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Regional Opportunities for Carbon Dioxide Capture and Storage in China

Project Highlights and Results

Robert Dahowski

China-Australia Geological Storage Workshop
Canberra, Australia
January 18-22, 2010

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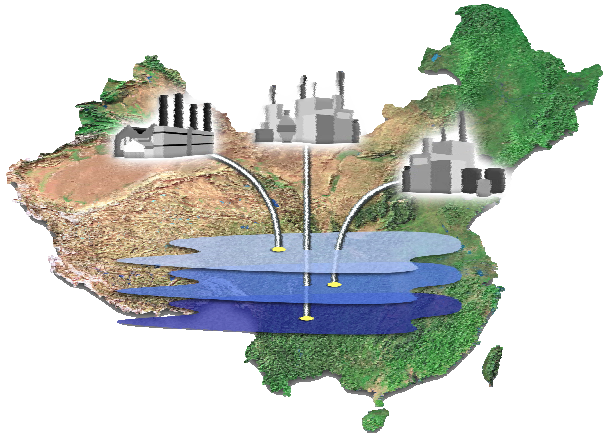
PNNL-SA-70369

Topics



- Project Overview
- CO_2 Source Inventory and Geologic Storage Capacity Assessment Results
- Source-Sink Matching and Cost Curves for CO_2 Transport and Storage
- Modeling Large-Scale CCS Deployment
- Key Findings
- Overview of Similar Analyses in U.S.

A Joint U.S.-China Research Collaboration

- Core Project Team:
  - Battelle / Pacific Northwest National Laboratory
  - Chinese Academy of Sciences Institute of Rock and Soil Mechanics
  - Leonardo Technologies, Inc.
- About the Project:
  - Examining the potential for CCS to deploy across China's economy
  - Cataloging large anthropogenic CO_2 point sources and candidate geologic CO_2 storage reservoirs in China
  - Assessing the economics of CCS and developing cost curves for CO_2 transport and storage
  - Recognized by the Carbon Sequestration Leadership Forum

LTI

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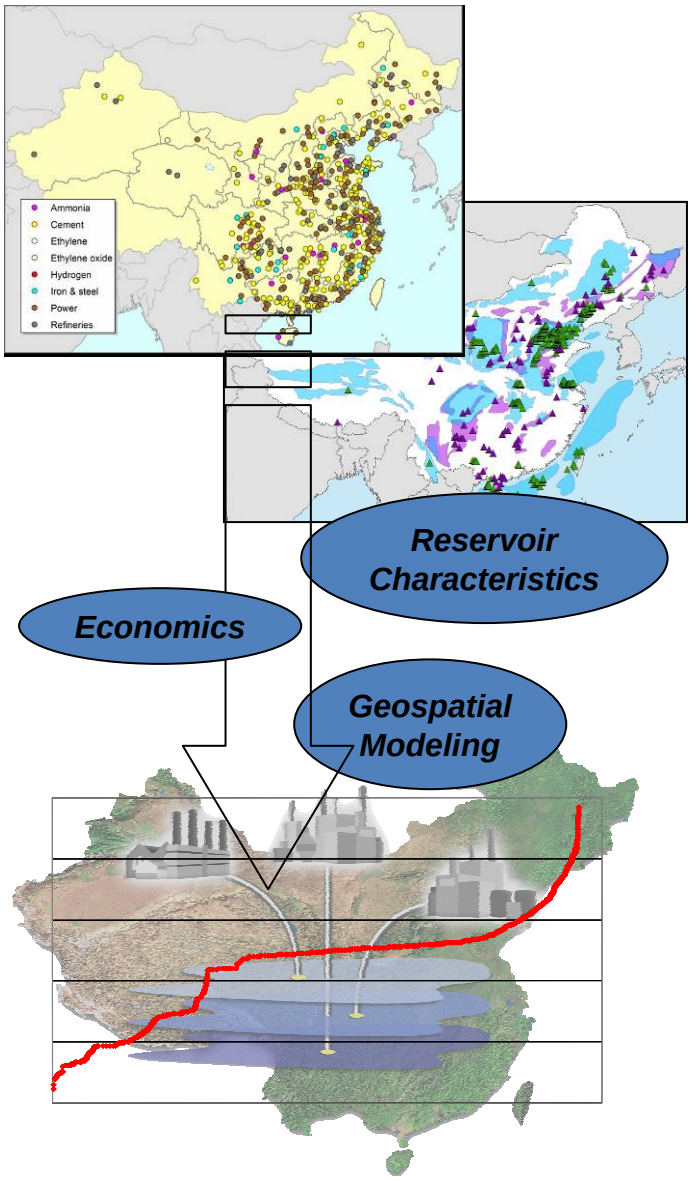
Project Overview



Sources + reservoirs + economics + analysis → cost curves

- A cataloging of existing CO_2 point sources and the following types of candidate CO_2 storage reservoirs:
  - Deep saline formations
  - Deep unmineable coal seams
  - Depleted oil and gas fields
- Incorporate data integrated into GIS modeling framework to enable integrated spatial and economic analyses
- Build CO_2 cost curve describing CCS potential versus cost
- Examine regional opportunities, economics, and technical constraints

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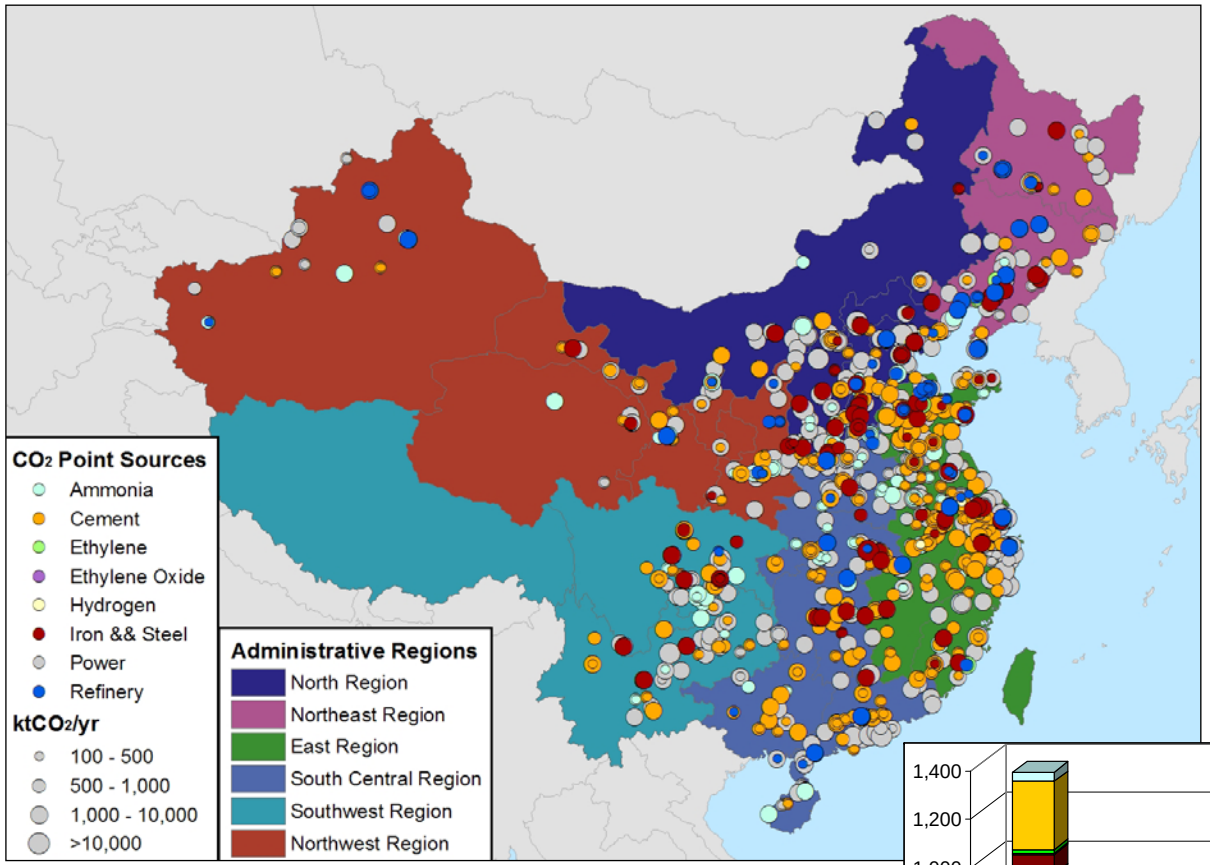
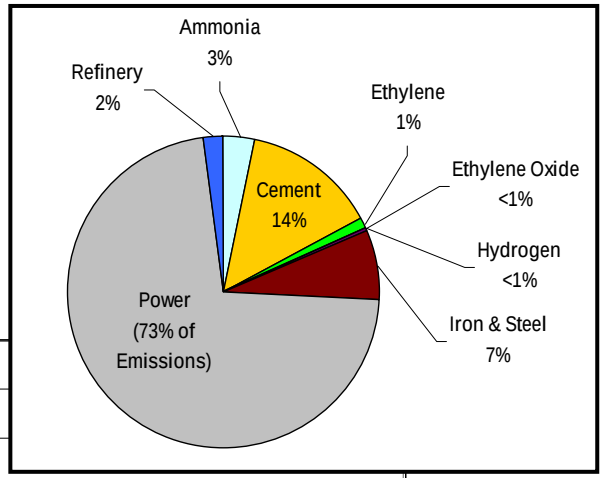
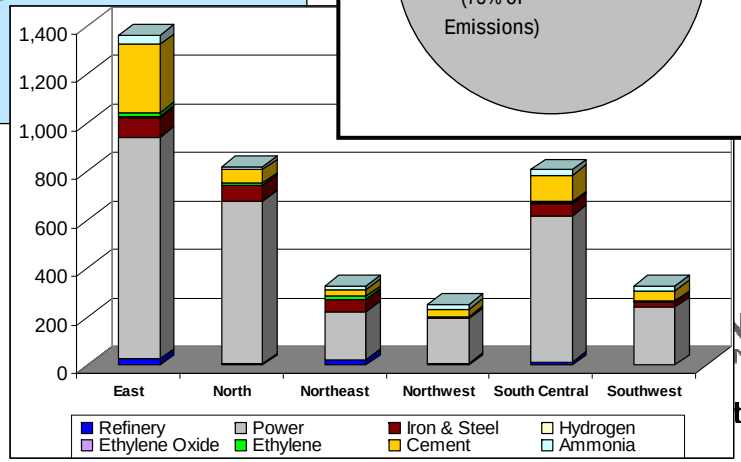
Large CO_2 Point Sources in China



- Over 1,600 CO_2 sources (100+ $ktCO_2/yr$ each)
- Total estimated CO_2 emissions from these large stationary sources: 3,890 $MtCO_2/yr$





