Economics and Deployment Potential of CCS in China

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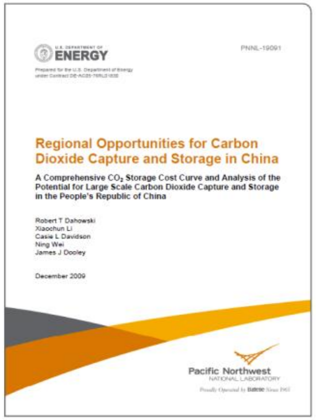
Topics

- Background and History of our China Collaboration
- Overview of Work to Date
  - CO_2 Source Inventory and Geologic Storage Capacity Assessment Results
  - Source-Sink Matching and Cost Curves for CO_2 Transport and Storage
- Evaluating Capture and Compression
- Putting it all Together – Modeling Large Scale CCS Deployment in China
- Continuing Research Efforts

Background

Regional Opportunities for Carbon Dioxide Capture and Storage in China

- CSLF-recognized project to assess CCS potential in China
- Inventoried and mapped large CO_2 point sources and candidate geologic CO_2 storage reservoirs
- Analyzed source-reservoir matching with economics of CO_2 transport and storage
- Established potential for cost-effective, large-scale deployment of CCS


U.S. DEPARTMENT OF ENERGY

PNNL-19091

Regional Opportunities for Carbon Dioxide Capture and Storage in China

A Comprehensive CO_2 Storage Cost Curve and Analysis of the Potential for Large Scale Carbon Dioxide Capture and Storage in the People's Republic of China

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December 2009

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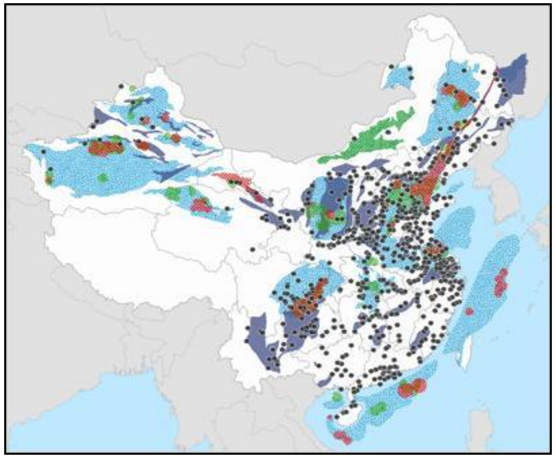

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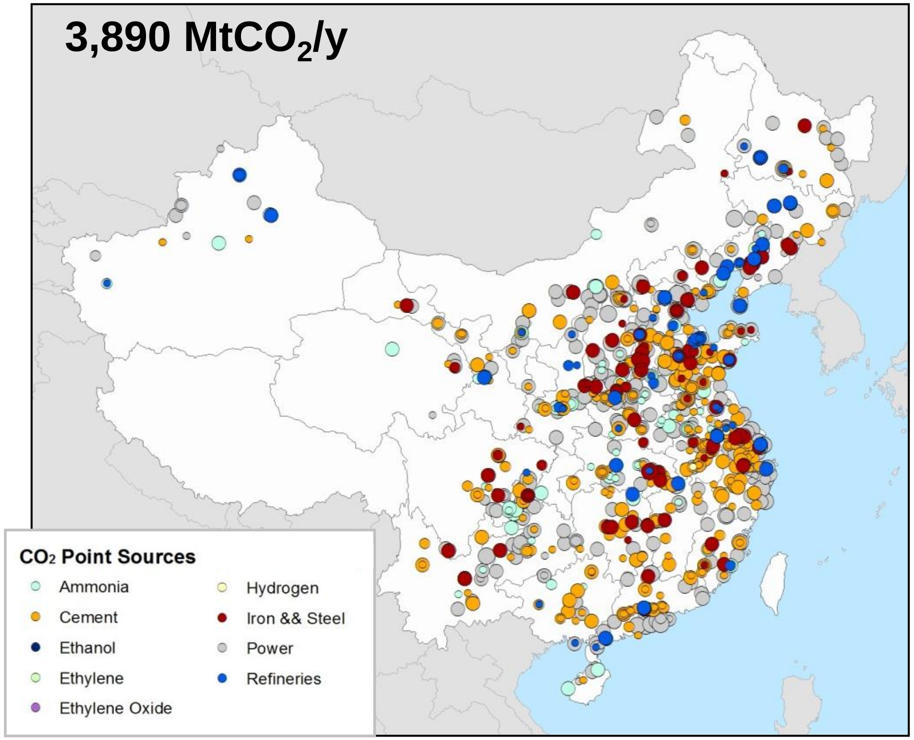
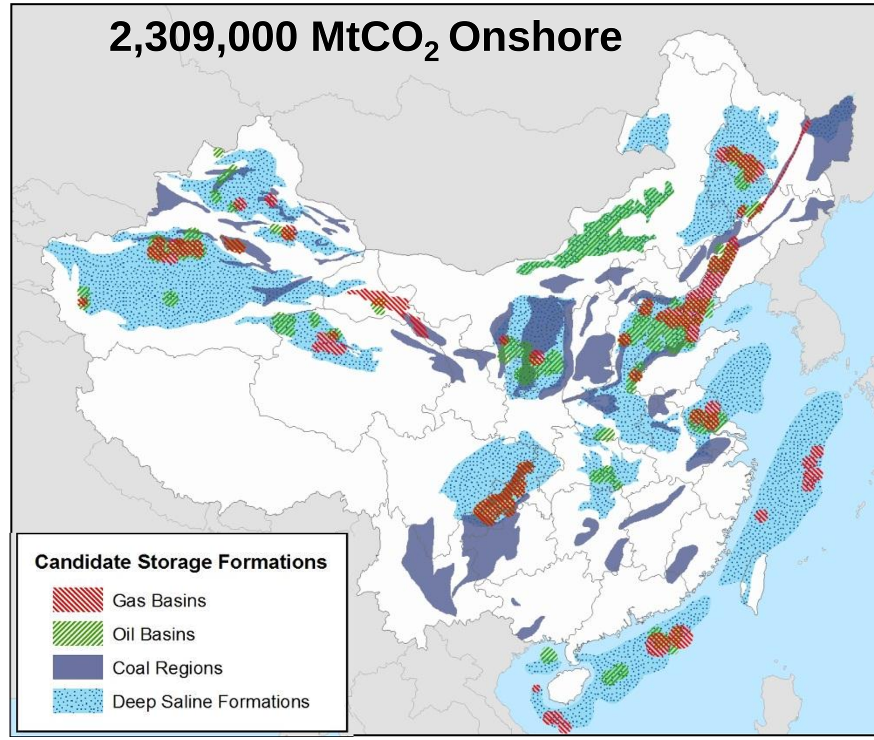
Large CO_2 Point Sources and Geologic CO_2 Storage Resource in China





