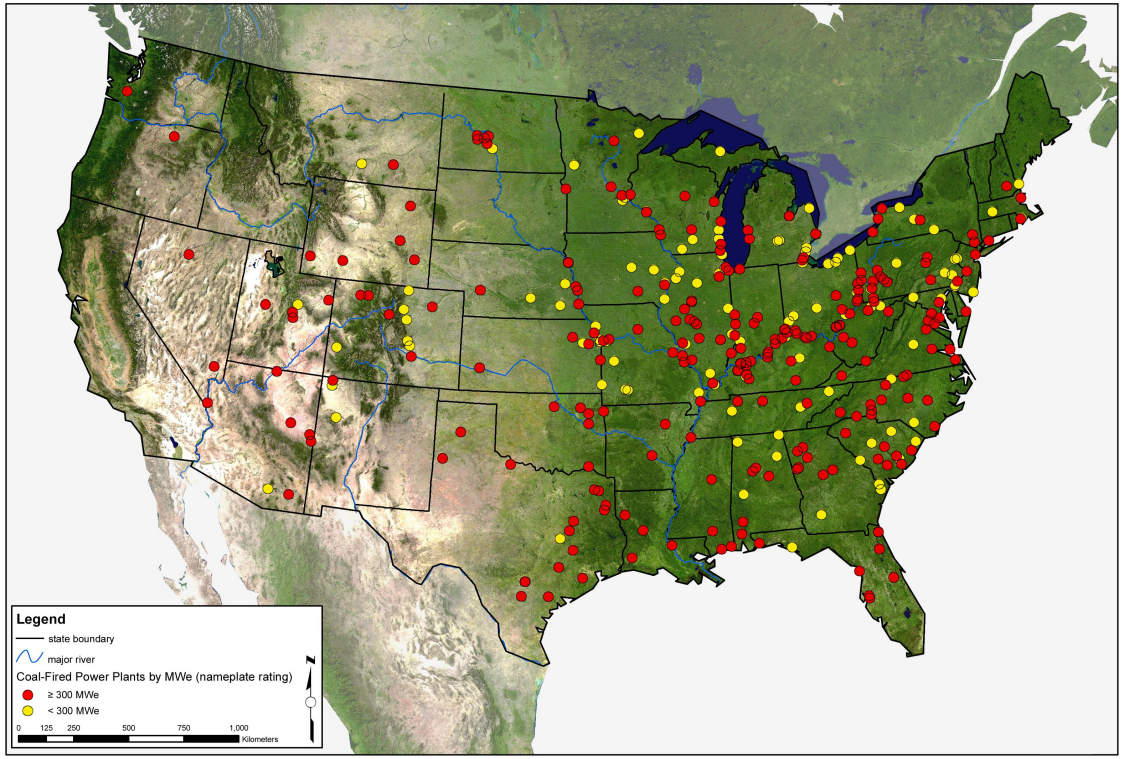
Comparison of Regional and Local CO_2 Pipeline Networks



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Lafayette, CA

7th Carbon Capture and Sequestration Conference
Pittsburgh, PA, May 7, 2008

Overview

- Large fraction of the current US coal plants are distant from potential sequestration sites.
- Transportation of captured gas to these sites can be a significant constraint to CCS implementation.
- To better evaluate the magnitude of the problem, we developed alternative scenarios of pipeline transport and associated costs for coal fired plants in the US.

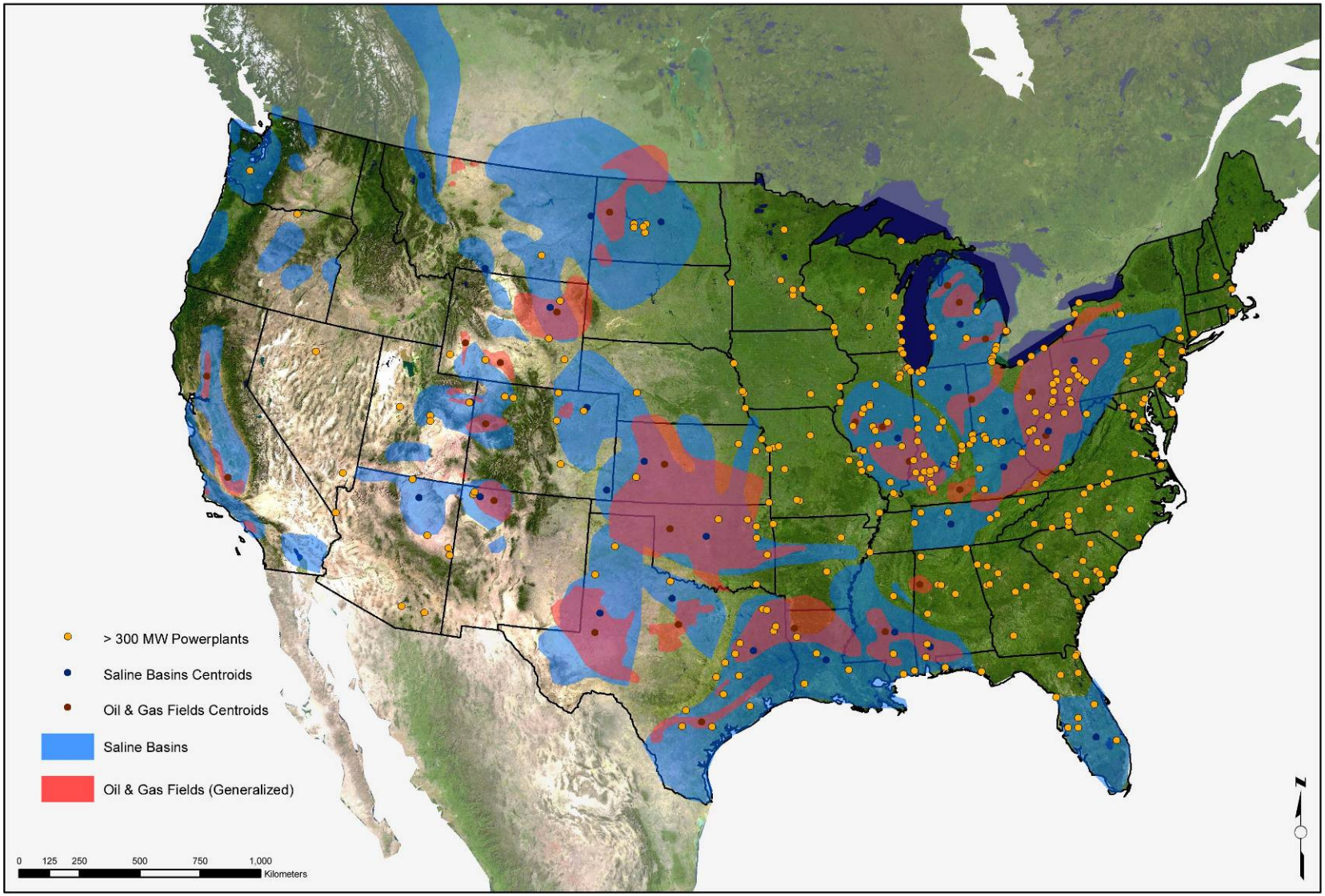
Assumptions

- Focus on coal plants > 300 MWe
- Assumes sequestration targets will be among the types of subsurface reservoirs previously evaluated: saline aquifers, oil and gas fields, and un-mineable coal seams (in future)
- Offshore sequestration not considered