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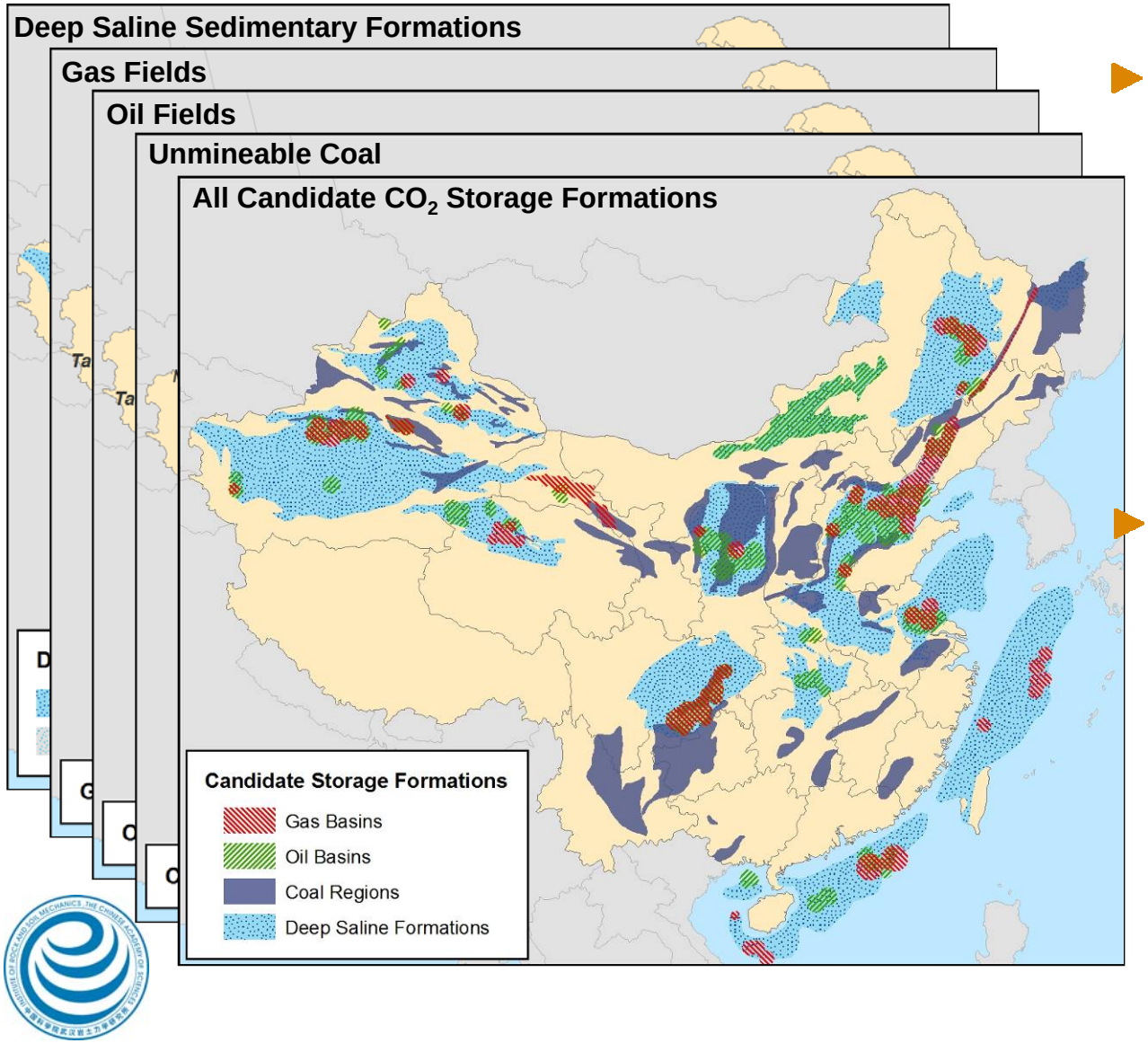
Geologic CO_2 Storage Capacity



- Estimated Onshore Storage Capacity, $MtCO_2$:

DSF:	2,288,000
Gas:	4,280
Oil:	4,610
Coal:	11,970
TOTAL:	**2,309,000**

- Potential Additional Offshore Storage Capacity:

  780,000 $MtCO_2$

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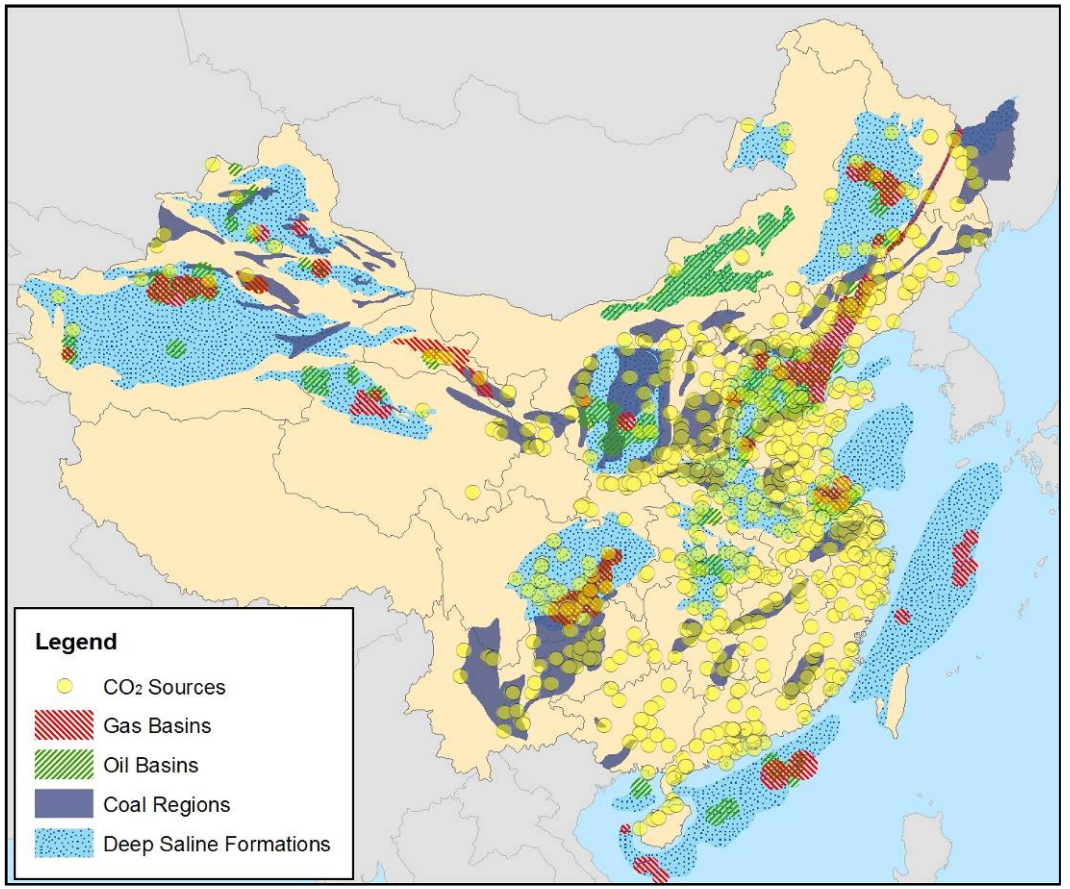
CO_2 Sources and Storage Reservoirs

- 2,300 $GtCO_2$ total potential onshore storage capacity
- 99% in deep saline formations
- 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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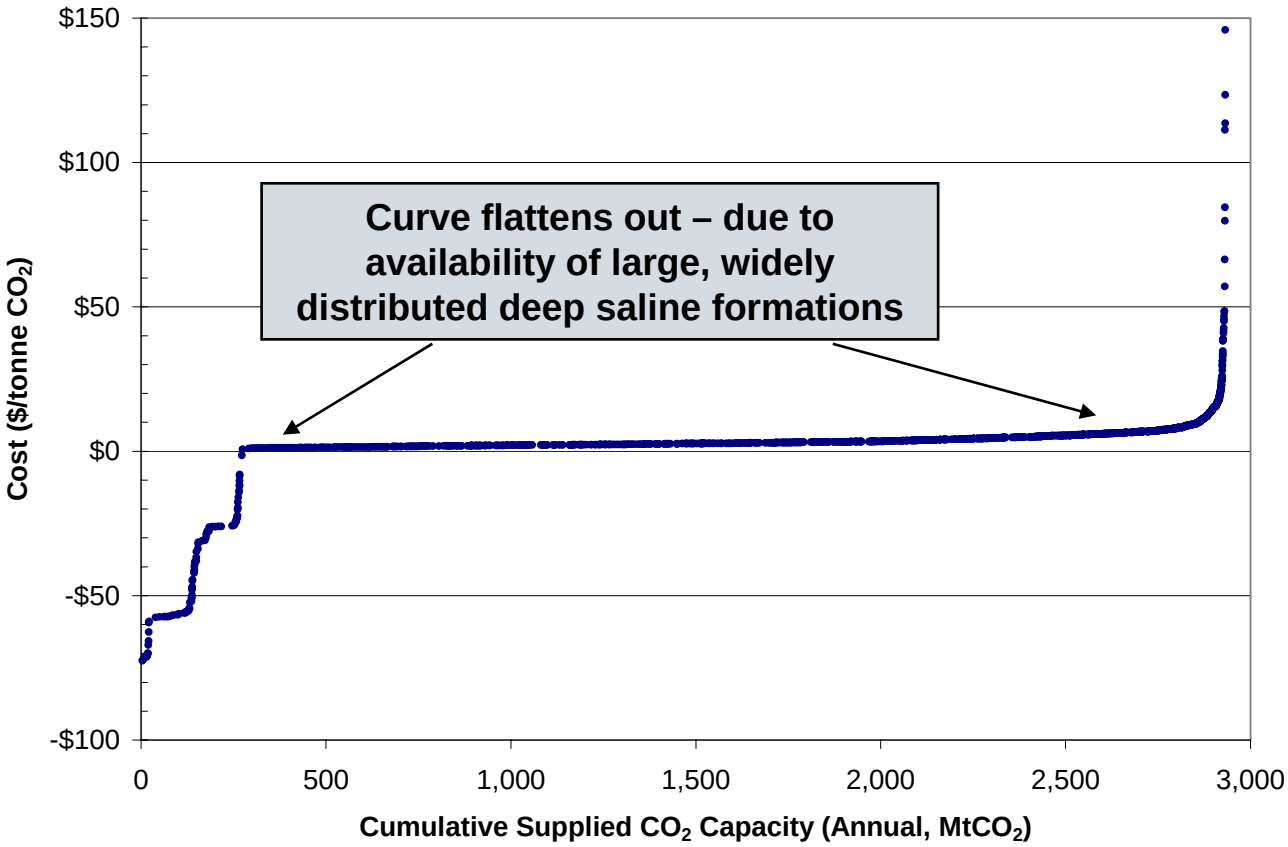
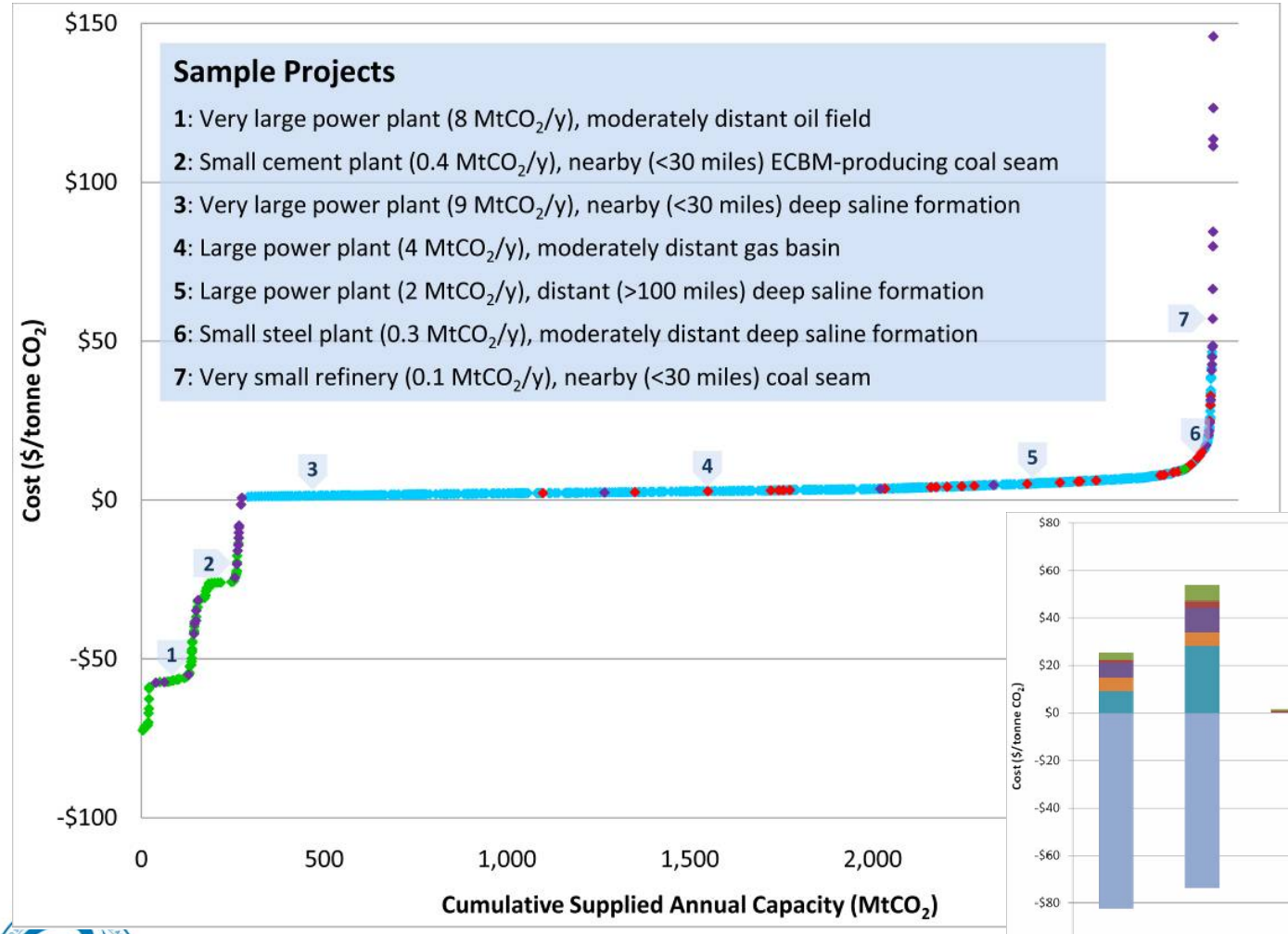
Cost Curve for CO_2 Transport & Storage in China