1623 large CO_2 sources

Power: 73% of emissions

High Purity CO_2: 132 $MtCO_2$/yr

DSF:	**2,288,000 $MtCO_2$**
Gas:	**4,280 $MtCO_2$**
Oil:	**4,610 $MtCO_2$**
Coal:	**11,970 $MtCO_2$**

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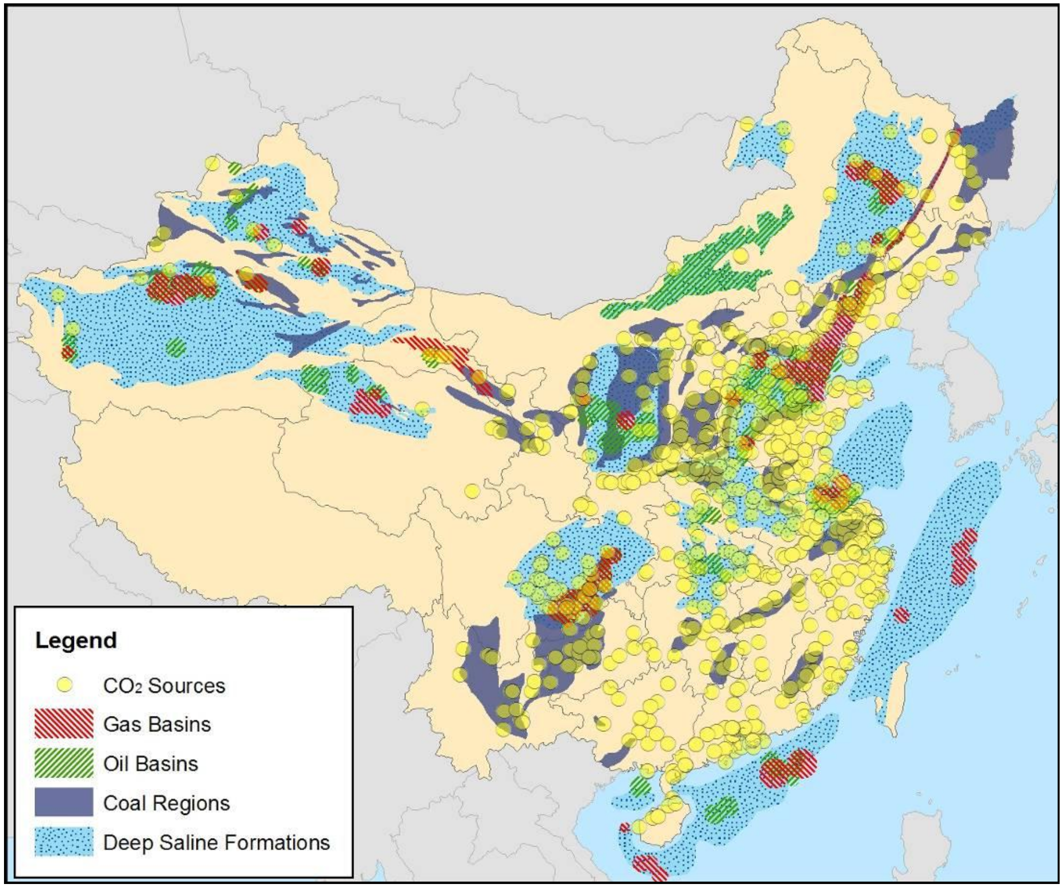
Key Findings: CO_2 Sources and Storage Options

- Good proximity of sources to possible storage basins:
  - 91% of large CO_2 point sources have a candidate storage formation within 160 km (100 miles)
  - 83% within 80 km (50 miles)
- Some sources in coastal regions do not appear to have many onshore storage options