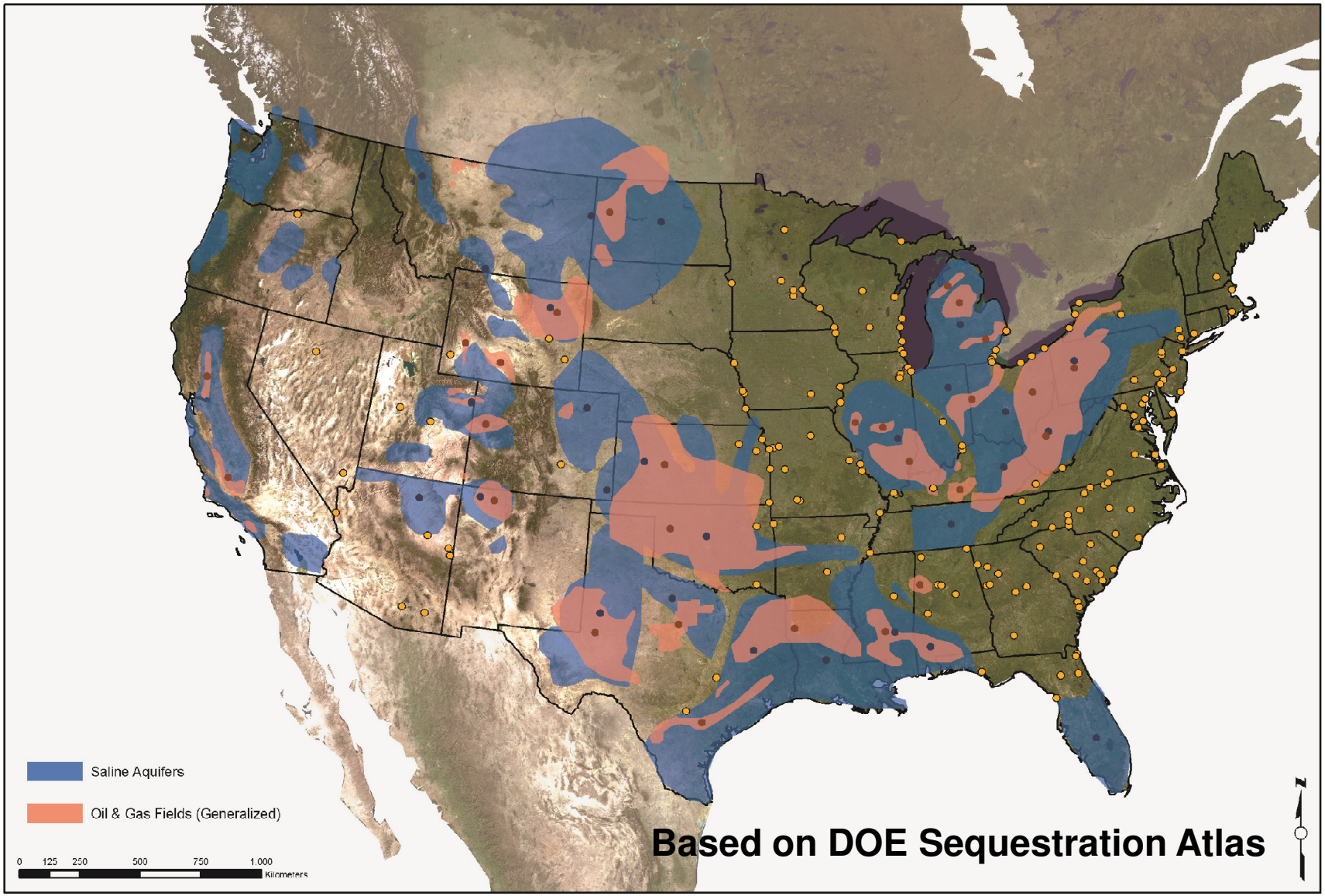
Approach

- Consider 3 pipeline scenarios:
  - Scenario 1: sequestration only for plants overlying or near (<50 mi) potential deep saline formations
  - Scenario 2: Propose a network of trunk lines, with captured gas from distant plants transported using feeder lines
  - Scenario 3: More extensive trunk link network than Scenario 2
- Representative locations for captured gas injection selected within generally defined formations from DOE Sequestration Atlas
- Distances of feeder lines to trunk lines, and distances of trunk lines to injection points calculated using GIS tools

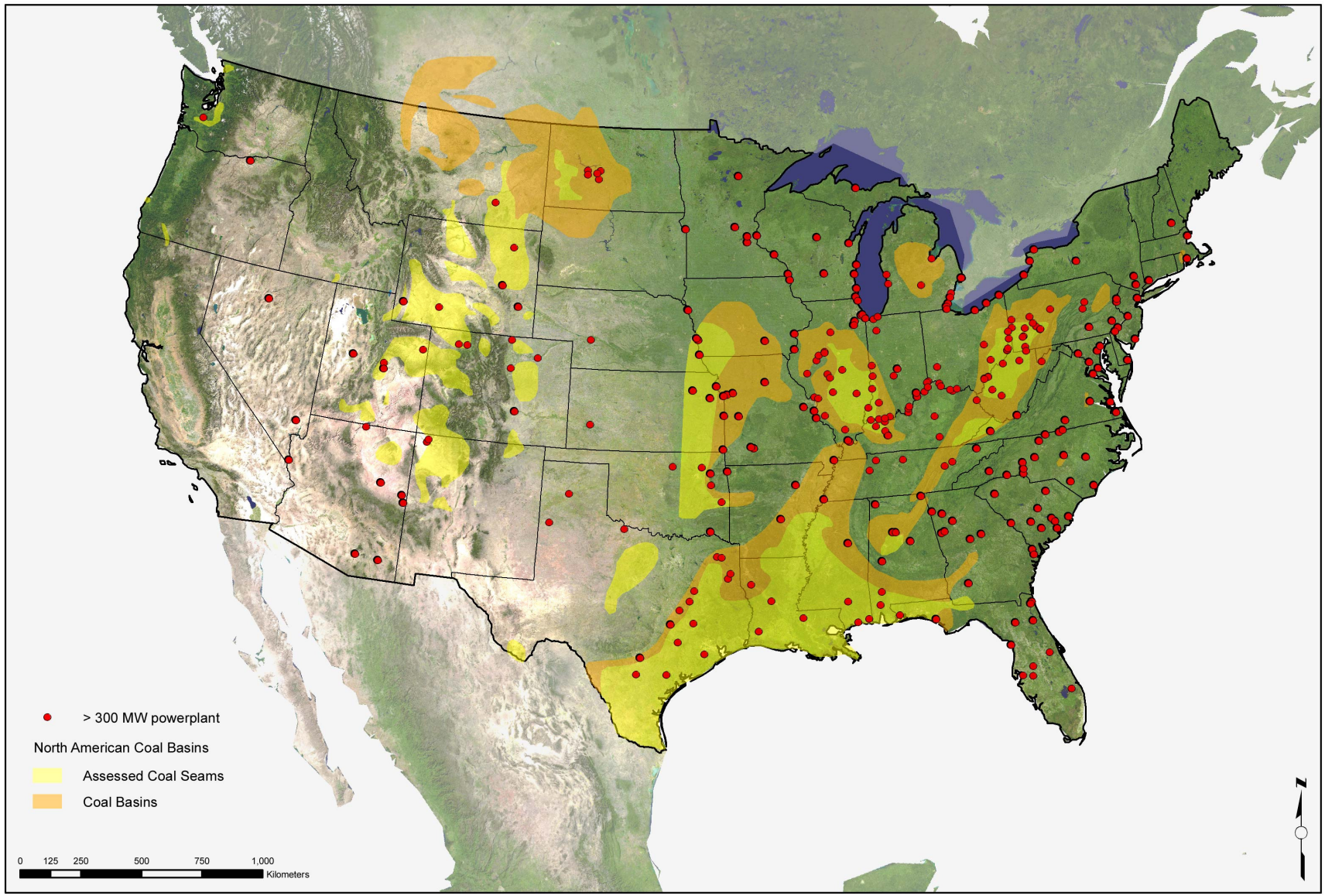
Coal-Fired Power Plants (>300 MW)



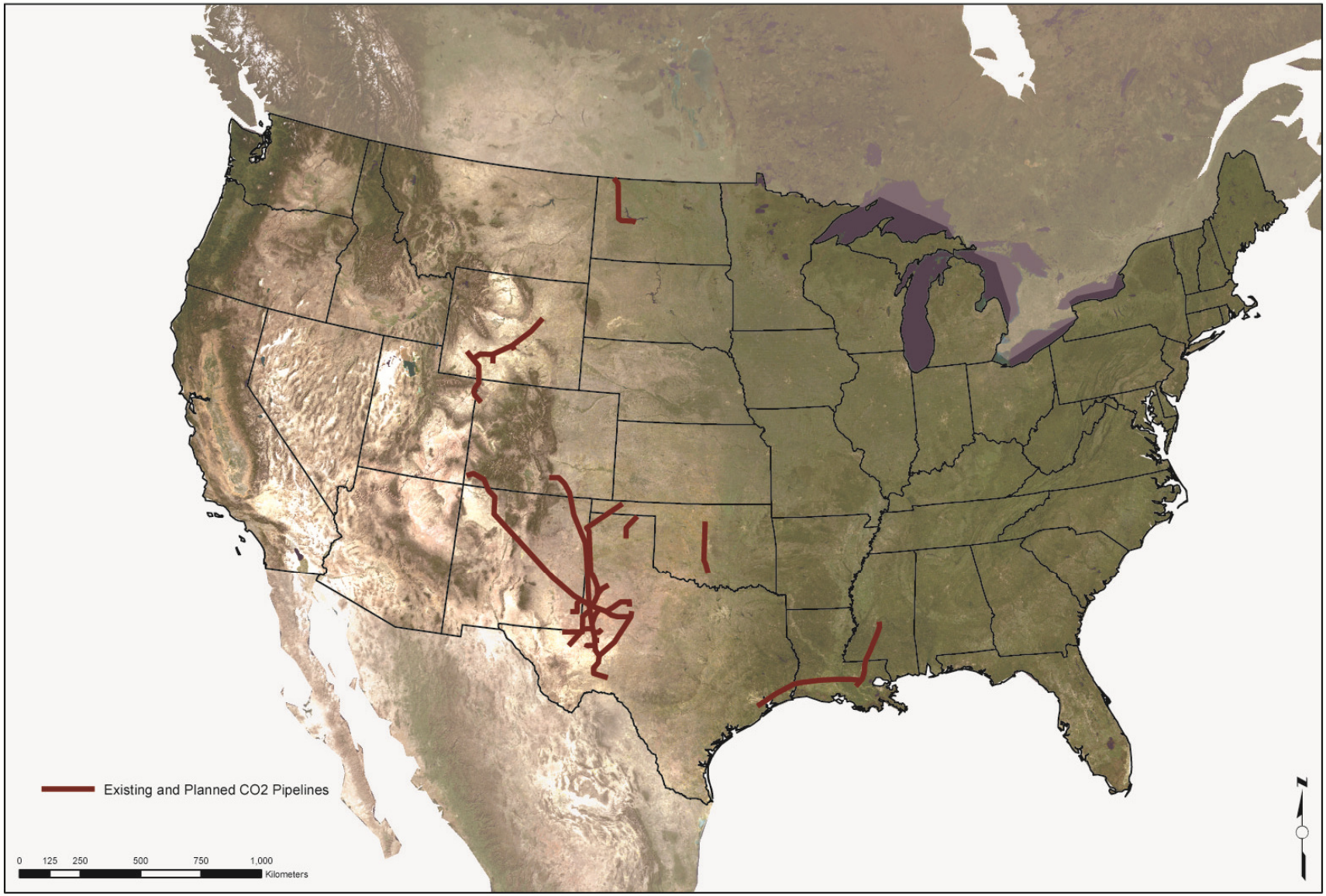
Plants Outside Major Potential Carbon Sequestration Areas