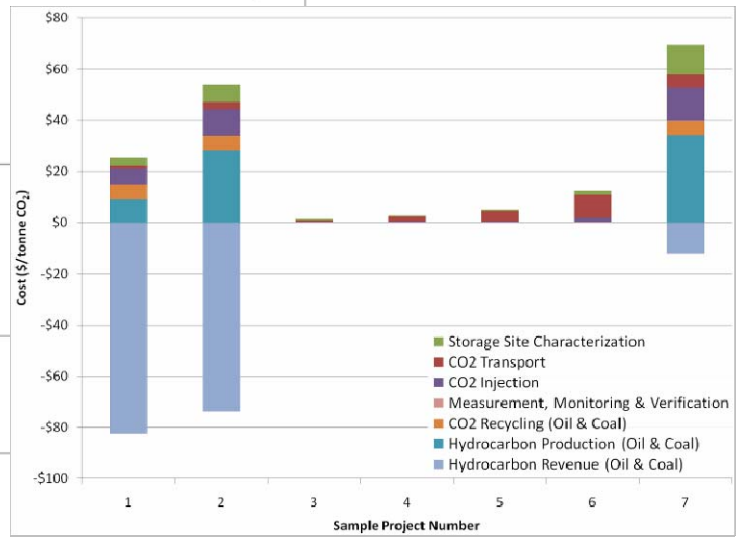
- CO_2 capture, dehydration, and compression cost intentionally excluded
- Each point on the curve represents a unique CO_2 source and its selected CO_2 storage reservoir.
- This curve represents the potential for annual storage at the specified costs assuming that all sources seek to begin storing their CO_2 at the same time and all capacity is available on day one, based on a 20-year commitment.



- Deep saline formations provide storage for over 90% of the individual source-reservoir pairs on this curve.
- Low-cost storage opportunities appear to be available in China but are likely exaggerated here due to a number of factors (e.g., timing of availability, smaller overall and individual capacities, lack of demonstrated performance)

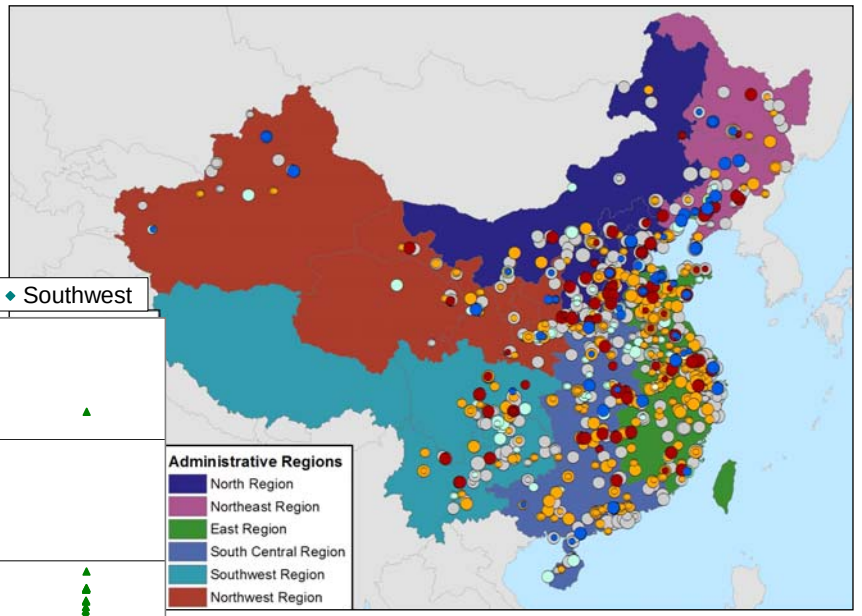
Cost Curve for CO_2 Transport and Storage with Sample Points Highlighted

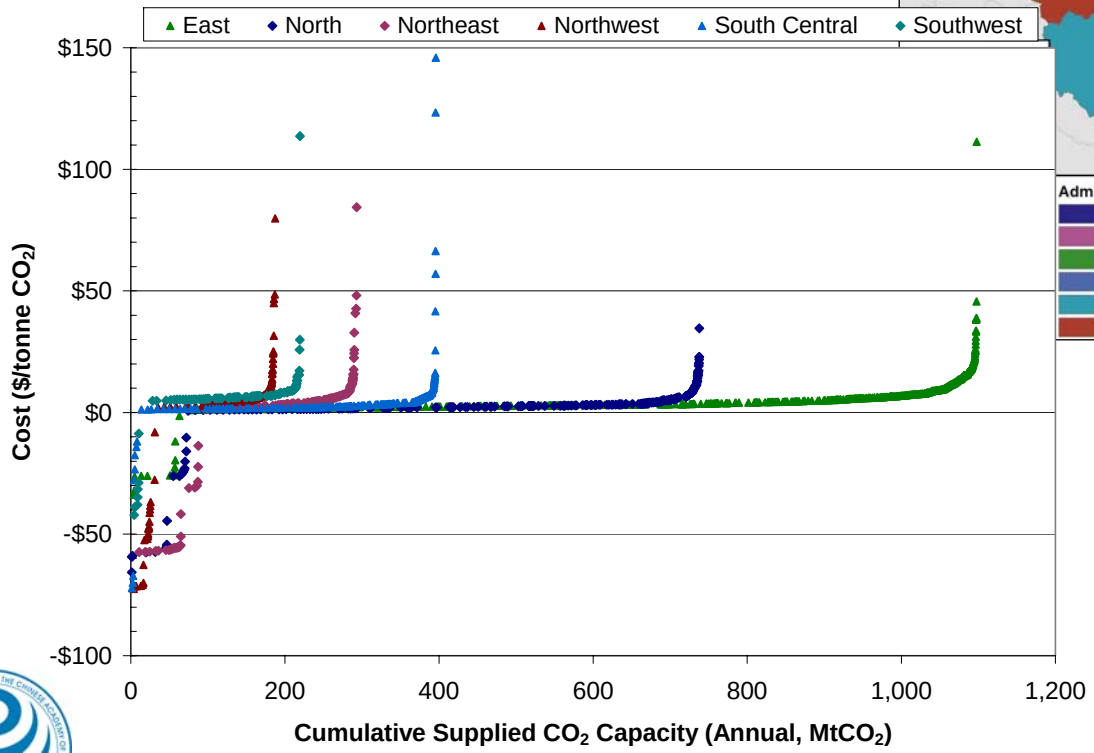




Regional Cost Curves for CO_2 Transport & Storage in China

- Regional cost curves highlight variations in CO_2 emissions distribution plus accessibility and cost of CO_2 storage capacity





