture technology, CCS option likely to be feasible primarily for coal plants in next 20 years
- Total CO₂ emissions from major non-coal stationary sources overlying sequestration reservoirs are 285.2 M metric tons

Proposed CO₂ Reduction Targets



- Targets for electricity sector up to 2020 can be met using coal-fired plants
- In 2030, could meet with all “within” coal plants and 9 natural gas power plants; or 5 coal plants up to 50 miles from reservoirs
- To meet total goal for covered source types in 2020, also need reductions at industrial facilities

Summary

- Large stationary sources are located near potential sequestration sites: coal sources likely to be most promising CCS targets
- Total CO₂ emissions from stationary sources within deep saline reservoir footprints estimated as 1,249.2 M Metric tons; 964 MMT from coal-fired plants >300 MW
- Carbon capture and storage option needs time for full-scale development
 - Post-capture amine-based sorption tested at 10 ton/day for coal-based flue gas
 - Target date of 2012 likely to be delayed: 2016 to 2020
 - IEO 2008 Outlook does not expect significant commercial CCS before 2020
- To promote geologic sequestration:
 - Need emission allowance price approximately \$5 per ton or greater
 - Add bonus allowances (e.g., Dingell-Boucher bill proposed \$90 to \$50/ton for first 10 years)
 - Improve capture technology so lower cost; current range from \$58 to \$300/ton
- Building capture facilities larger than needed for given plant increases cost, so unlikely to promote joint facilities from distant sources without support for long distance pipelines
- Capture of other types of industrial sources needed to meet long-term reduction goals: 1,441 MMT by 2020 and 3,026 MMT by 2030