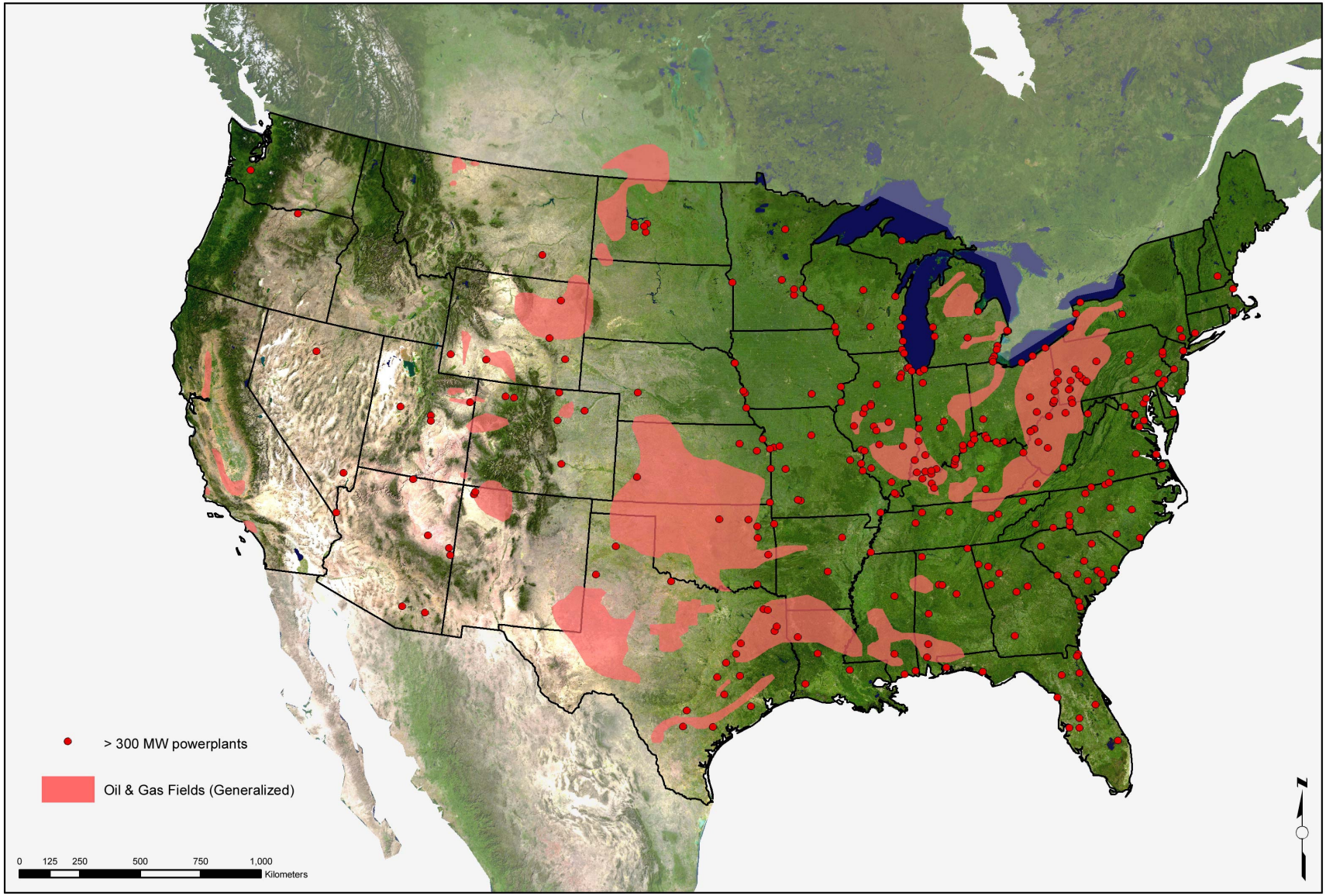
Potential Coal Basins and Coal Seams



Existing and Planned CO_2 Pipelines



Oil and Gas Reservoirs



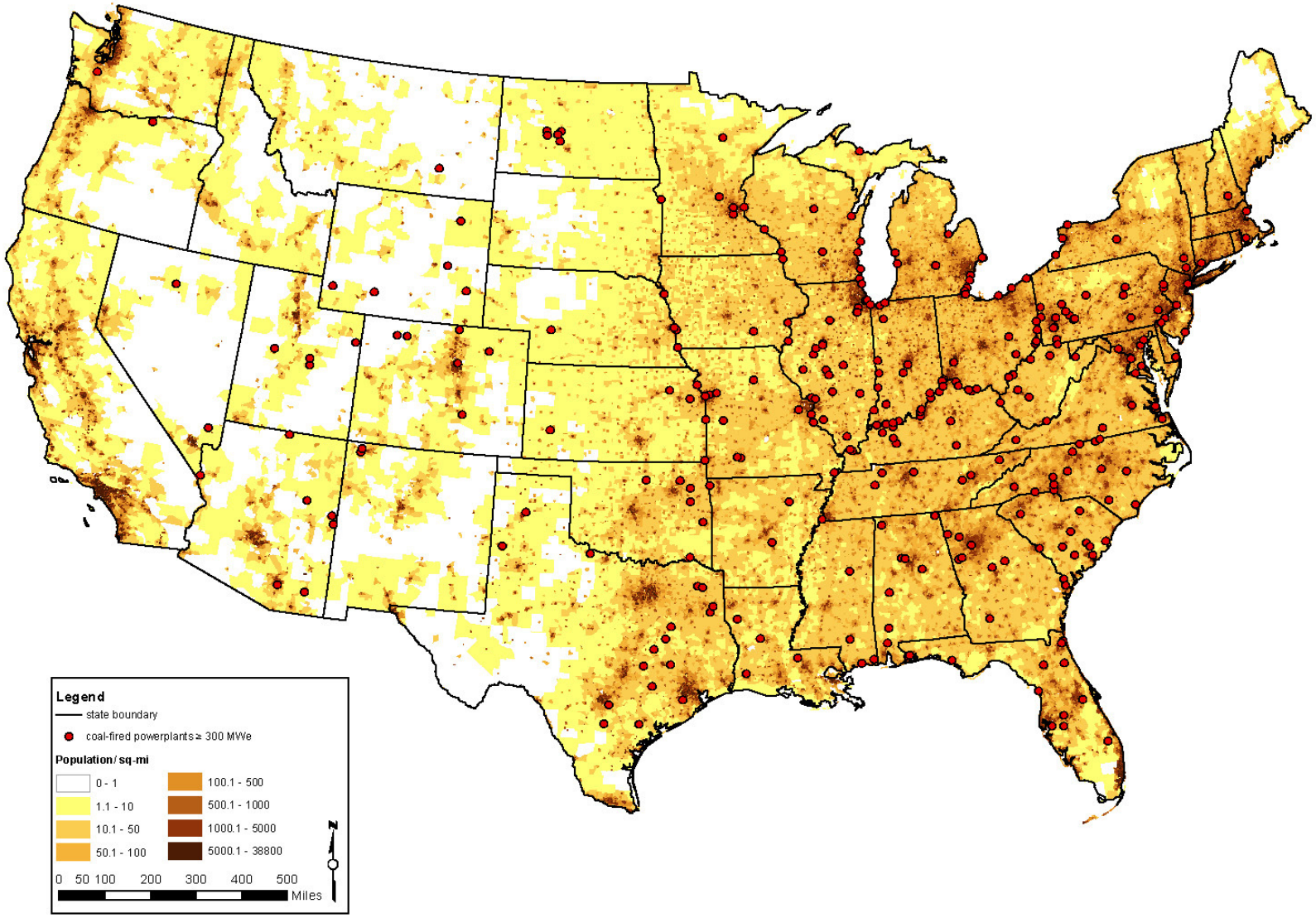
Considerations for Pipeline Siting

- Population Density ✓
- Distance from Plant to Sequestration Site ✓
- Topography ✓
- Proximity to Existing Pipeline Rights of Way ✓

- Major Waterbodies and Crossings
- Proximity to Sensitive Areas
  - National and State Parks
  - Wildlife Refuges, Preserves, Wetlands
  - Schools, Hospitals