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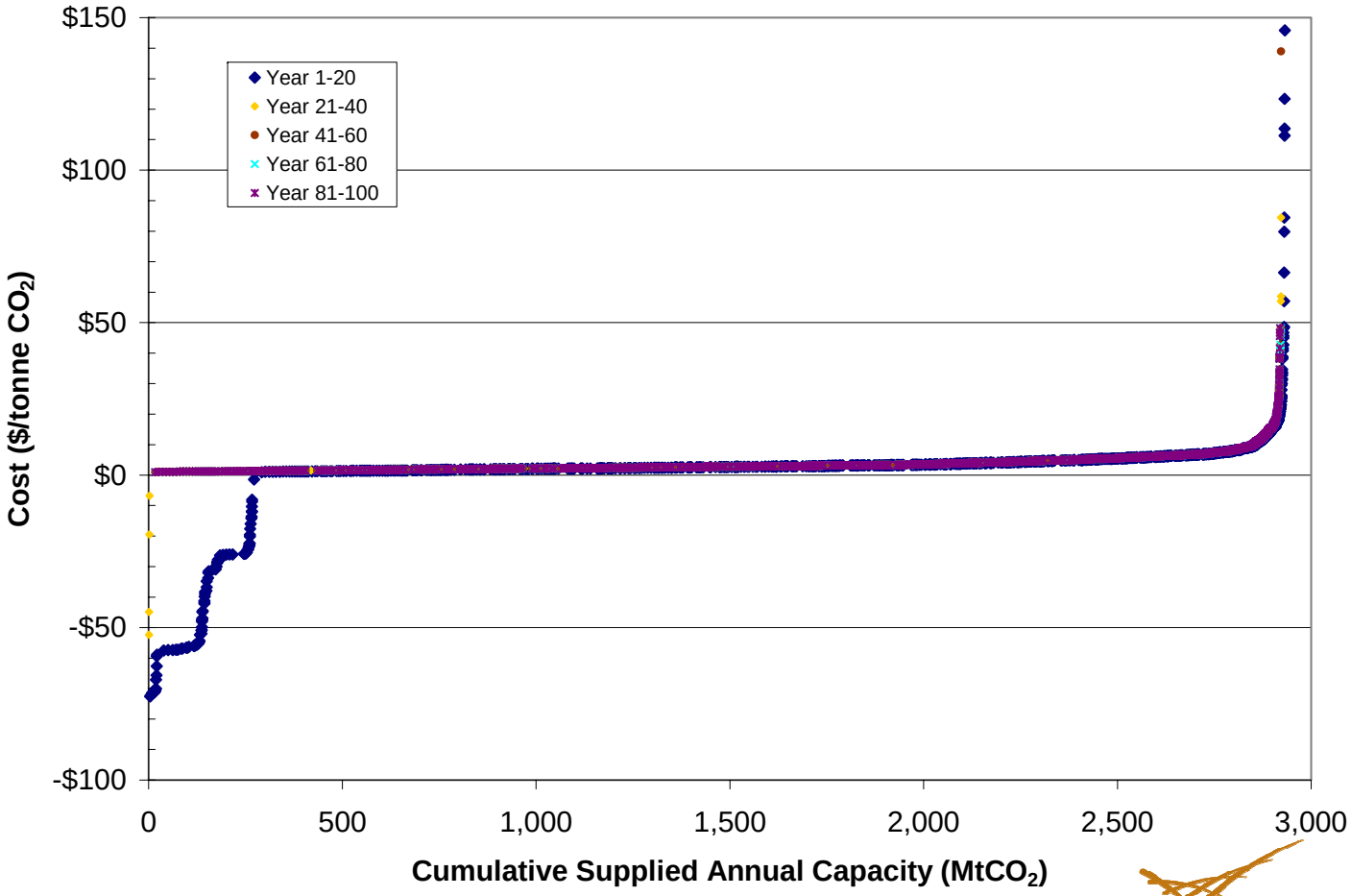
Cost Curves for 100 Years of Full-Scale CCS Deployment

- Low cost CO_2 storage opportunities are available, but overall capacity is relatively small, and timing of availability remains uncertain at this time
- Negative cost transport and storage capacity gone after first 40 years
- Additional storage demand taken up by large and broadly distributed deep saline formations



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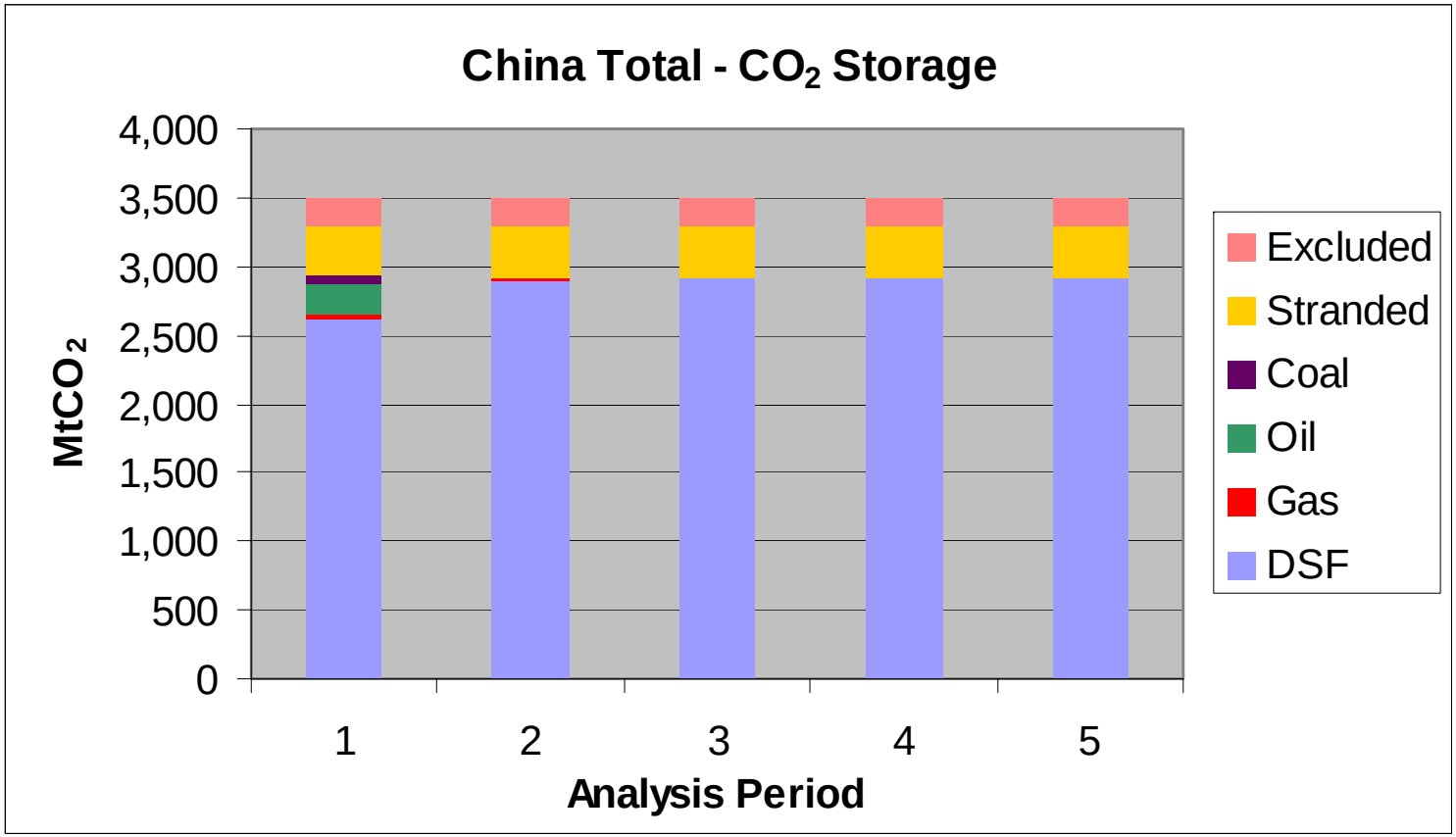
100 Years of Storage
Reference Case; By Sink Type



Excluded = CO_2 sources that had no storage options within 240 km search distance

Stranded = CO_2 sources that were not able to access sufficient capacity in nearby storage reservoirs

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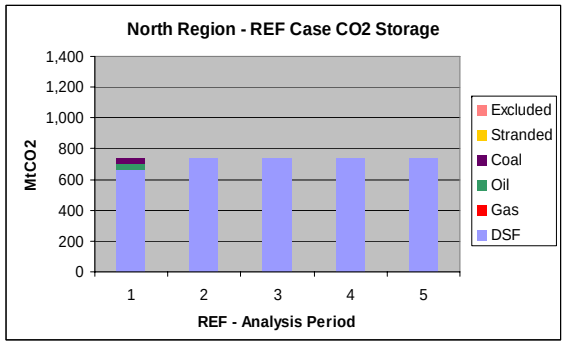
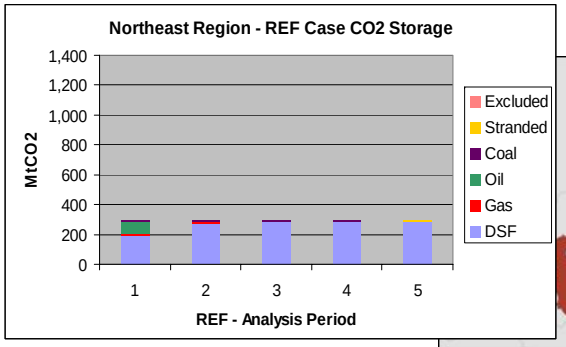
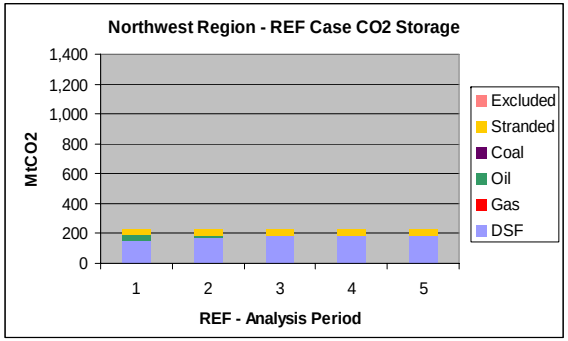
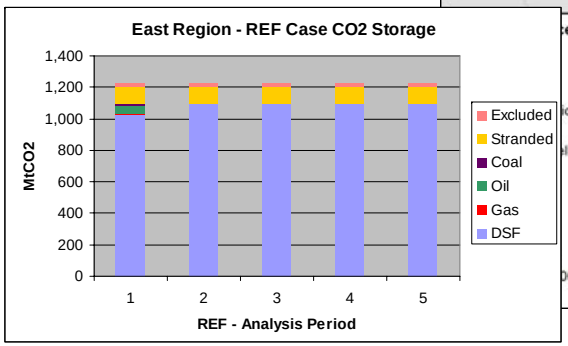
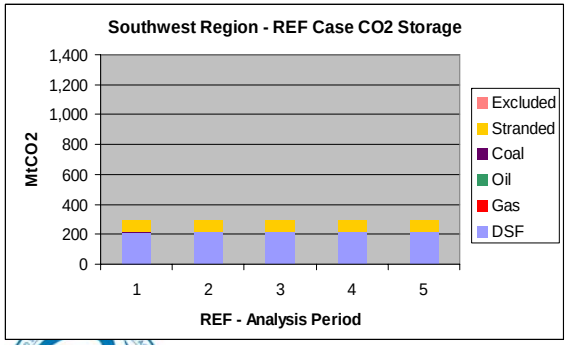
100 Years of Storage
Reference Case; By Region and Sink Type