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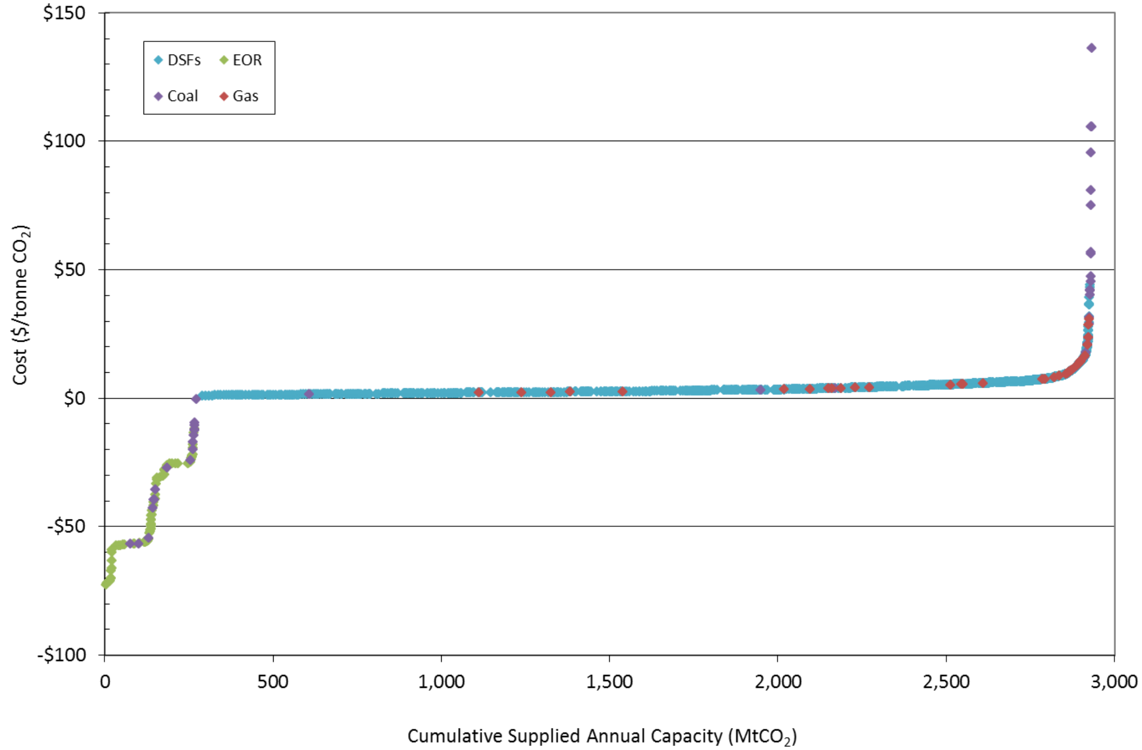
Key Findings: CO_2 Transport and Storage Cost Curves

- Strong potential for CCS in China, at transport and storage costs up to about $10/tCO$_2$
- China's modeled storage options appear robust and able to provide value even under significant reductions to ultimately accessible capacity



- Storage demand may exceed onshore storage resource in select regions – near offshore basins should be evaluated

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Research Continuing under U.S.- China Clean Energy Partnership

- Focus: significantly reduce environmental emissions and improve efficiency of fossil fuel conversion
- Three primary focus areas:

Area 1: High volume CO_2 sequestration and utilization

- Investigations of CO_2 migration in heterogeneous porous media
- Modeling CCS deployment in China

Area 2: Advanced syngas conversion technologies - Removal of contaminants and CO_2 from warm syngas

Area 3: Advanced syngas conversion technologies - SNG catalyst & CO_2 adsorbent integration

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CO_2 Capture in China

- Key factors in China that impact CO_2 capture potential:
  - Surging growth in new generation capacity:
    - A very young fleet of power plants that will be operating for many years to come; high efficiency plants that are strong candidates for retrofit capture technologies
  - Reliance on domestic coal in growing fuel and chemical industries:
    - Coal gasification based processes present opportunities for integration of lower cost pre-combustion capture technologies

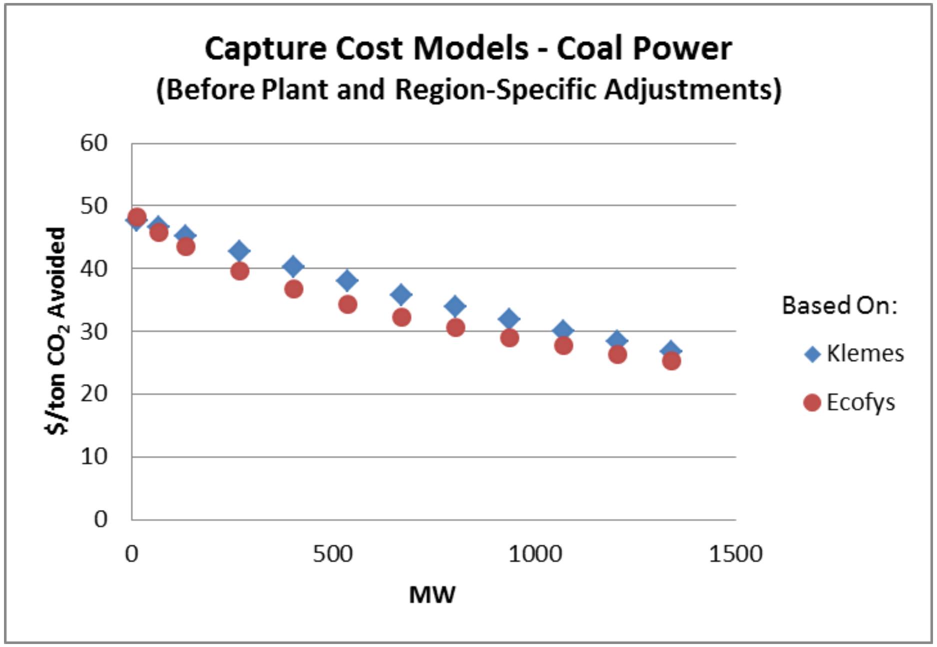
Modeling Capture Costs

- High variability and uncertainty in expected capture costs
  - Limited experience of commercial technologies at large scales and across target industries
  - Advanced technologies still developing
  - Literature presents a wide range of cost estimates based on a mix of assumptions, including
    - Varying plant and capture technologies and assumptions ("n^{th}-unit" vs. early demonstration costs)
    - New build vs. retrofit scenarios
    - Energy costs, efficiencies, etc.
  - Reported on unspecified or inconsistent bases:
    - Often capture + compression; sometimes + transport/storage
    - $/tonne captured vs. avoided vs. mitigated
    - Unspecified assumptions regarding factors including presence of emissions controls, etc.
- Detailed process cost modeling not feasible for our work