- Major Industrial Facilities, Airports, Rail Centers

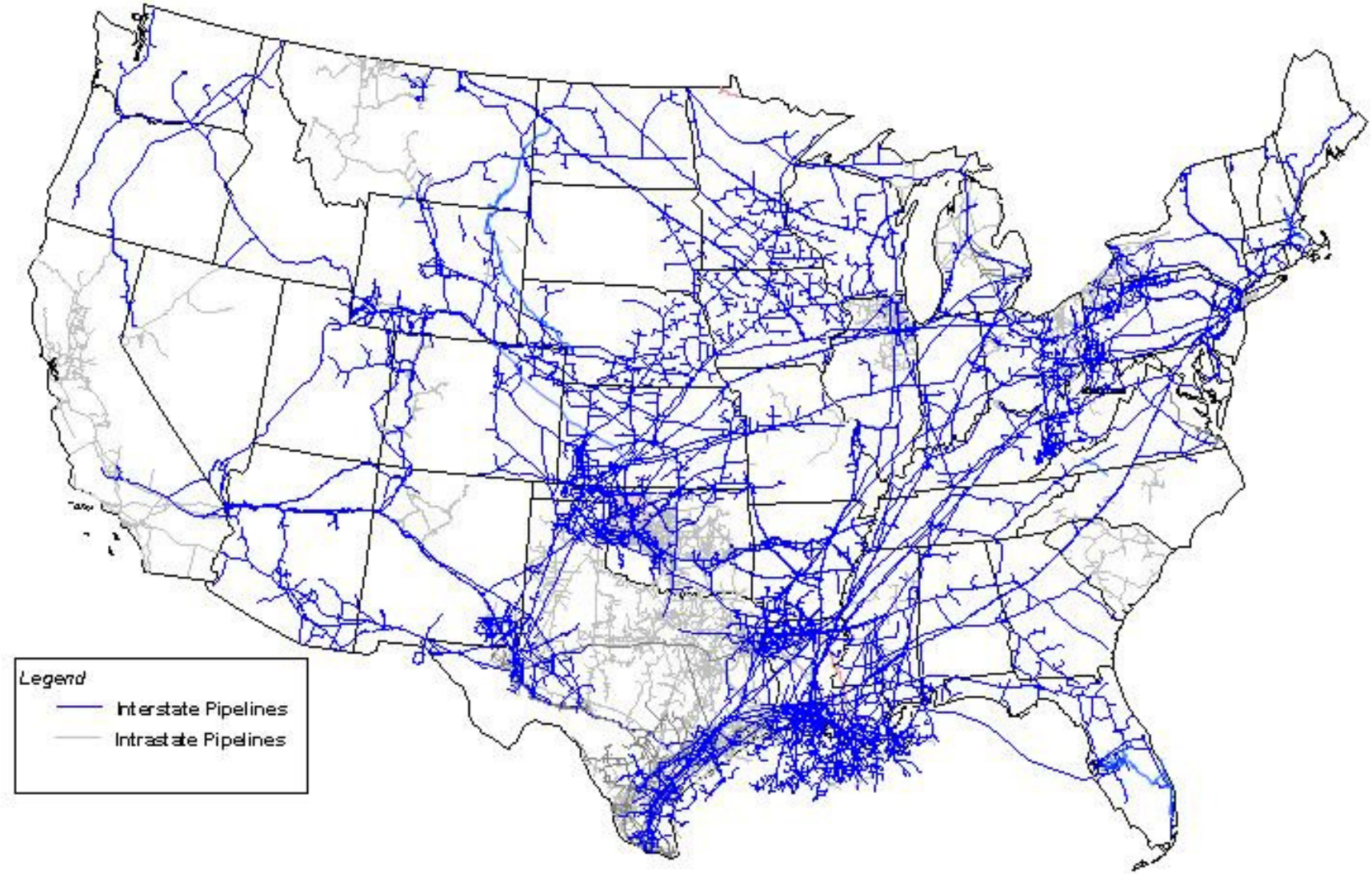
Population Density and >300 MWe Coal-fired Power Plants



Trunk Lines

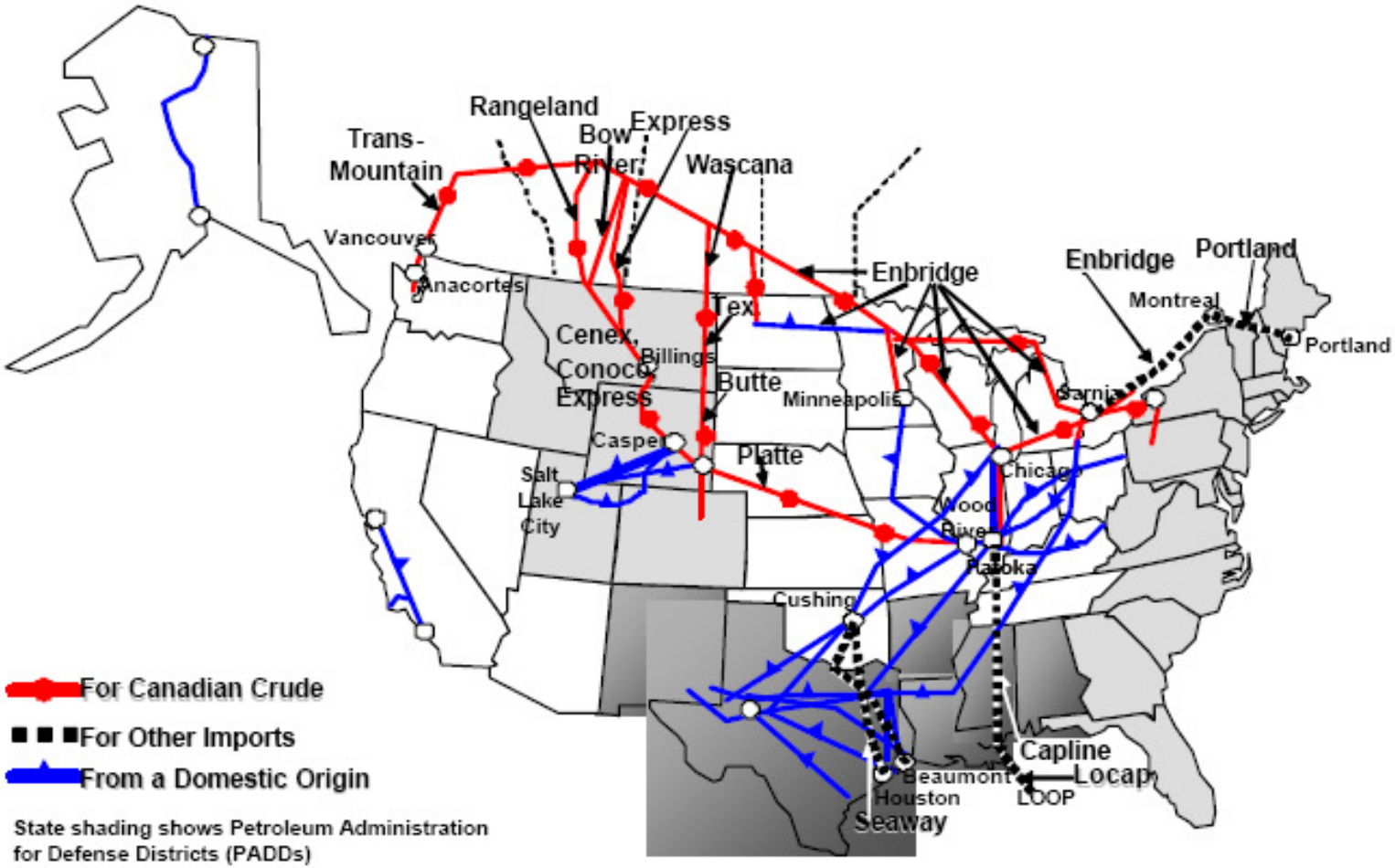
- Trunk line locations based on existing rights of way for major natural gas pipelines, locations of major coal-burning CO_2 sources, and distribution of population
- Trunk pipeline diameter based on the maximum amount of CO_2 to be transported
- Pipeline diameter in integer inches
- Maximum pipeline diameter used 30 inches; if larger capacity needed, multiple 30-inch pipelines assumed.

2007 Natural Gas Pipeline Network

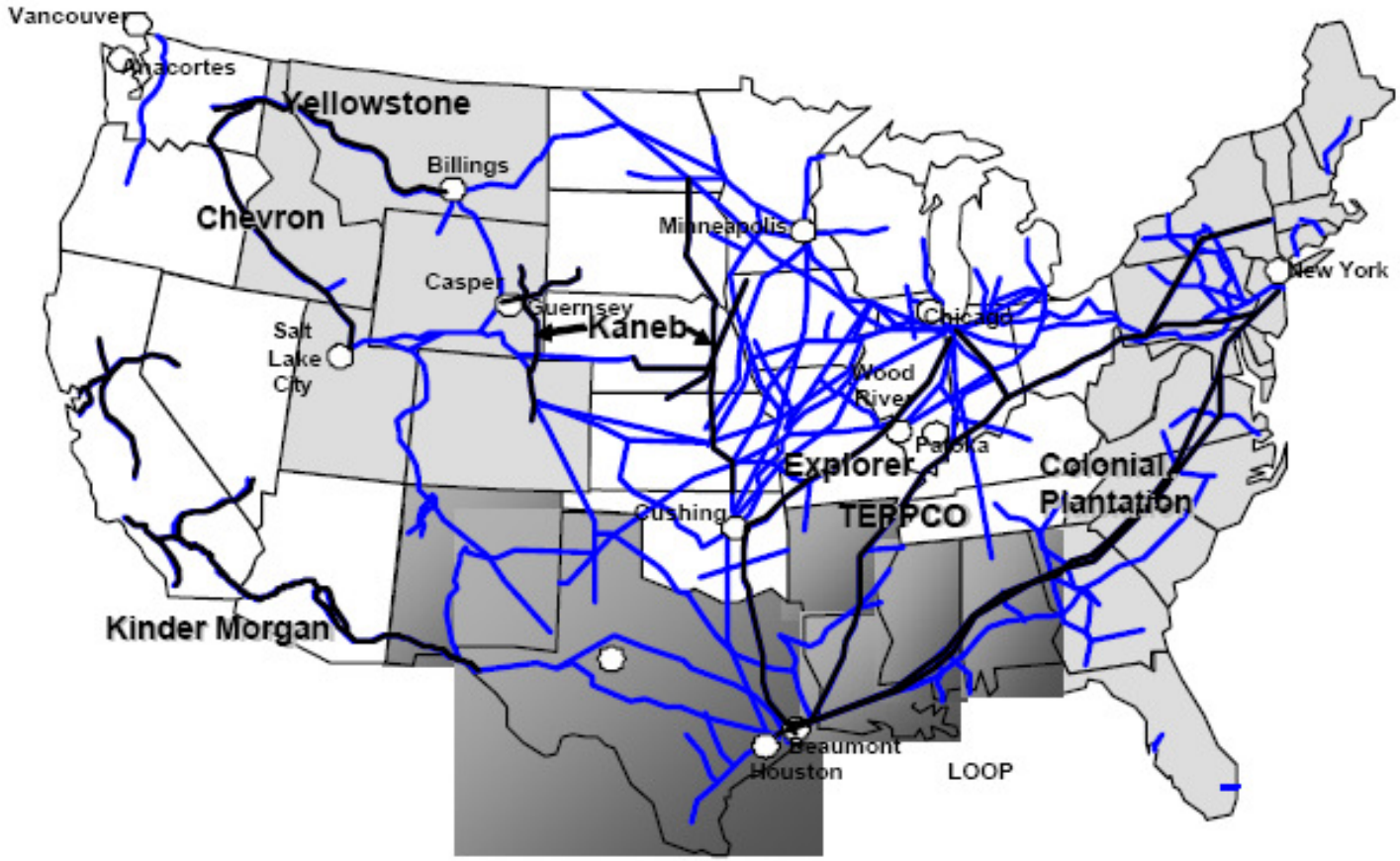


Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

Existing Crude Oil Major Pipe Network (Rabinow, 2004)