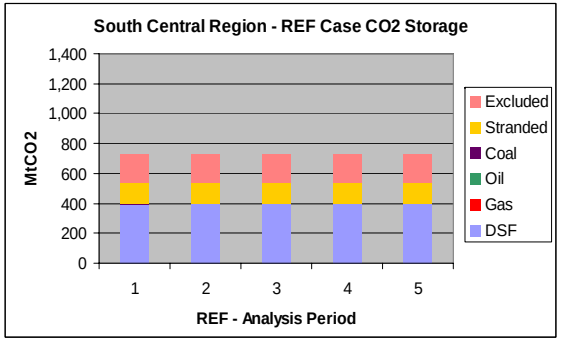












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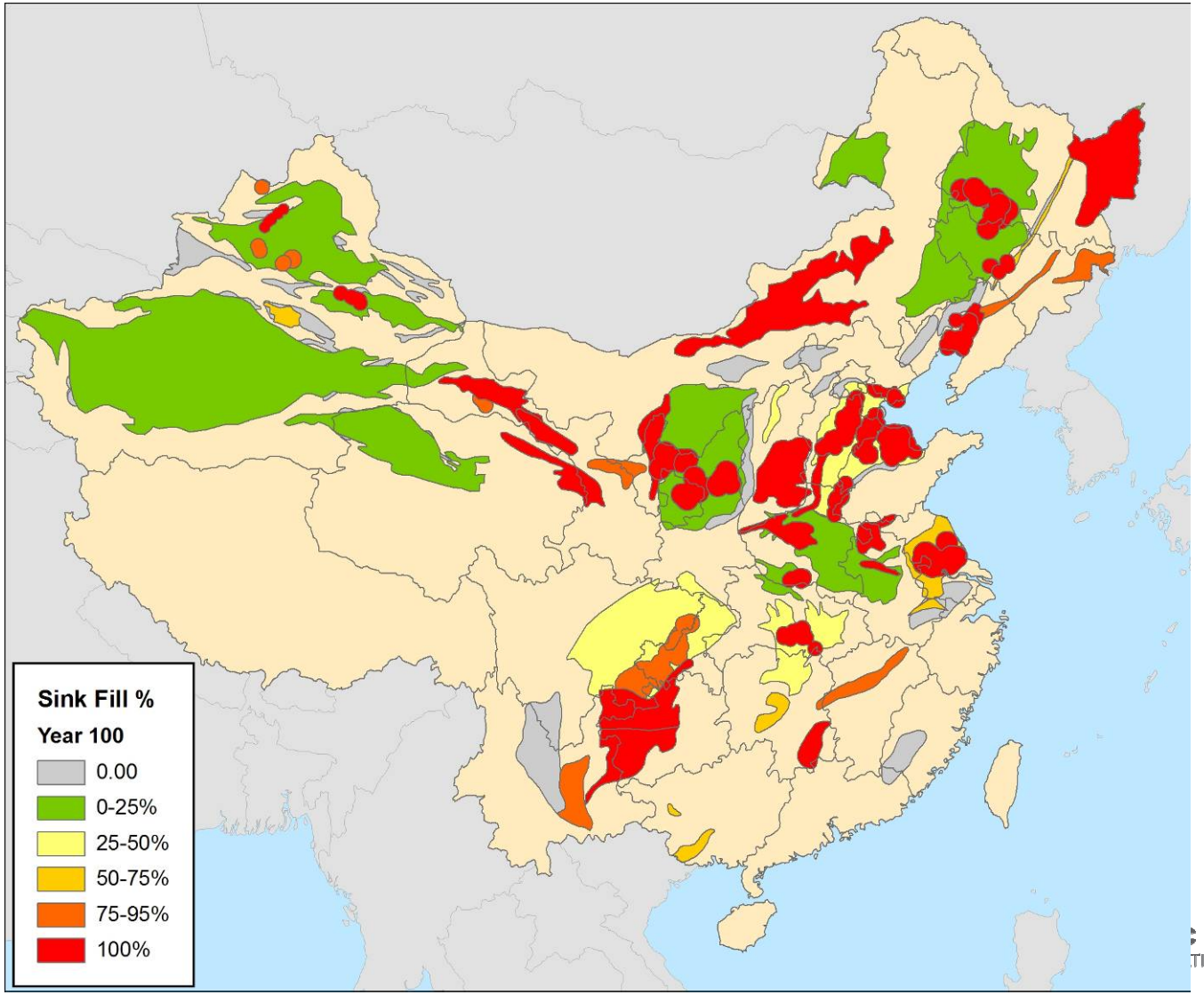
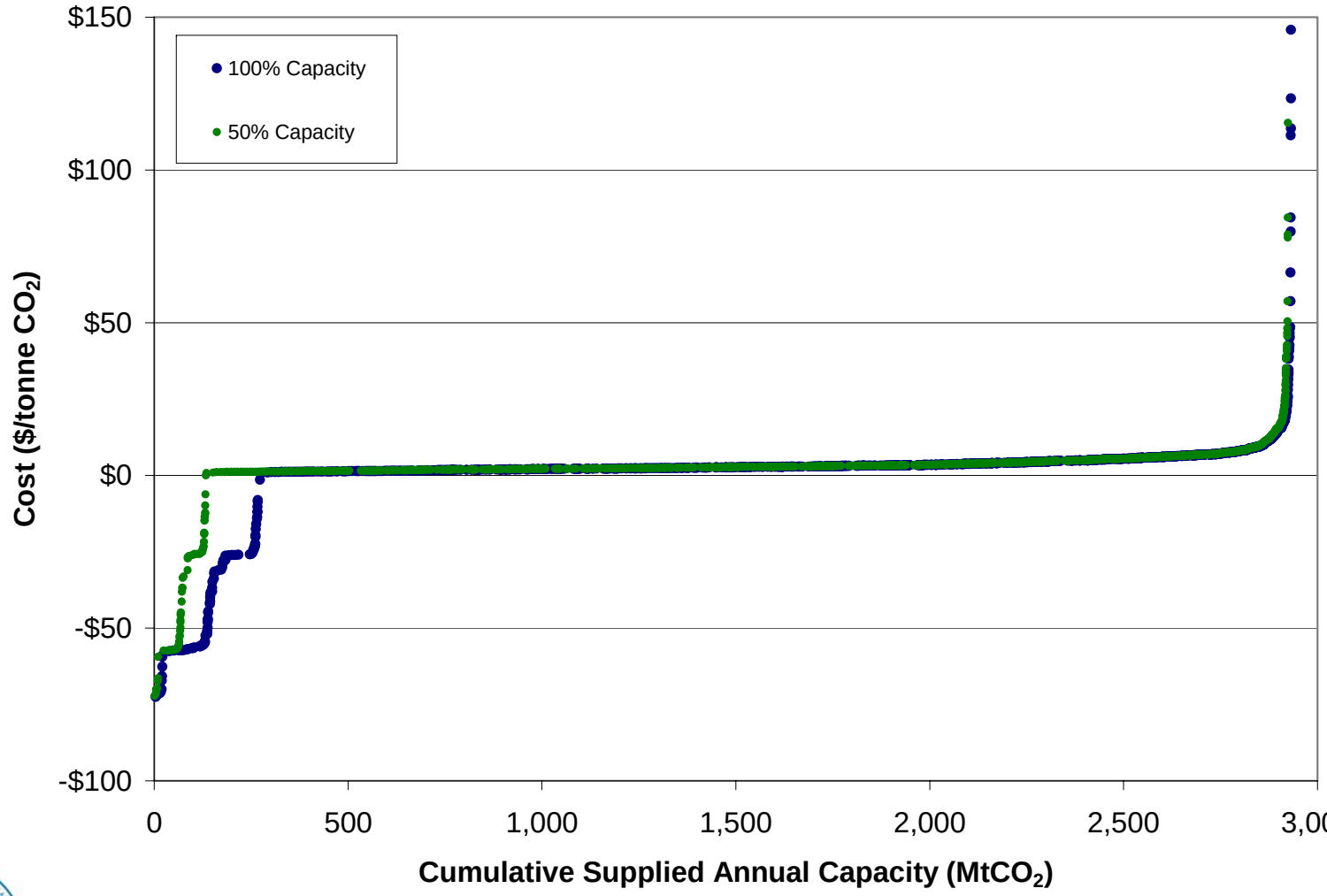
Map of Storage Capacity Utilization
Reference Case: 0 – 100 years



Sensitivity: Reduced Storage Capacity
50% Capacity Case



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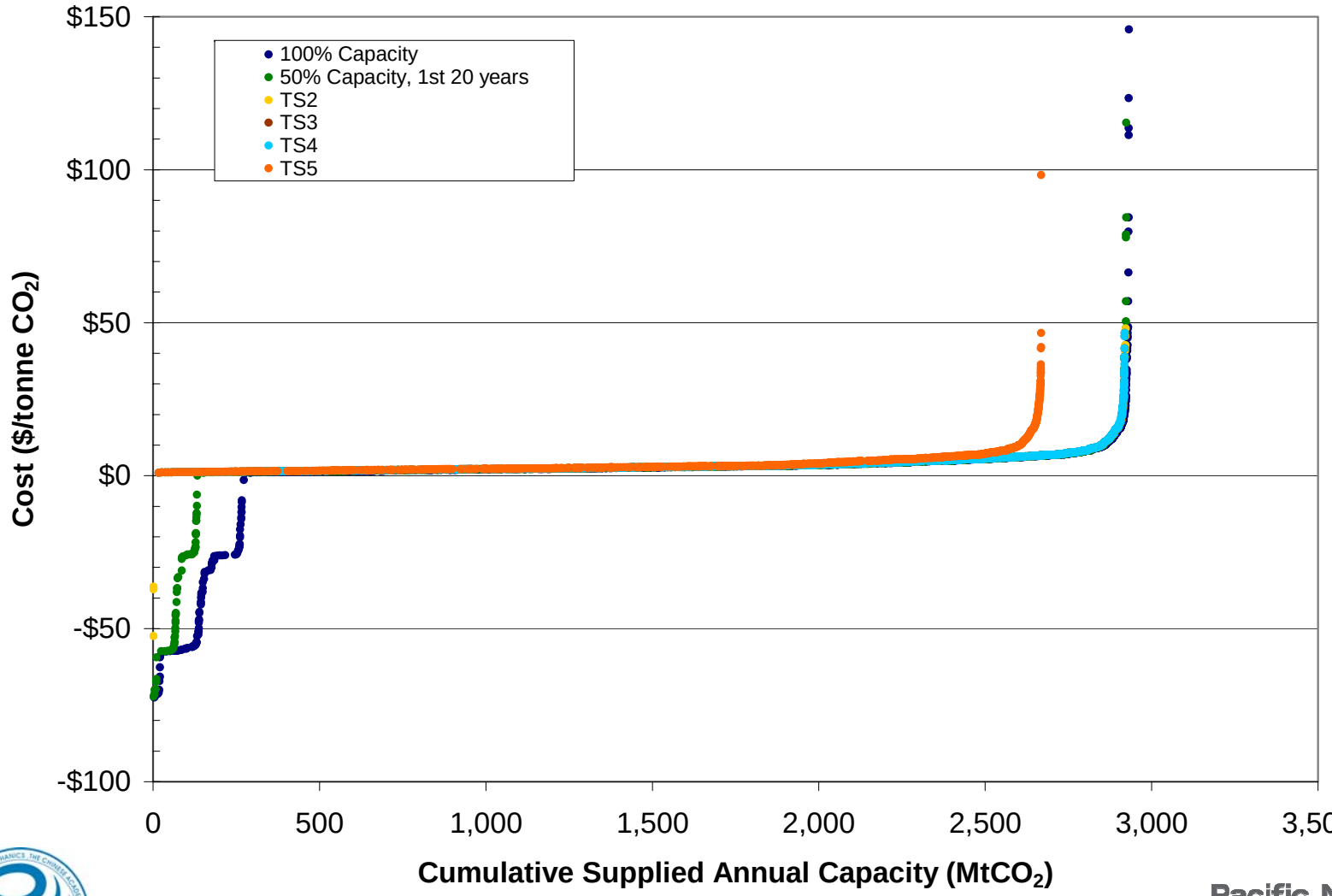
100 Years of Storage