Modeling Capture Costs - Approach

Power: Modified and benchmarked relationships reported by Klemes, et al., 2007 and Ecofys, 2004 against literature for post-combustion capture

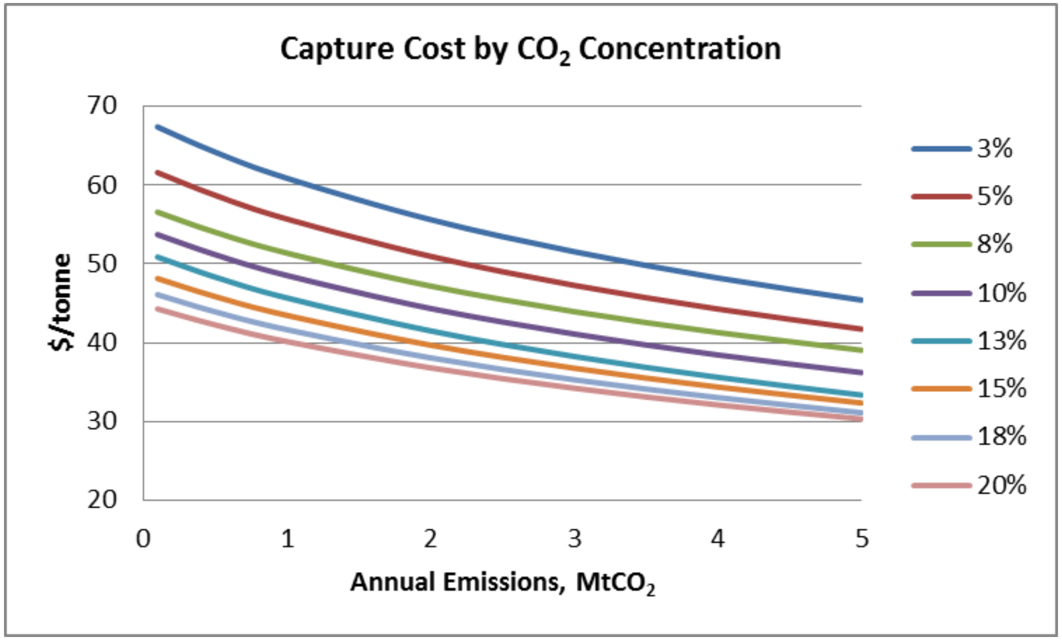
- Coal-Fired Plants:
  - Adjusted Klemes relationship to remove compression costs
  - Used data on unit vintage to adjust costs for older plants to account for lower efficiencies, shorter remaining lifetimes, and lower likelihood for the presence of FGD and similar controls
  - Applied 4% discount to capital costs for plants with multiple units (per NETL 2011)
  - Adjusted costs for China (based on IEA ETP model factors)
    - 90% for capital costs
    - 80% O&M (60% for labor)
- Gas- and Oil-Fired:
  - Relationship based on costs by CO_2 emissions rate and concentration reported by Ecofys, escalated to present
  - Applied similar multiple unit and regional cost adjustments



Modeling Capture Costs - Approach

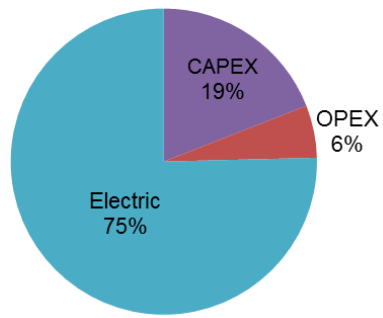
Industrial Sources:

- High Purity Sources: Ammonia, Ethylene Oxide, Hydrogen
  - Assumed zero capture cost for ammonia and ethylene oxide facilities; small cost for hydrogen assuming coal gasification based process with PSA purification
- Low Purity Sources: Cement, Ethylene, Iron & Steel, Refineries
  - Cost models derived from reported costs by CO_2 concentration and emissions rate (escalated from Ecofys 2004)
  - Benchmarked costs against literature
  - Applied regional cost adjustment for China