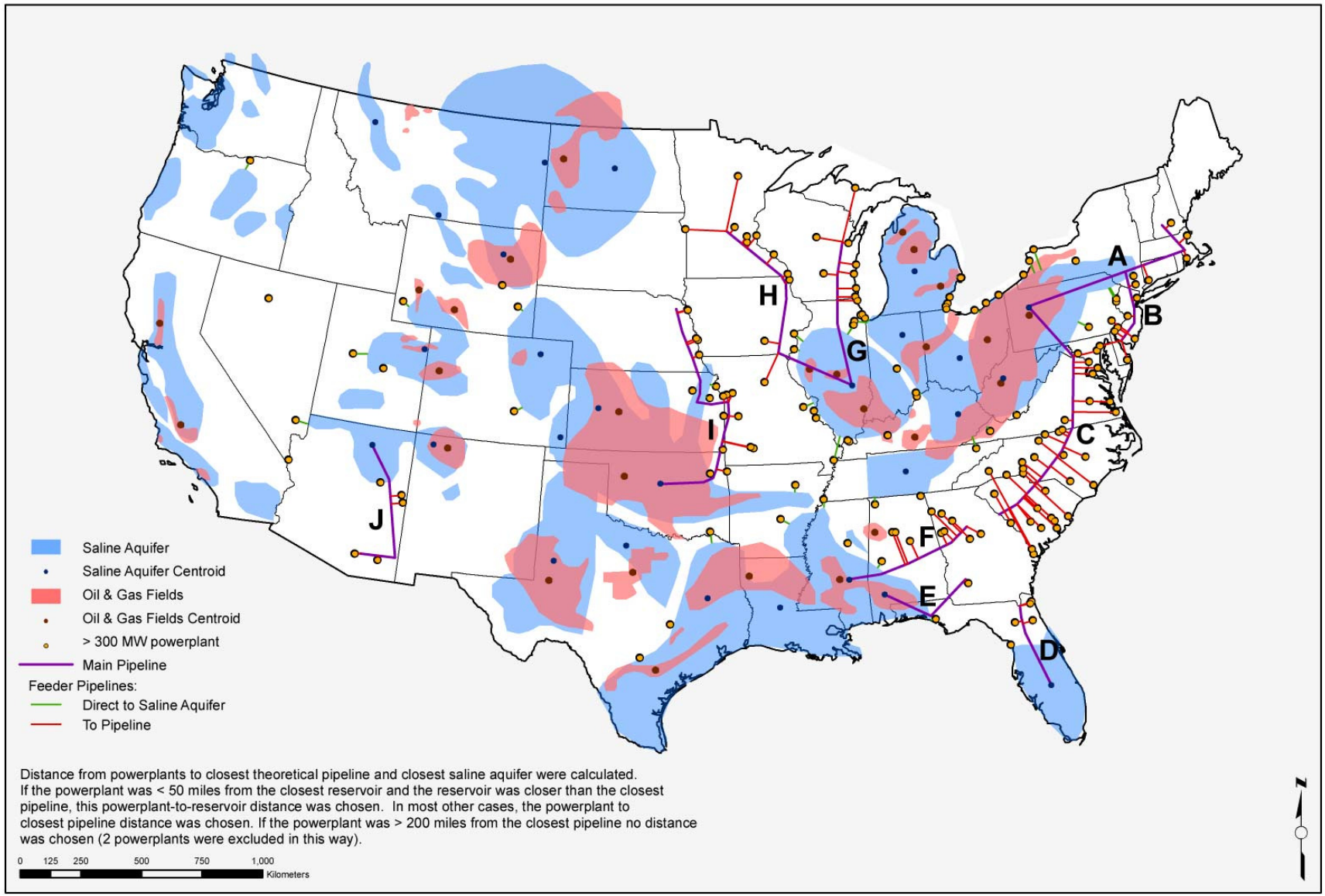
Major Refined Petroleum Products Pipeline Network (Rabinow, 2004)



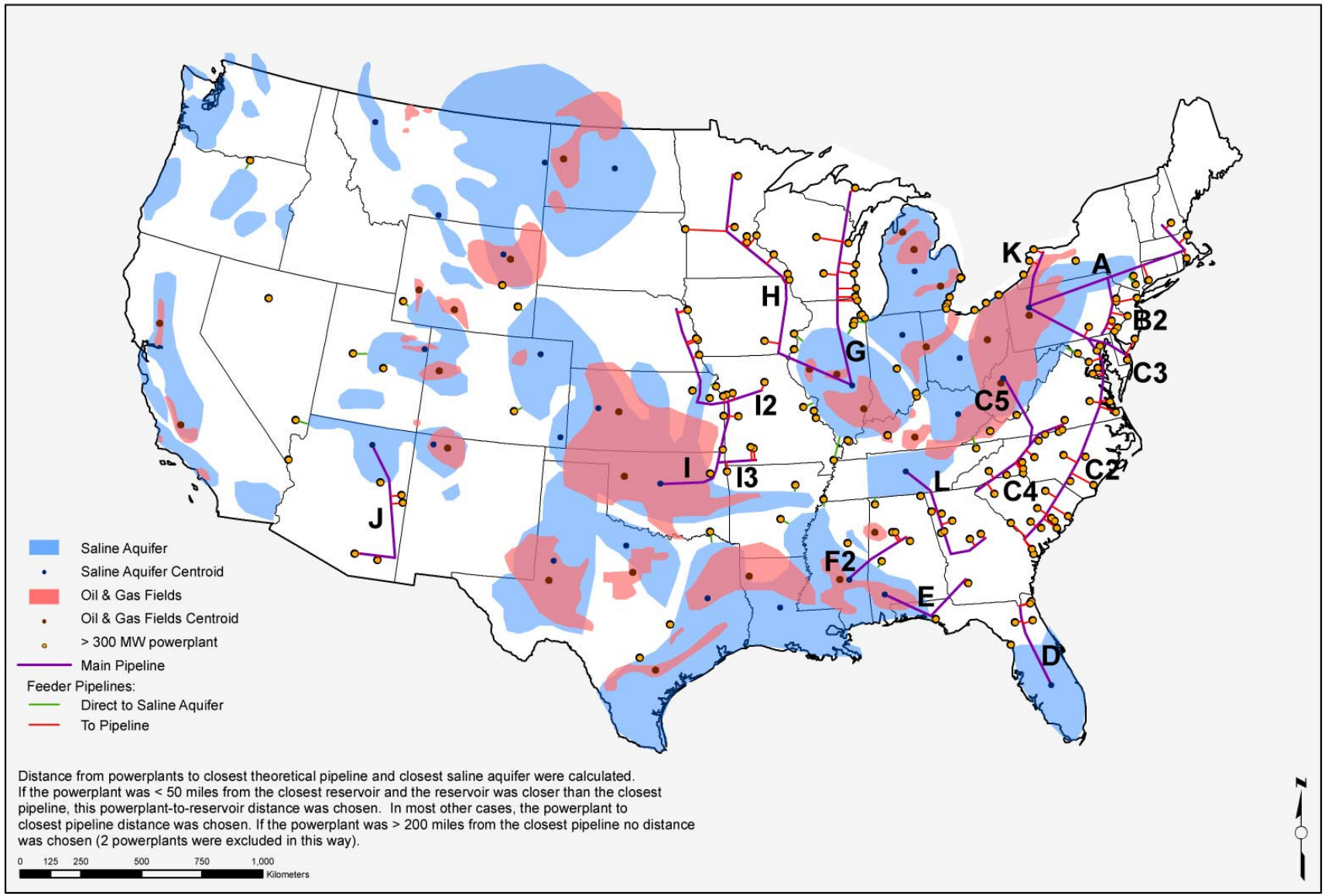
Scenario 1: Near Site

- Plants within Saline Aquifer Footprint Account for 964 M Metric Tons of CO_2
- Plants within 50 miles of Saline Aquifer Boundary Account for 386.6 M Metric Tons of CO_2
- 51% of total annual CO_2 emitted by plants >300 MWe could be sequestered close to power plant
- 46% of Plants >300 MWe are within potential sequestration sites