50% Capacity Case



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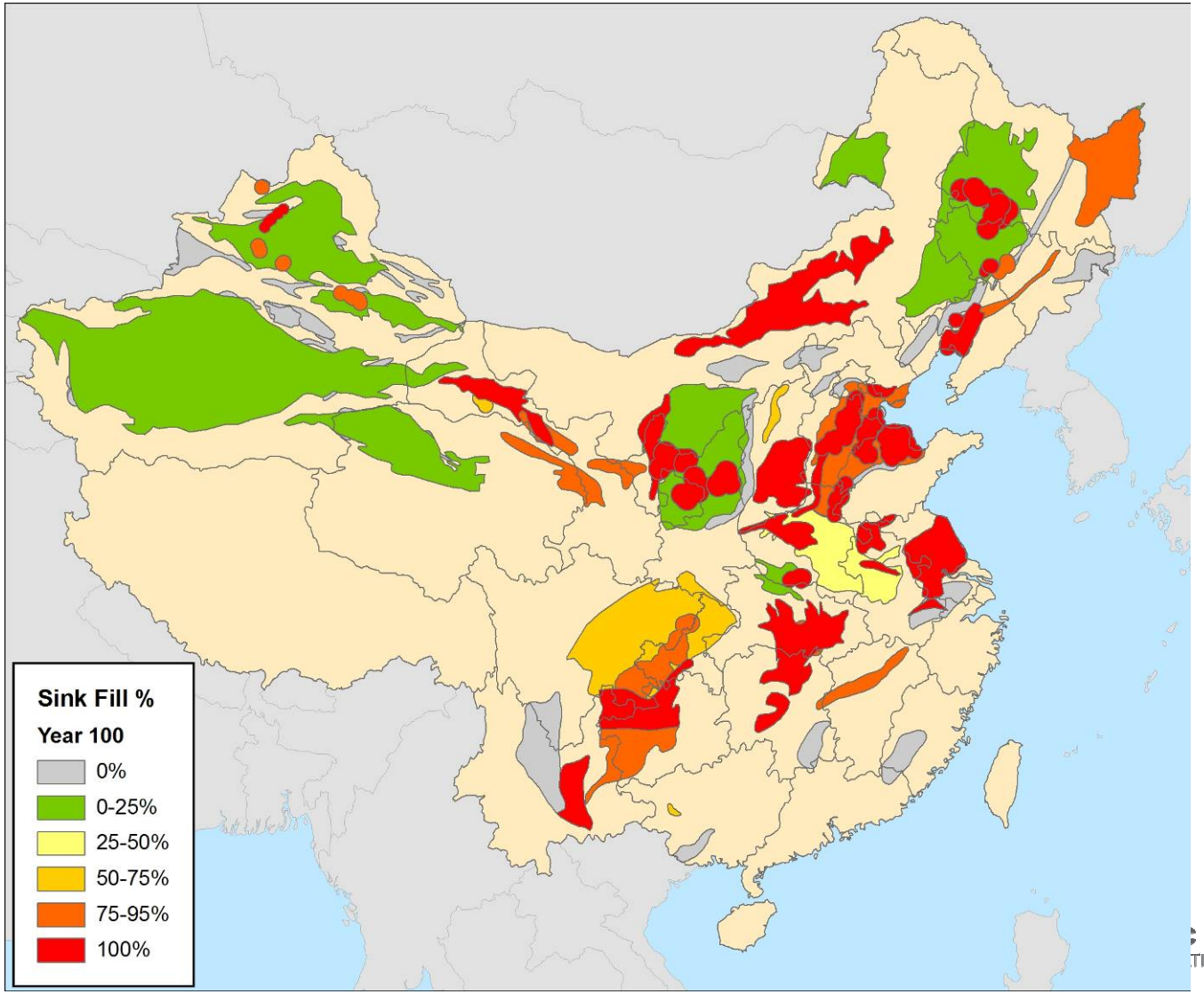
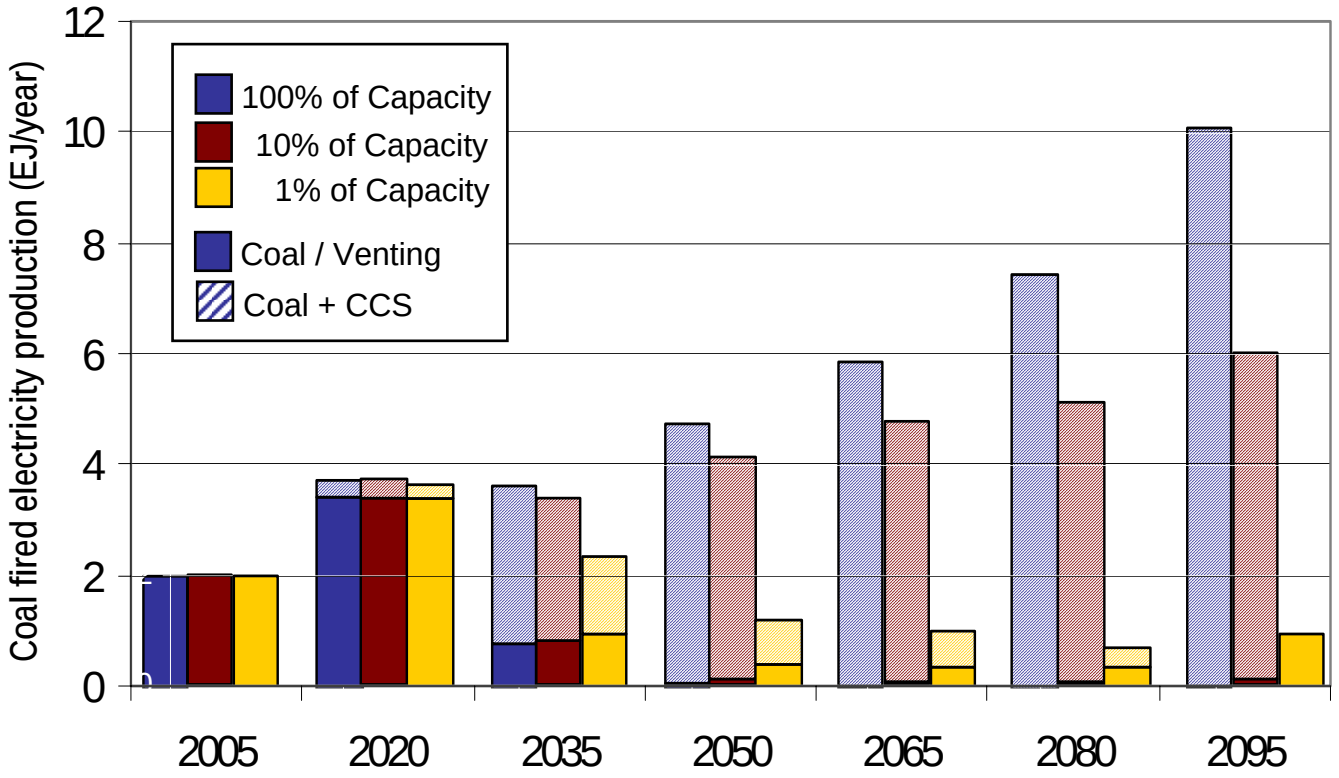
Map of Storage Capacity Utilization
50% Capacity Case: 0 – 100 years



Value of CCS in China

- China's Electricity Sector Use of Coal under WRE450 Constraint and Varying Storage Capacity Availability



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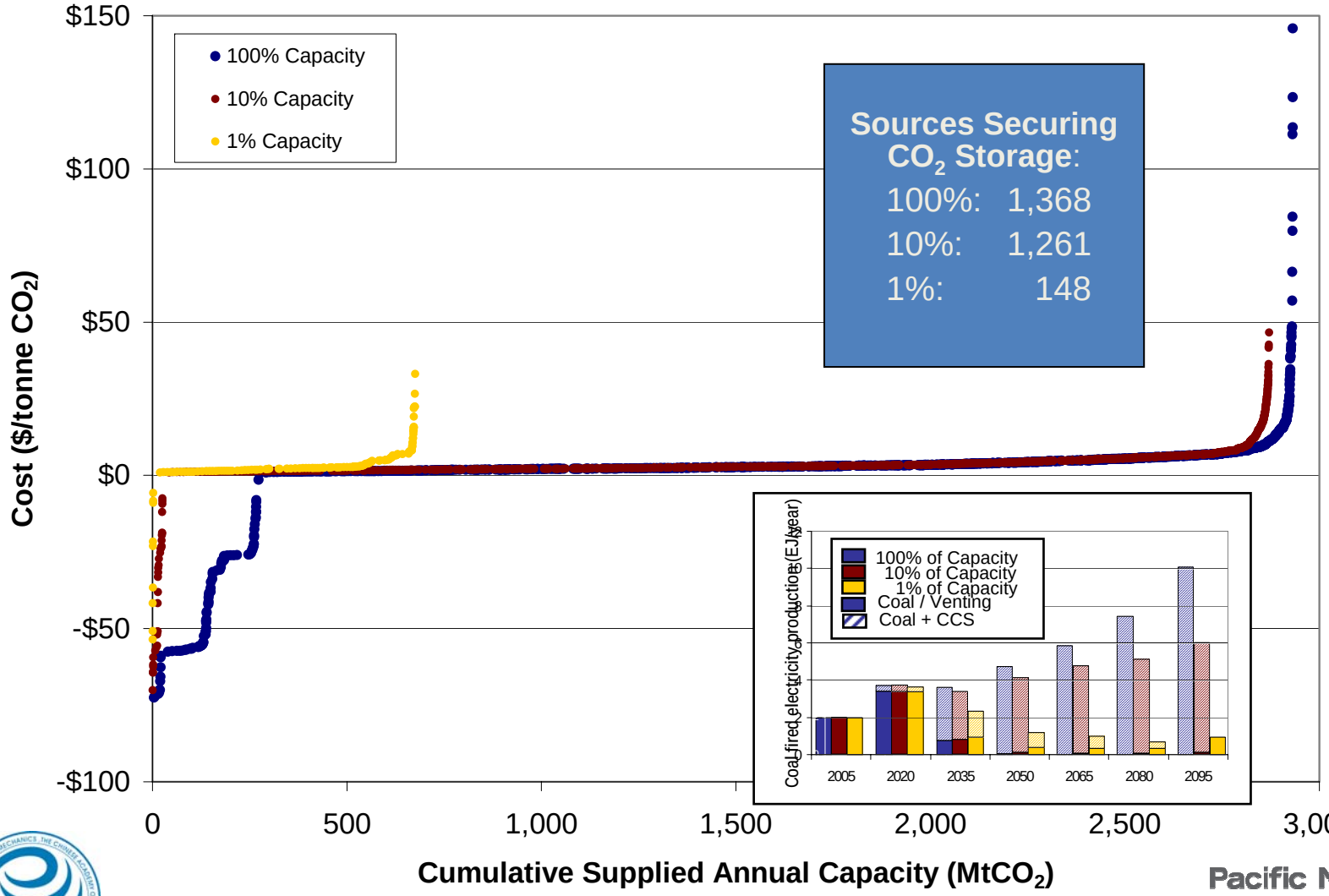
Value of CCS in China – Cost Curve

Results for 100%, 10%, 1% Storage Capacity



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Key Findings

- Over 1,600 large CO_2 point sources → 3,890 $MtCO_2$/yr
- 2,300 $GtCO_2$ theoretical storage capacity in onshore reservoirs
- There is strong potential for CCS technologies to offer significant emissions reductions in China, at transport and storage costs of up to about \$10/tCO_2
- Sensitivity analyses suggest that the storage capacity in China is robust and able to withstand significant reductions in ultimately accessible capacity and possible increases in component costs
- However, certain key regions may not have ready access to sufficient storage capacity in onshore basins – and may need to consider basins near offshore
- This work represents an initial step; follow-on research is critical to validate storage capacity estimates and further understand the technical and economic potential and challenges for CCS to help reduce the carbon emissions from the growing Chinese economy

Experience with Similar Research in U.S.