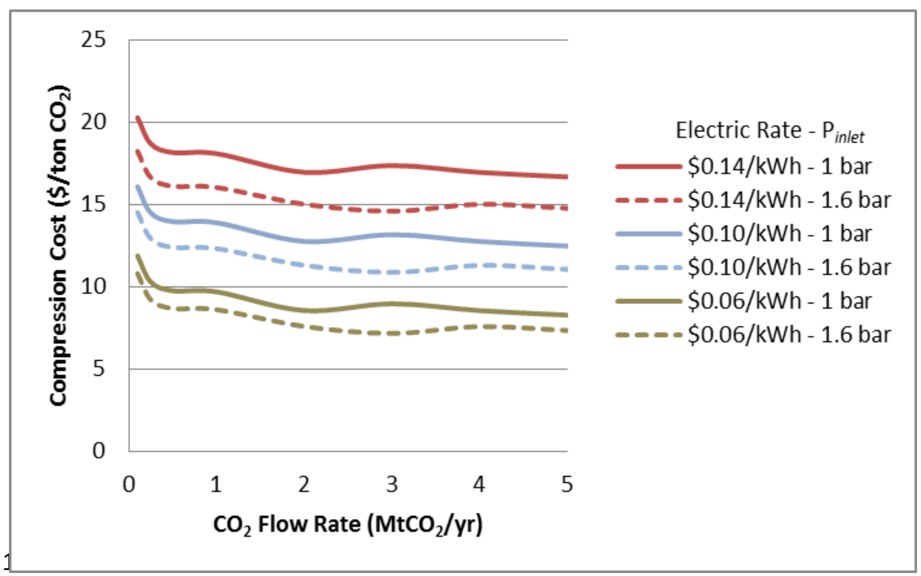


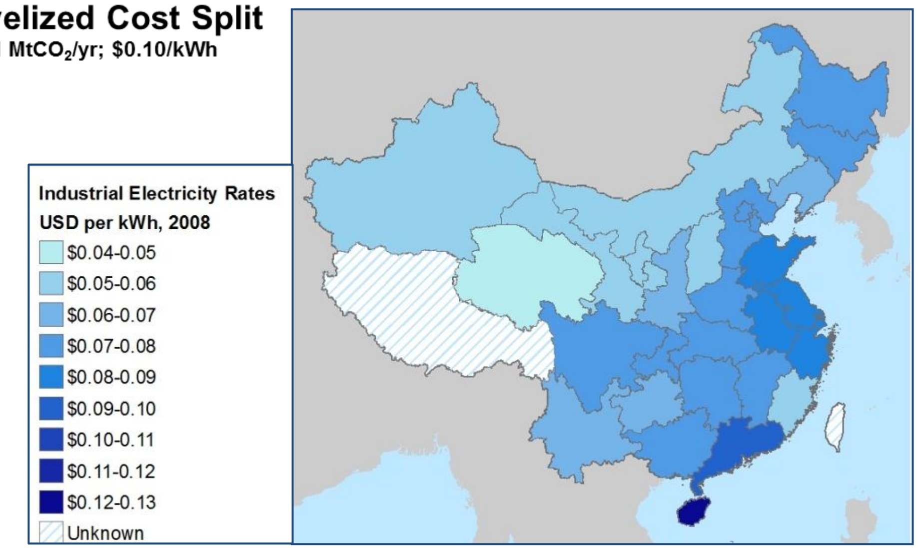
Modeling Compression Costs

- Adapted from McCollum and Ogden. 2006. *Techno-Economic Models for Carbon Dioxide Compression, Transport, and Storage.* Institute of Transportation Studies, University of California, Davis.
- Assumptions:
  - 5-stage compression
  - 85% capacity factor
  - P_{in}: variable
  - P_{out}: 150 bar
  - Per train limit: 40,000 kW



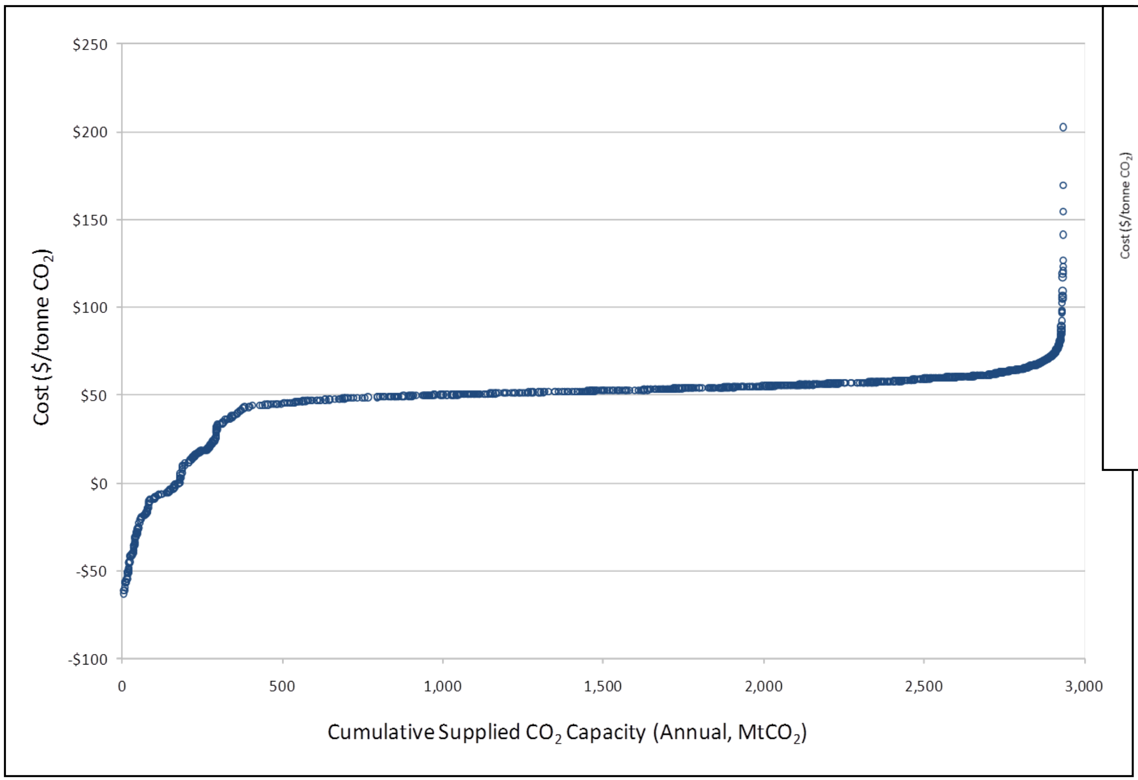
Levelized Cost Split
1 $MtCO_2$/yr; $0.10/kWh