Scenario 2 Network with Potential Sequestration Sites



Scenario 3 with Potential Sequestration Sites



Mass of Captured Gas

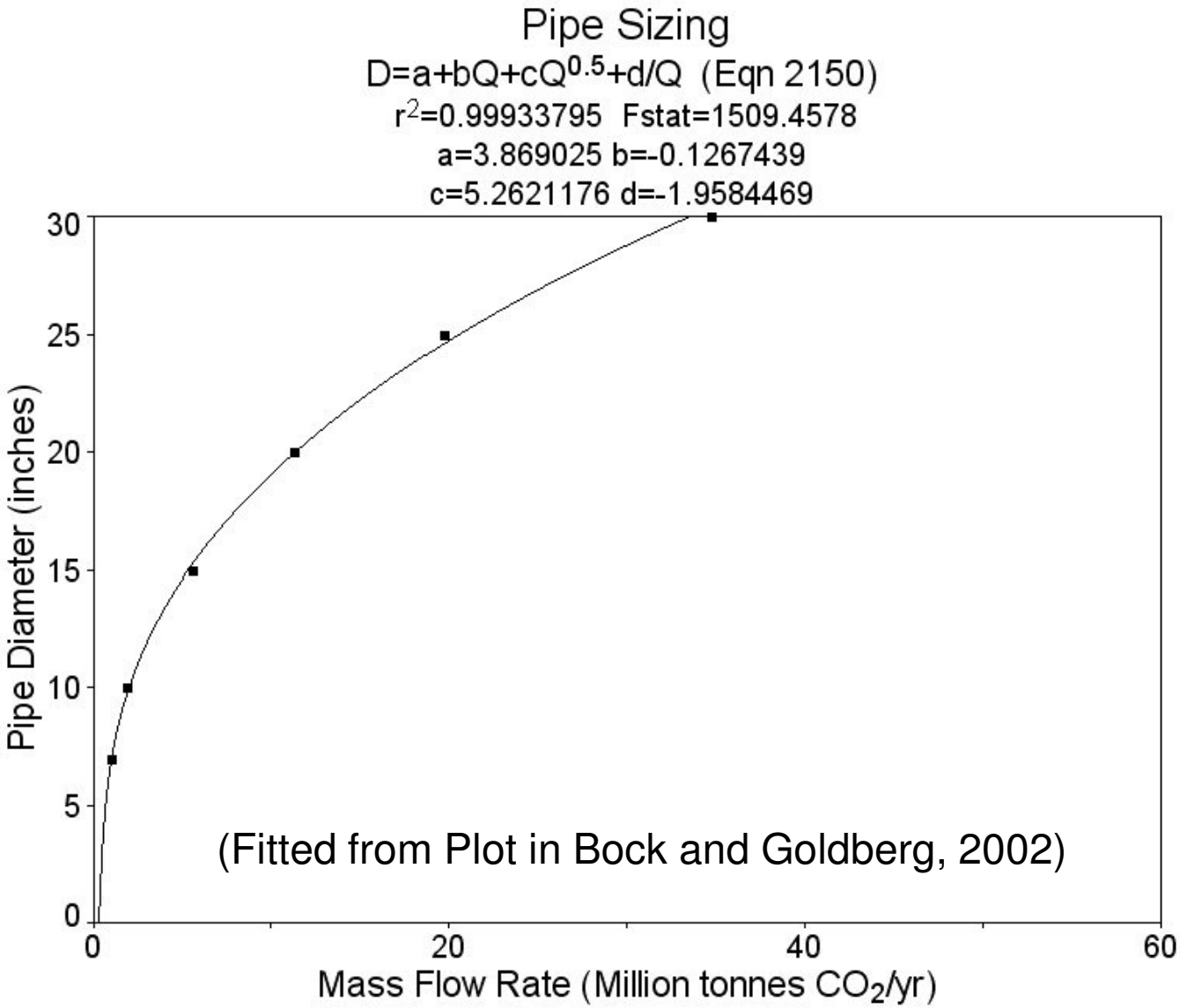
- **Scenario 1**: 1,350.6 Million Metric Tons/yr
- **Scenario 2**: Additional 486 Million Metric Tons/yr, or 1,836.6 Million Metric Tons/yr
- **Scenario 3:** Additional 503 Million Metric Tons/yr, or 1,853.6 Million Metric Tons/yr

- 2 Plants >200 miles to any site or trunk line: 13.64 M Metric Tons/yr
- Total CO_2 from Coal Plants (>300 MW): 1,867.2 M Metric Tons/yr

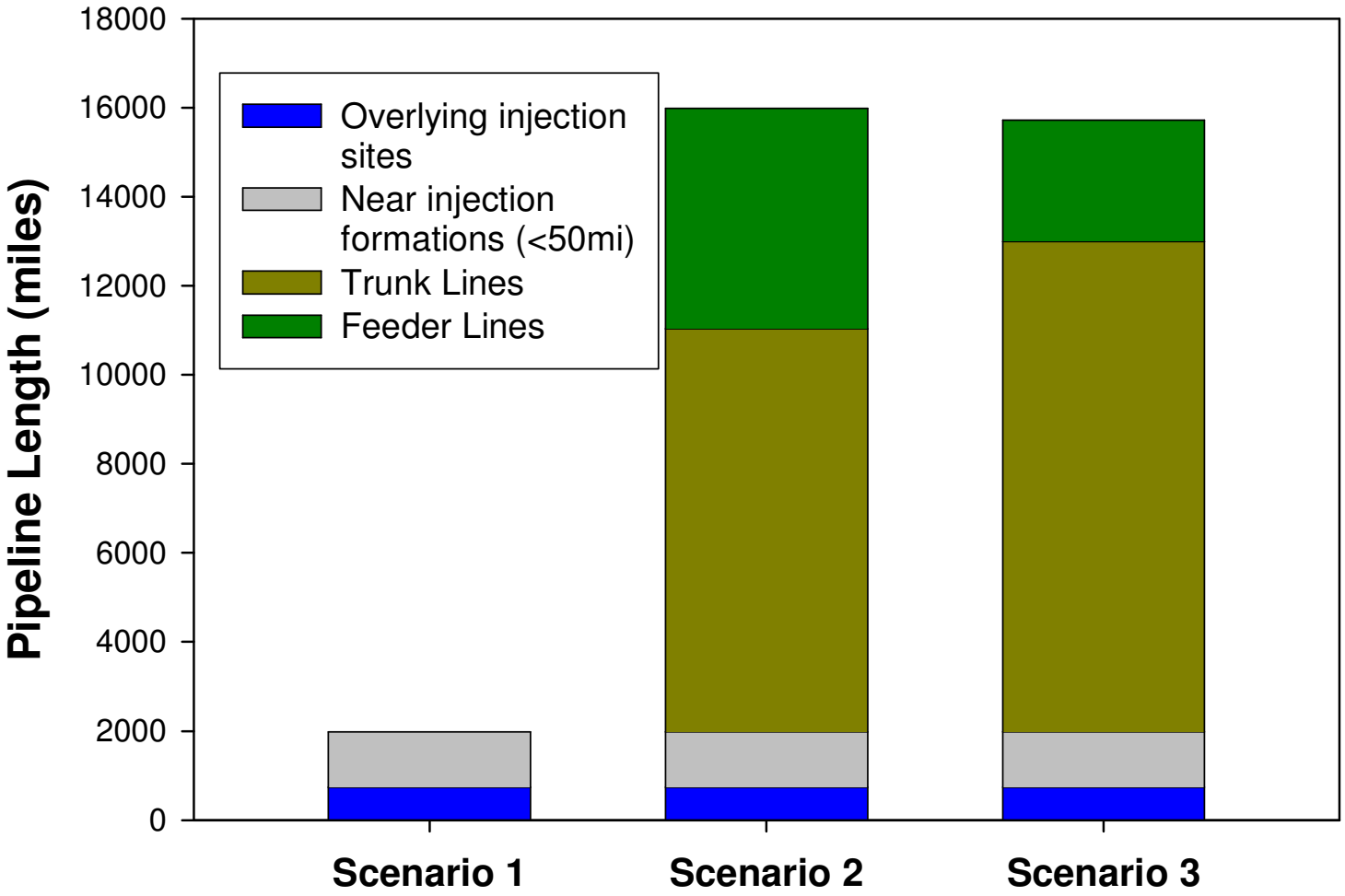
Pipe Size and Cost Estimation Method

- Plant emission of CO_2 per year from eGrid2006 database.
- Pipe sizing regression equation used to convert the mass flow rate into estimated pipe size diameter (inches).
- If pipe size diameter is ≤ 30 inches, calculate construction cost.
- If pipe size diameter is > 30 inches, then the mass flow rate is reduced by largest capacity for one pipe; pipe sizing procedure repeated using the remaining flow rate. (Some trunk lines required 3, parallel 30 inch pipes.)
- The average construction cost per mile of pipe is estimated using the linear equation (C = 33,853 x pipe diameter in inches) (from Bock and Goldberg, 2002).
- The total O&M cost is estimated as average O&M cost of $5,000/mile of pipeline times the total length of pipe (from Bock and Goldberg, 2002).
- The above process is repeated for two pipeline scenarios.