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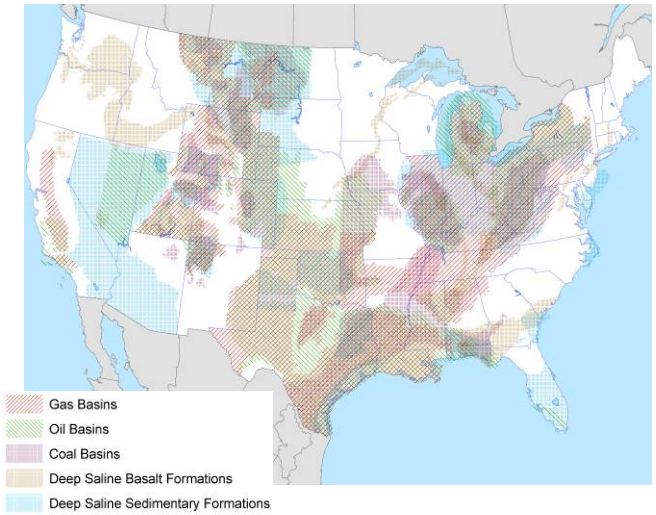
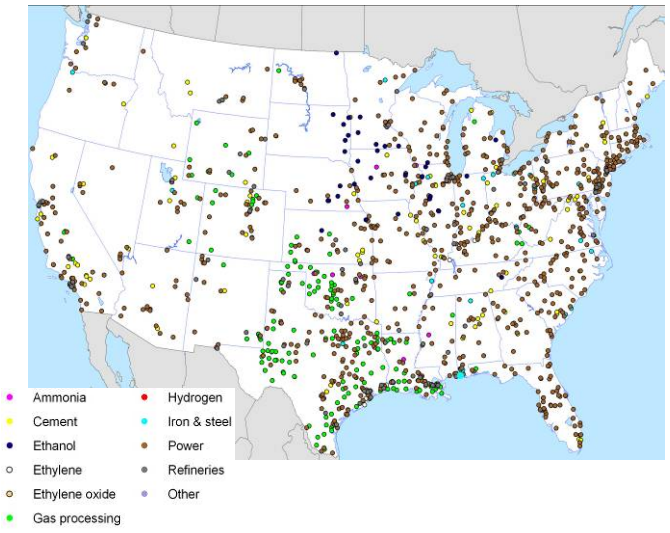
Early Examination of CCS Potential in the United States



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 CO_2 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

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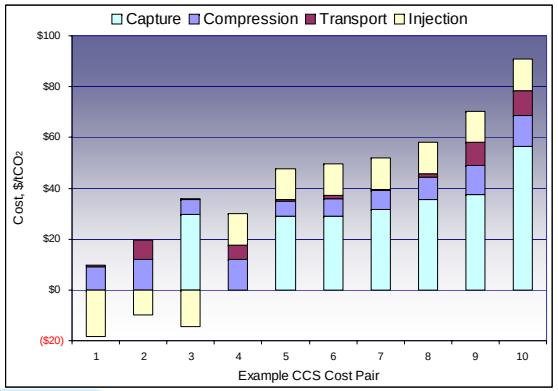
Comparison of North American Storage Capacity Estimates (U.S. & Canada)

CO_2 Storage Capacity, $GtCO_2$	IEA GHG 2005	RCSPs* (Low)	RCSPs* (High)
Deep Saline Formations	3,730	3,297	12,618
Oil & Gas Fields	51	138	138
Coal Seams	65	157	178
Total	3,846	3,592	12,934

*2008 Carbon Sequestration Atlas of the United States and Canada

Cost Curve for CO_2 Capture, Transport, and Storage in the U.S.



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-fired power plant / distant (>50 miles) deep saline formation

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

(9) Cement plant / distant (>50 miles) deep saline formation

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

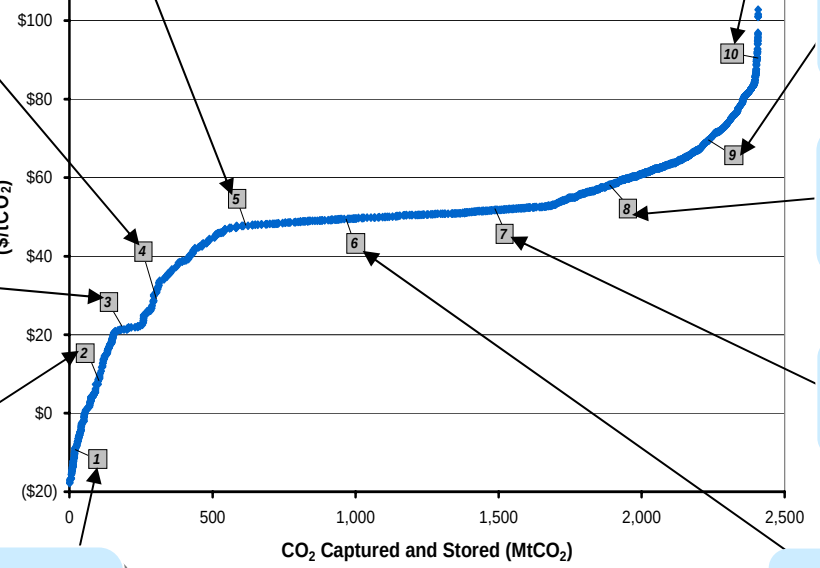
(8) Smaller coal-fired power plant / nearby (<25 miles) deep saline basalt formation

(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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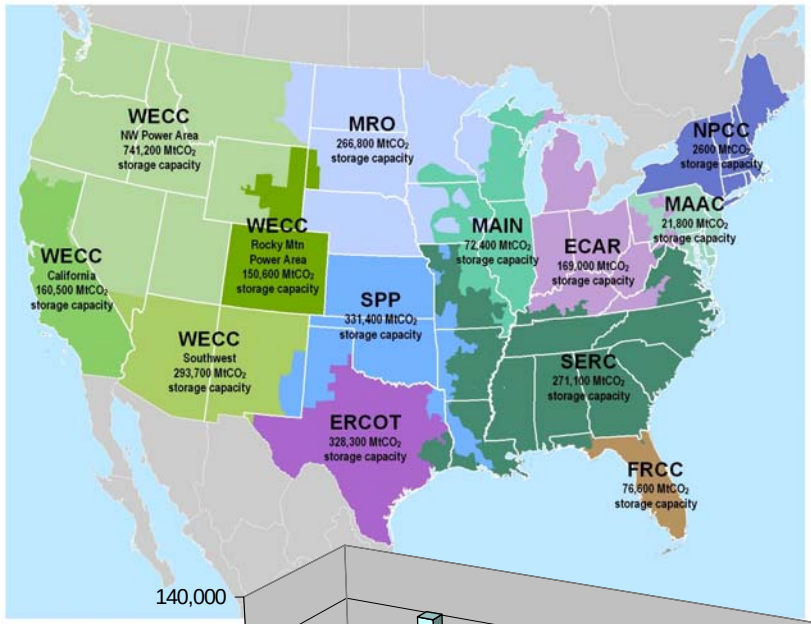
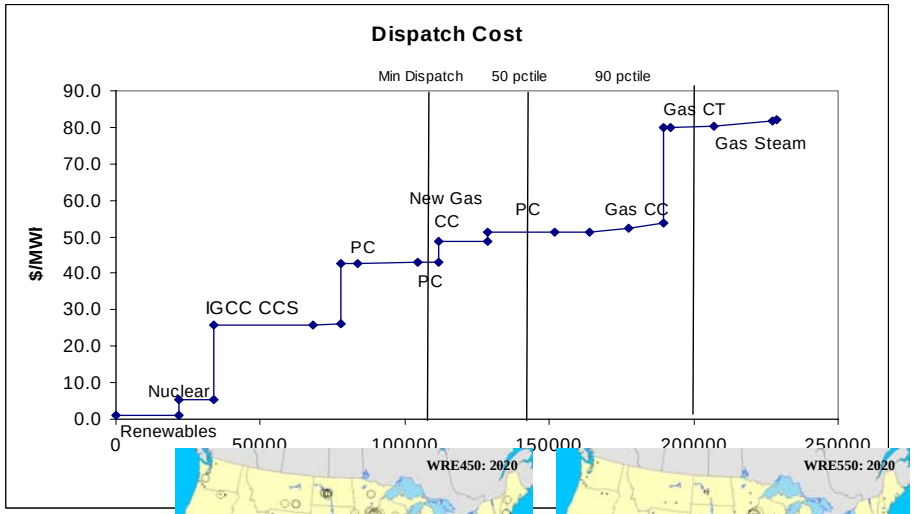
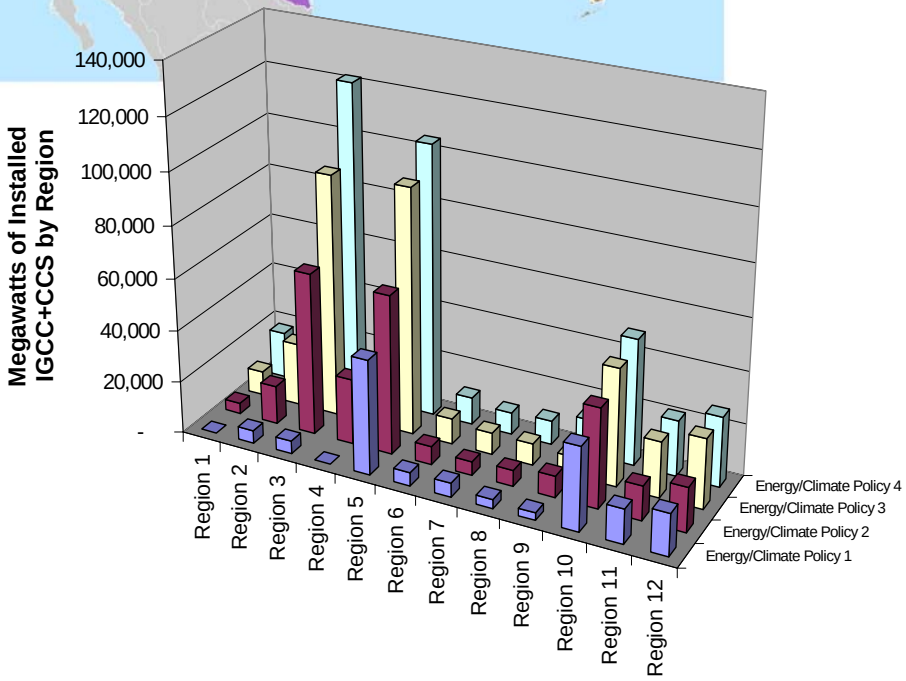
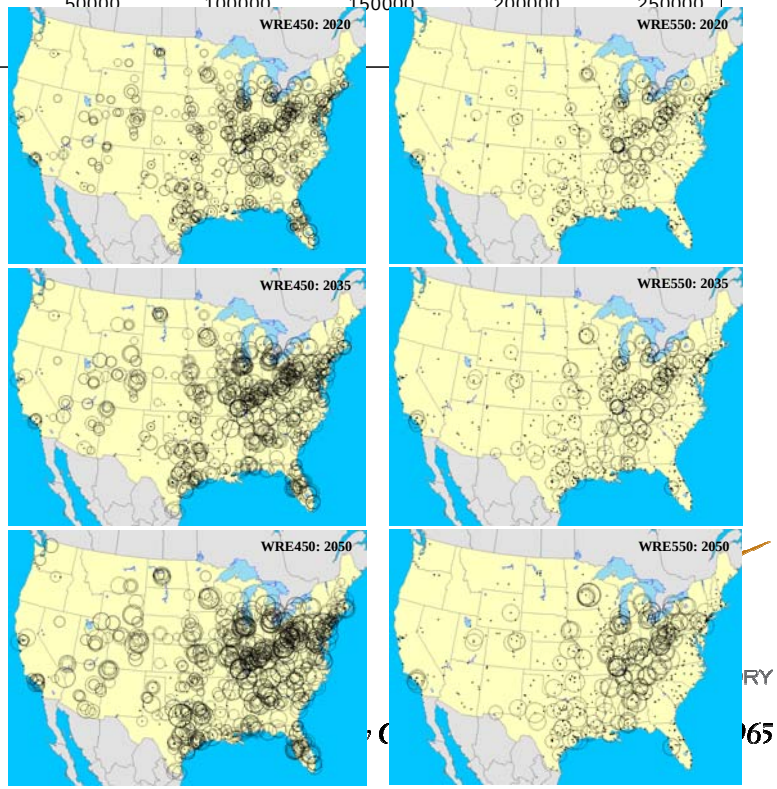
U.S. Electric Power Region Analyses