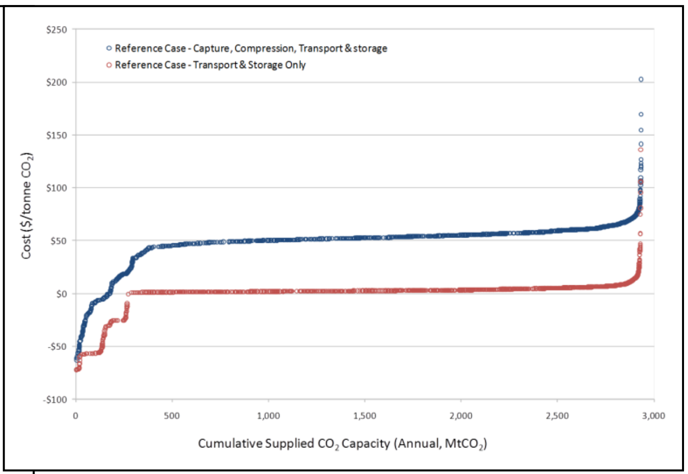




CCS System Cost Curves

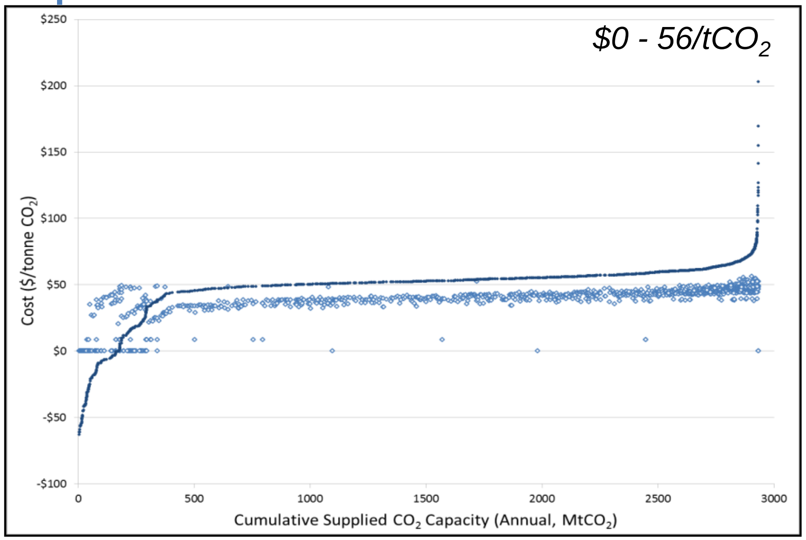
- Include: Capture, compression, transport, and storage
- Storage costs include: site characterization, CO_2 flowlines, injection and monitoring wells, and other MMV
  - Also production wells, CO_2 recycling plants, and related costs and revenues for enhanced hydrocarbon recovery projects
- All include CAPEX, OPEX, and China cost adjustment factors