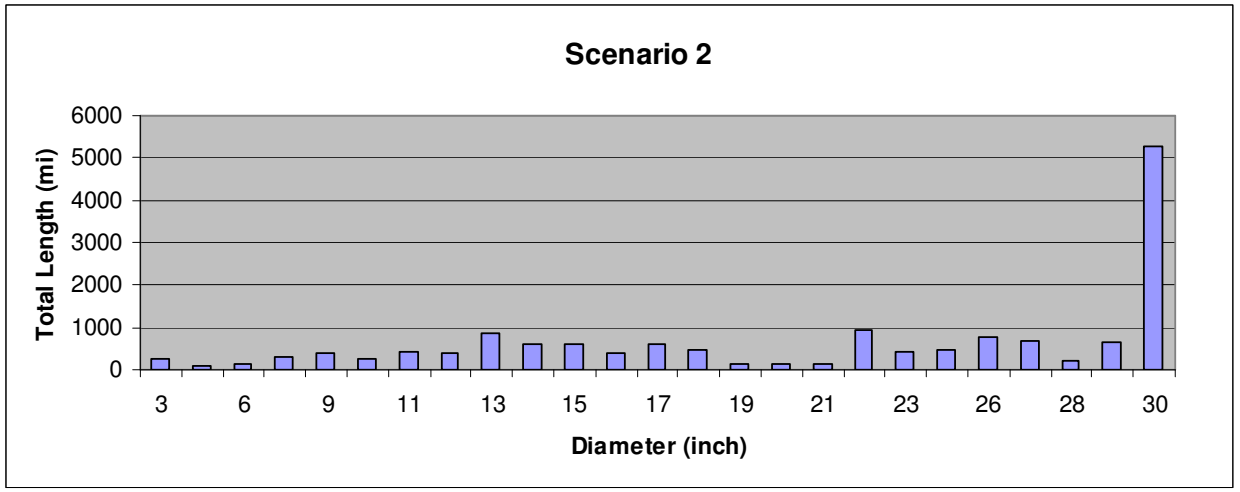
Pipeline Sizing Estimation

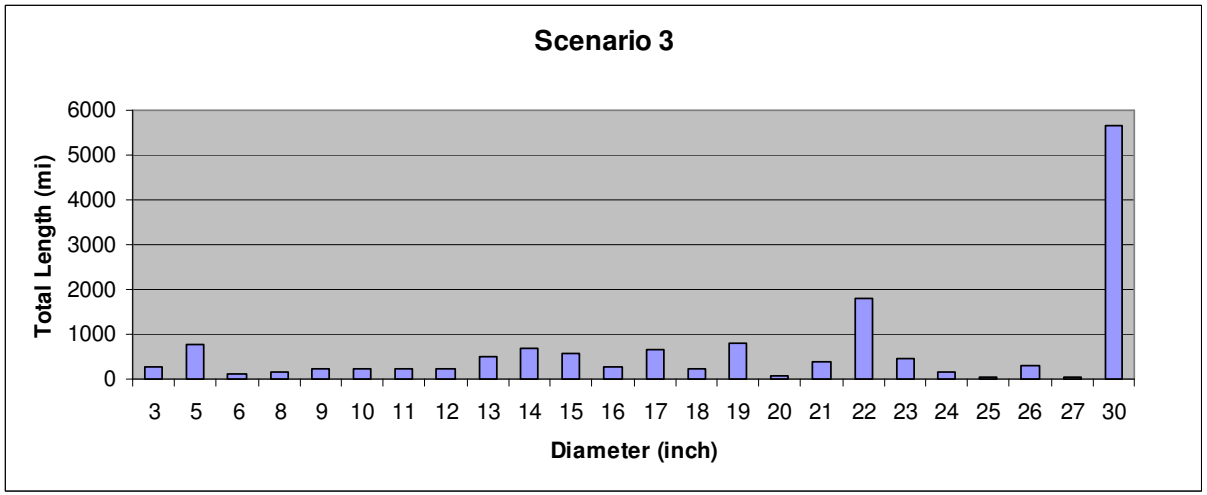


Total Pipeline Lengths

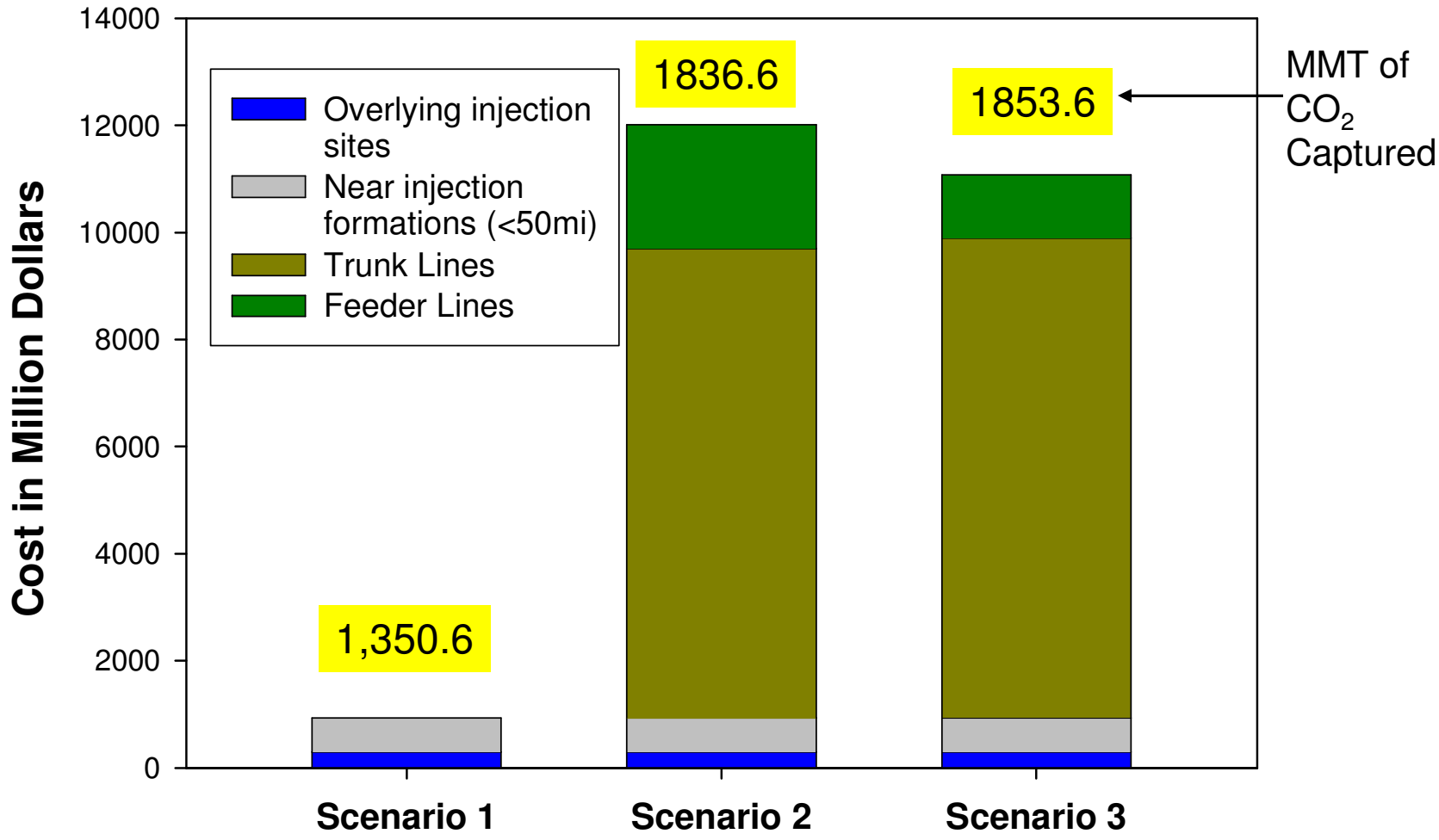


Pipeline Length by Diameter

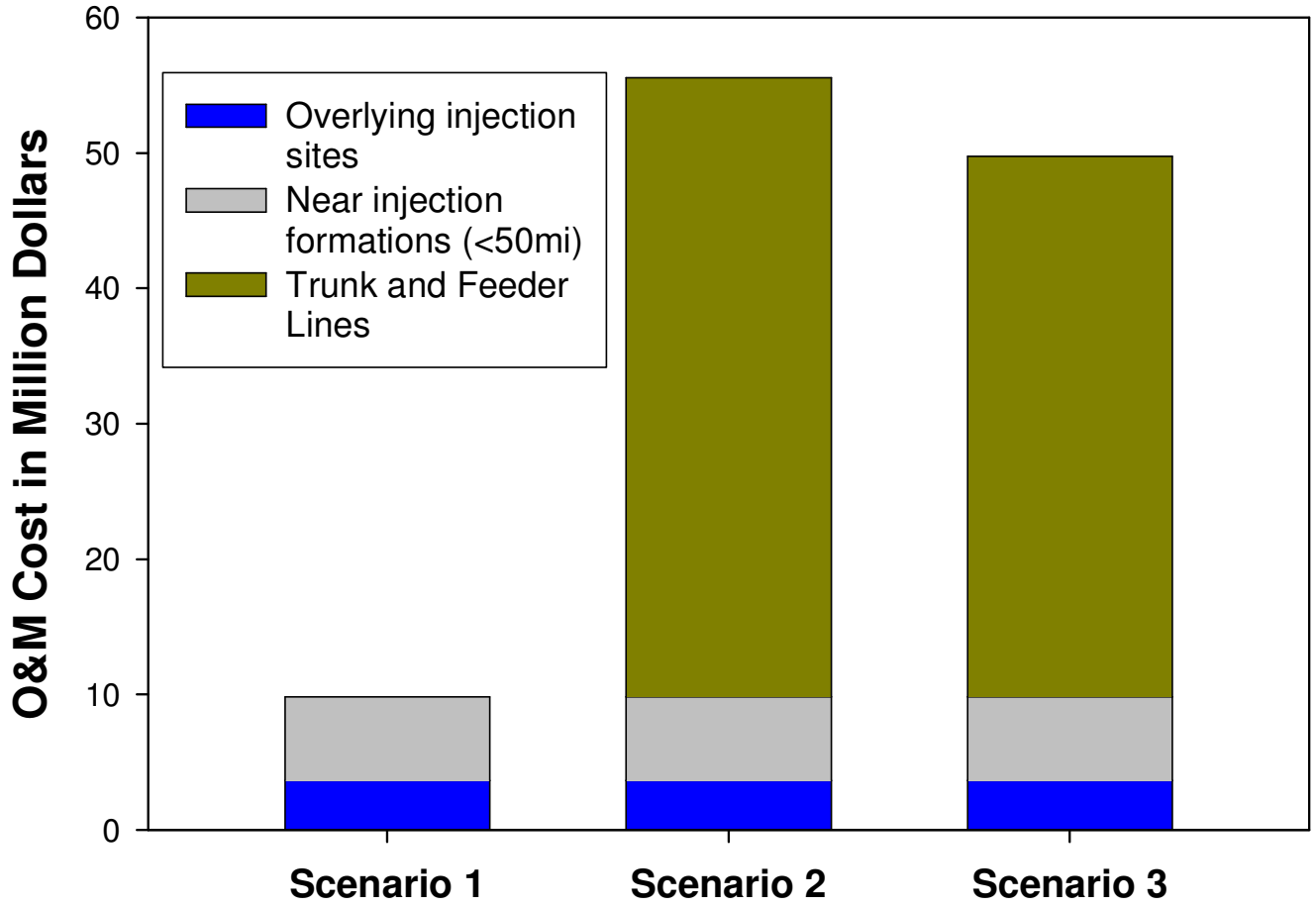




Comparison of Capital Costs



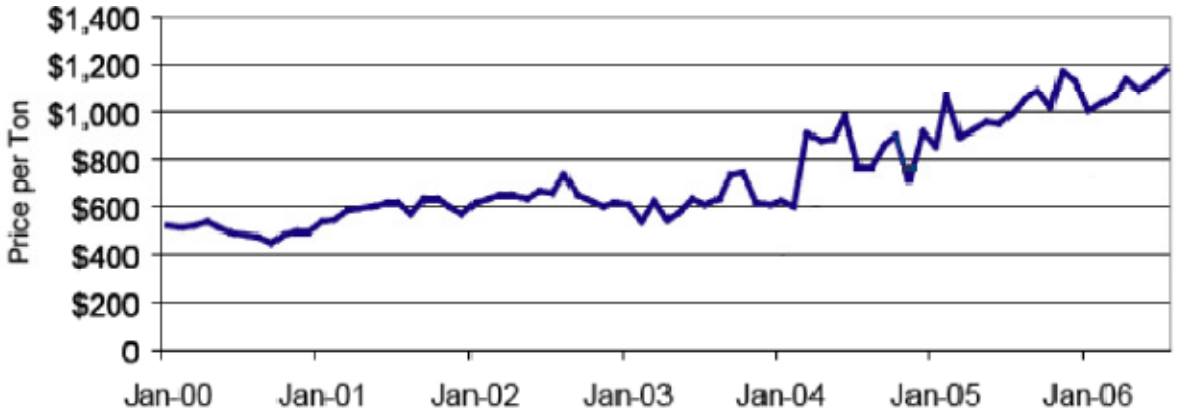
Comparison of O&M Costs



Caveats and Cost Factors

- Evaluated only plants >300 MWe
- Future new generation not considered
- Costs based on past natural gas pipelines; material inflation significant and not predictable
- Site-specific factors could add significantly to costs

Example of Cost Inflation of 24-inch Steel Pipe (Parfomak and Folger, 2007)



Source: *Preston Pipe & Tube Report*. Pipe prices represent average transaction price (by weighted average value) for double-submerged arc-welded pipe > 24" diameter, combining both domestic and import shipments.

Effect of Pipeline Diameter and Distance on Cost

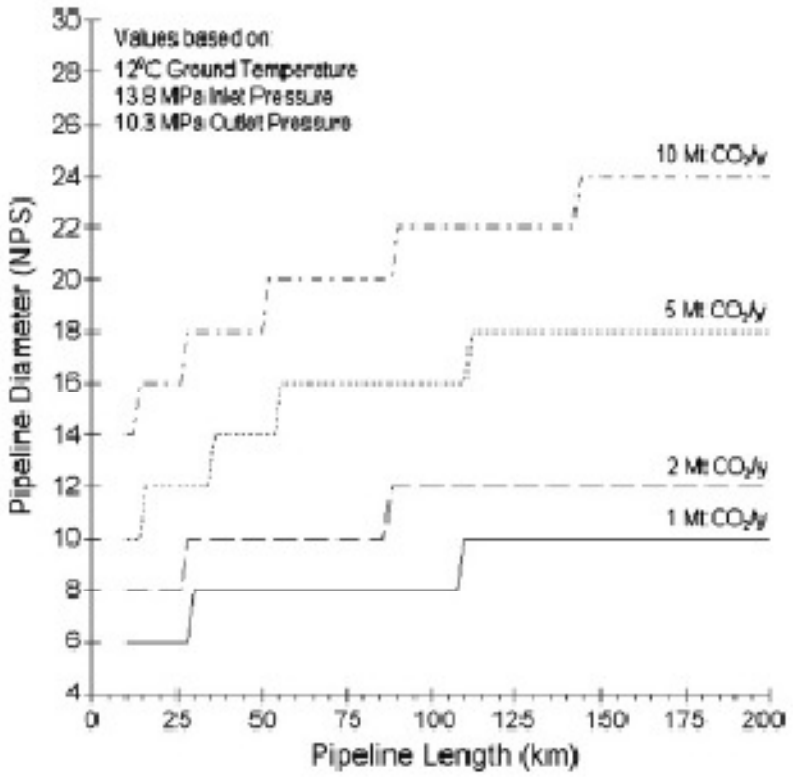
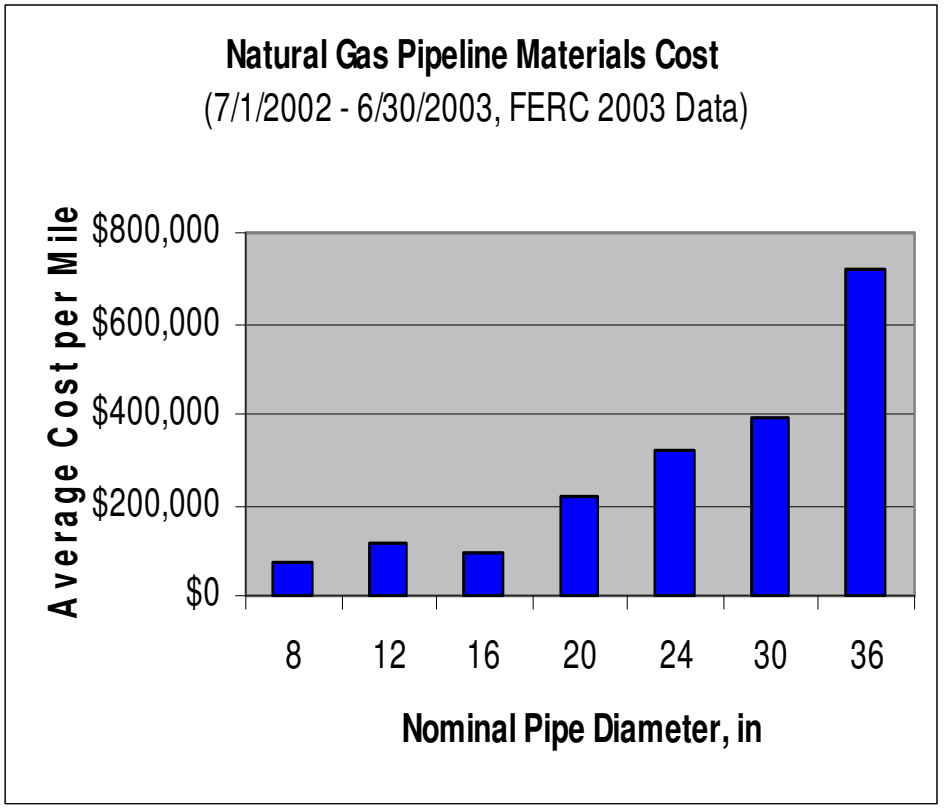


Fig. 3 – Required pipe diameter for the specified inlet and outlet pressures, for different pipeline lengths and four different design mass flow rates, as predicted by the performance model.

From McCoy and Rubin, 2008



Cost Variation Examples

- Average cost natural gas pipelines on land in 2002-2003 $1.28M/mile, of which 30% was for materials (FERC data-True, 2003)

- Estimates based on cost model of McCoy & Rubin, 2007 (from Parfomak and Folger, 2008)
  - 11 mile, 16-inch diameter pipe carrying 10 M Metric T CO_2; capital cost $6M
  - 130 mile, 22-inch diameter pipe carrying 10 M Metric T CO_2; capital cost $70M
  - 234 mile, 24-inch diameter pipe carrying 10 M Metric T CO_2; capital cost $150M

- Planned Southeast Pipeline to be constructed in 2007-2008
  - 314 mile, 24-inch diameter pipe designed for at least 10 M MeT CO_2, estimated total cost $700-750M, ~$210-225 for materials
  - Estimated total cost for large CO_2 pipeline: $2.2 – 2.4 M/mile

Conclusions

- Large capital cost required to capture 65% of CO_2 (1,350.6 MMT); cost to achieve >90% capture would be greater than ten times initial investment
- Distribution of known storage formations and emission sources strongly suggests the need for trunk lines to manage transport of CO_2
- For two alternative trunk line scenarios, total capital costs were similar; trunk lines >> feeder line costs
- Additional piping and equipment (valves, pumps, and compressors) needed to reach specific sequestration sites.