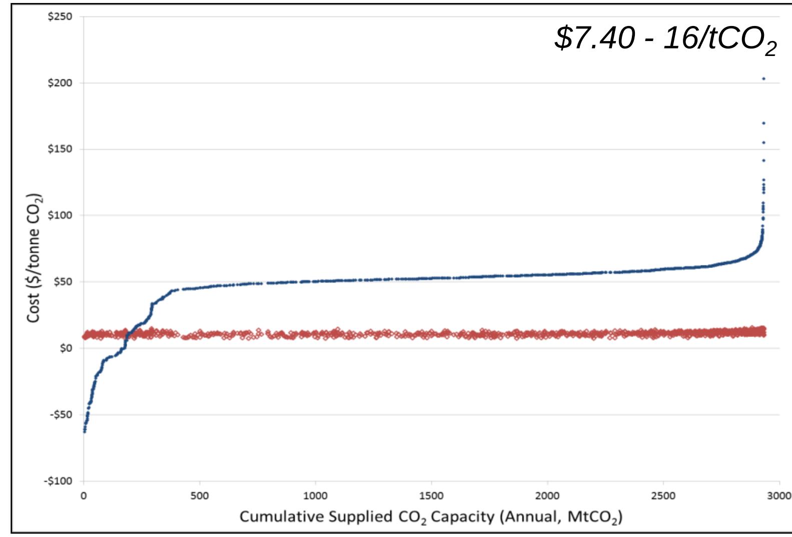


Reference Case: Building the Cost Curve

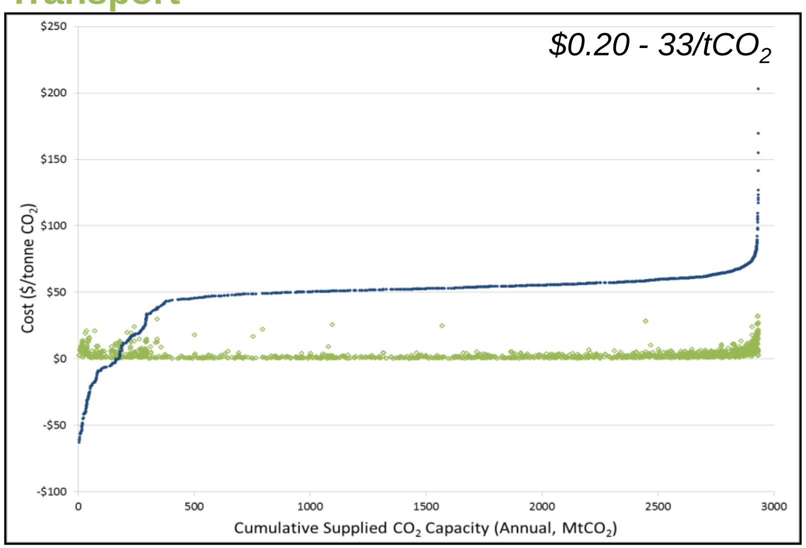
Capture



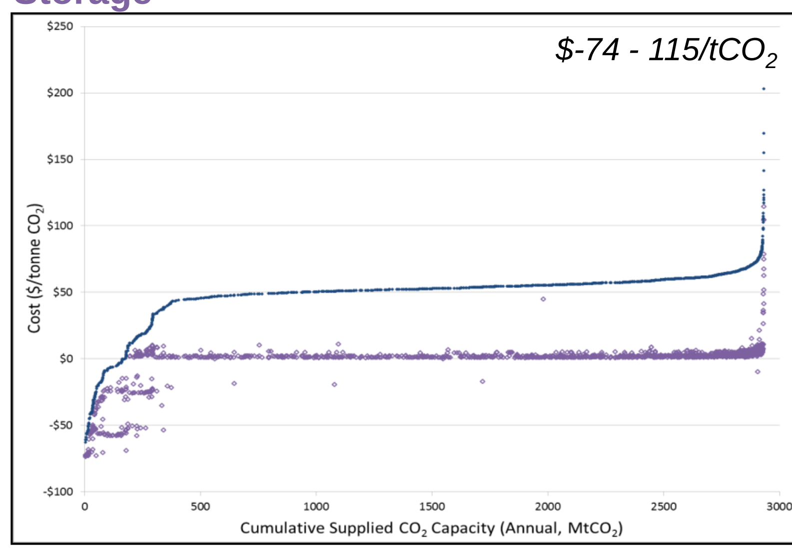
Compression



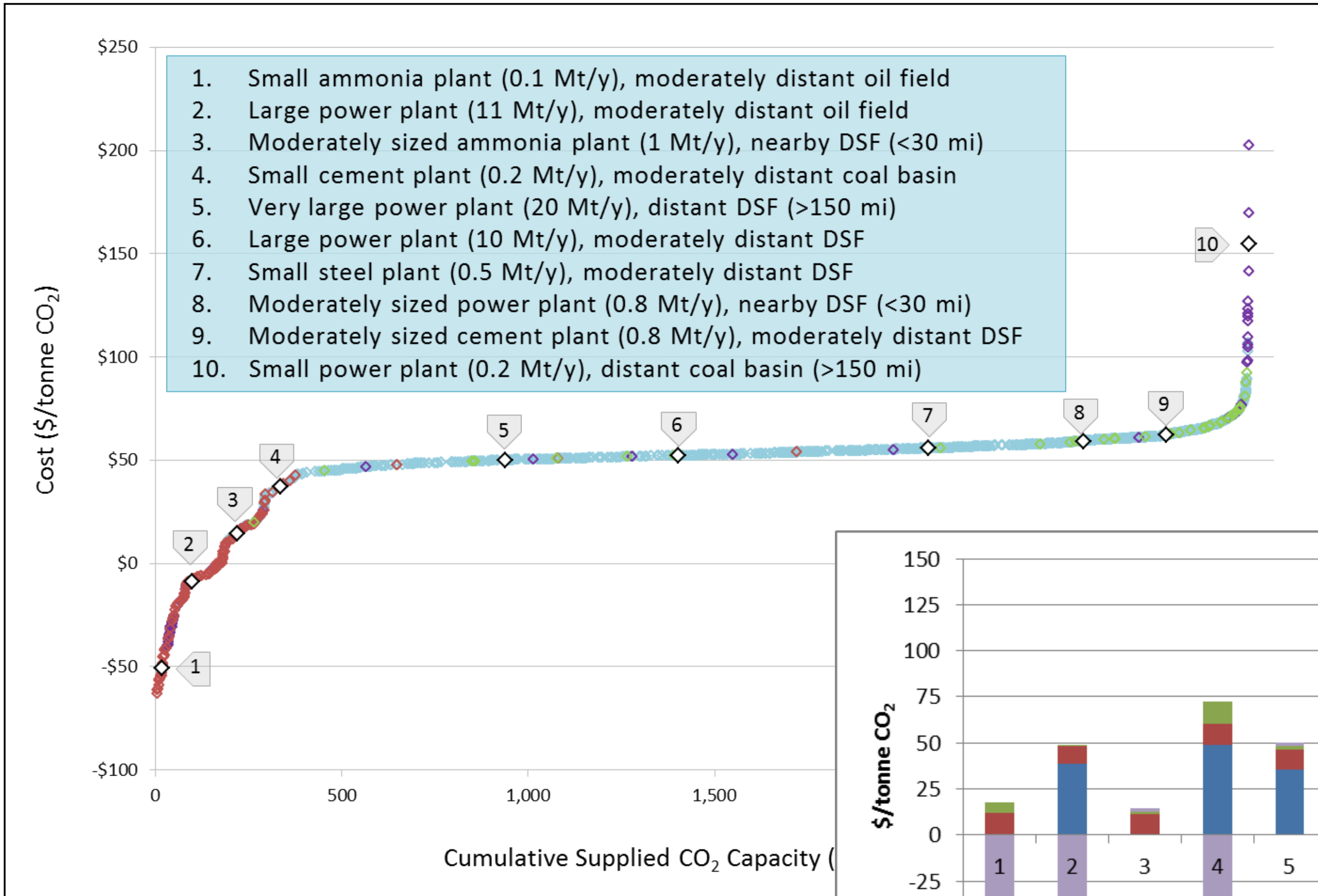
Transport

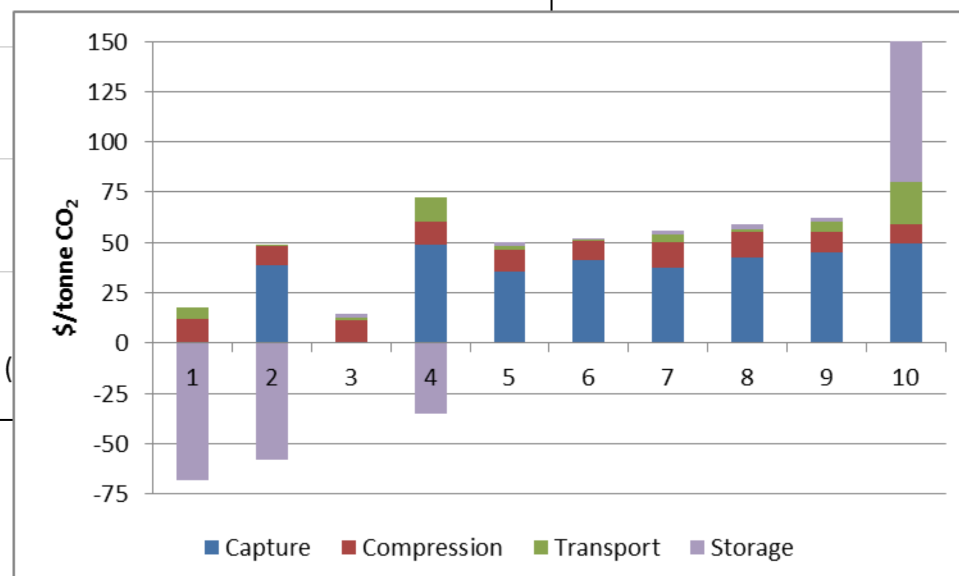


Storage

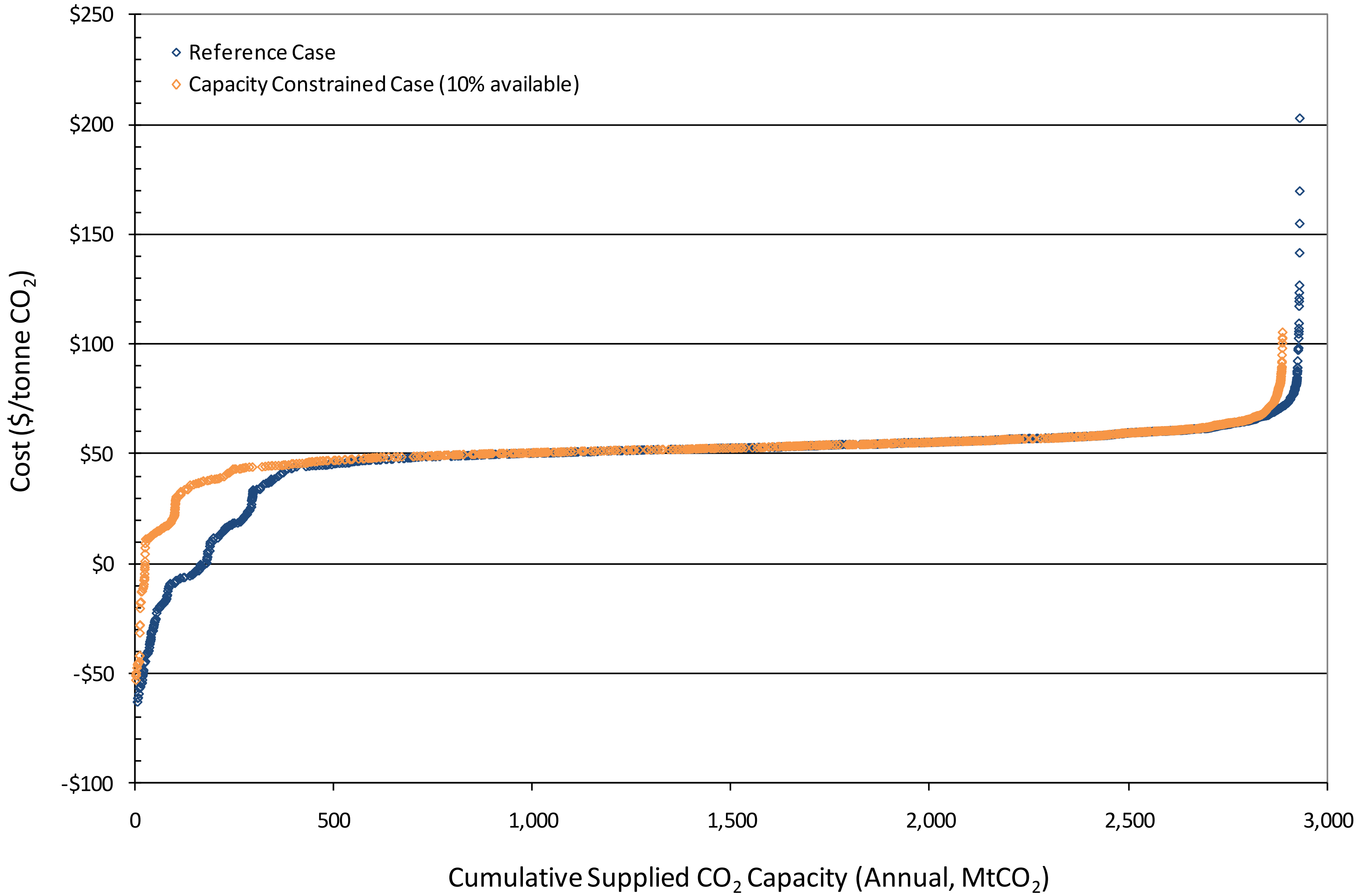


Sample Source-Sink Pairs Illustrate Project Set Heterogeneity





Reduced Capacity Case: CCTS Curve with 90% reduction in available storage capacity



Goals of this Research

- Better understand the potential (and challenges) for CCS to deploy at scale within China
- Help to inform both “top-down” modeling and “bottom-up” efforts to characterize geologic storage potential at multiple scales
  - Top-down: modeling the relative potential and costs for CCS in various regions of the world and against other technologies
  - Bottom-up: help to identify regional opportunities and challenges for possible early demonstration projects; site screening and selection support

Continuing Research Efforts

- Validation and enhanced parameterization of geologic storage potential and costs
  - Further evaluate complex Chinese basin geologies and impacts on storage viability and economics
  - Refine the representation and costs for CO_2-enhanced oil recovery and enhanced coalbed methane recovery potential in China
  - Assess costs for near offshore geologic storage
- Incorporation of data and understanding of CCS performance and economics from evolving research and demonstration projects
- Multi-criteria approach for identifying near-term deployment opportunities

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