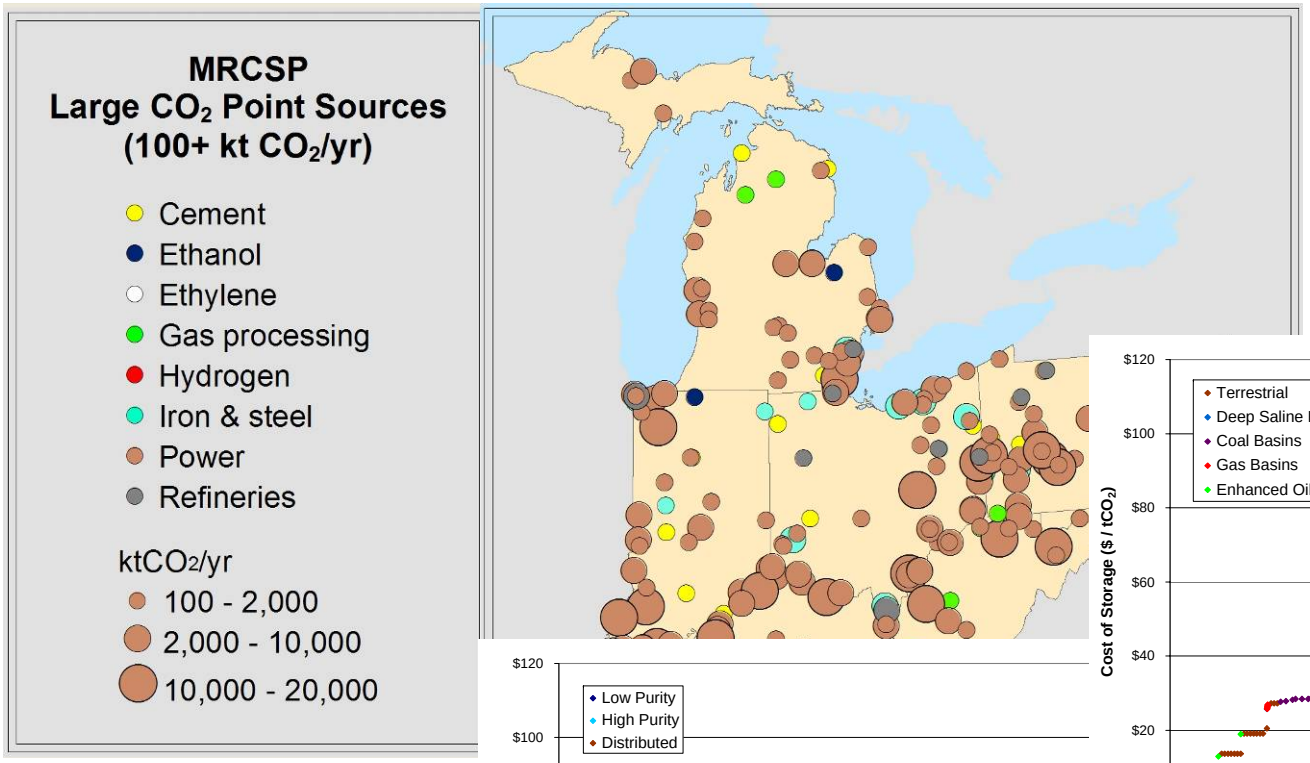


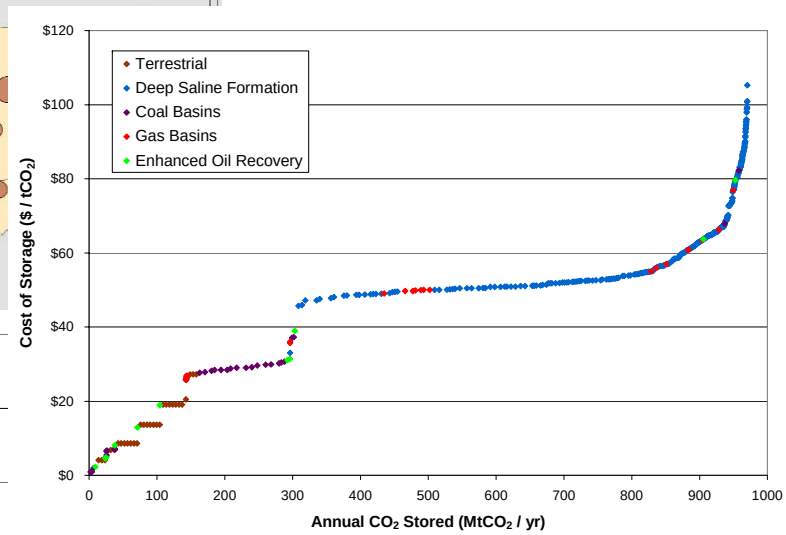


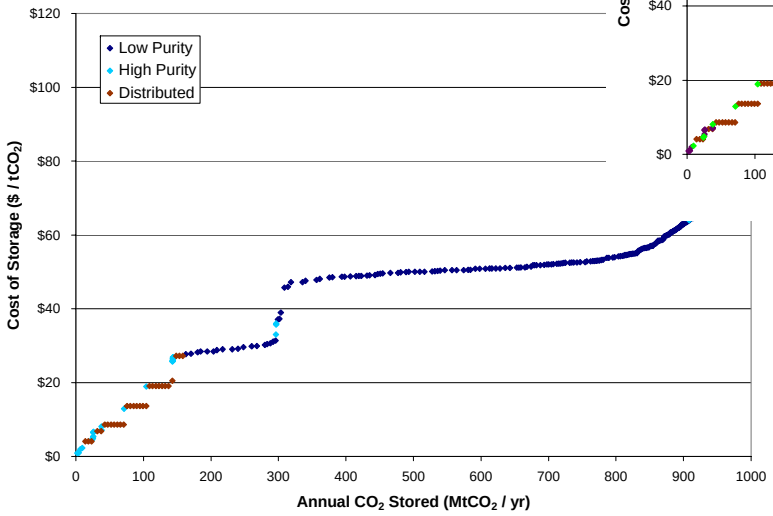




U.S. Regional Analyses: MRCSP







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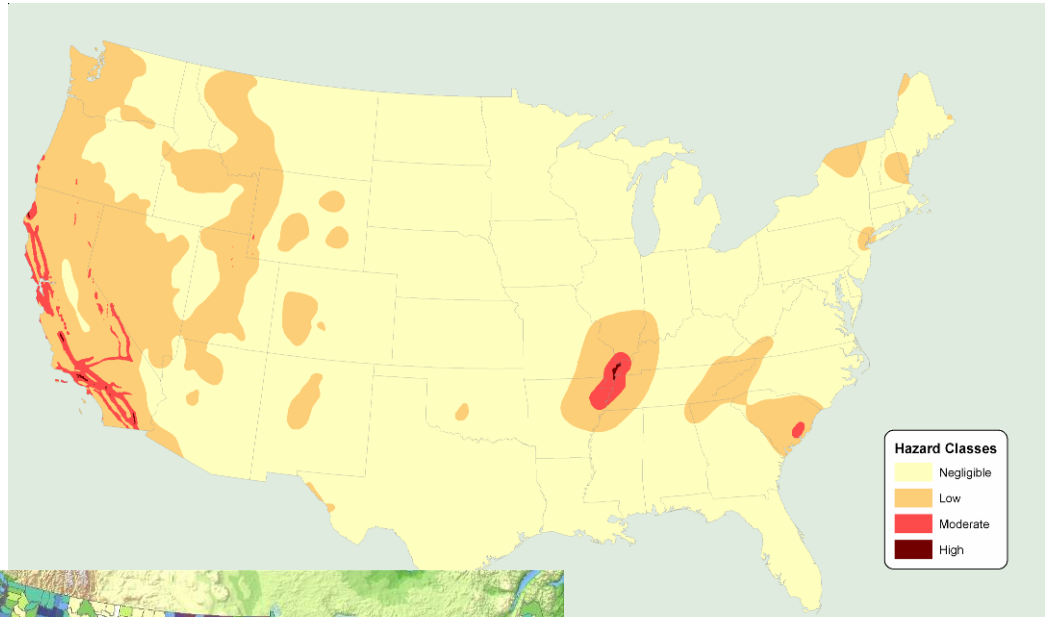
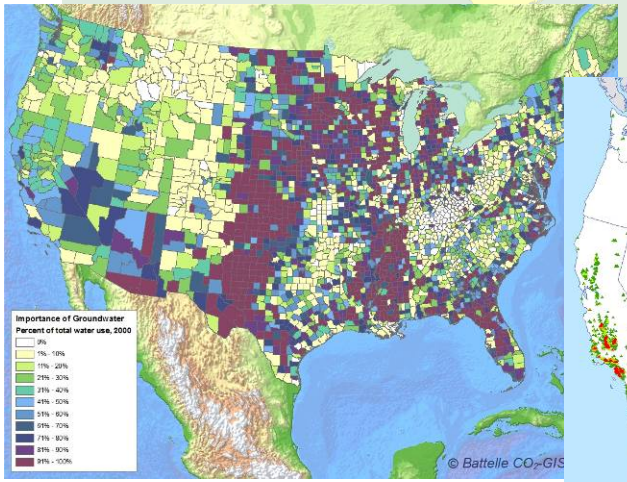
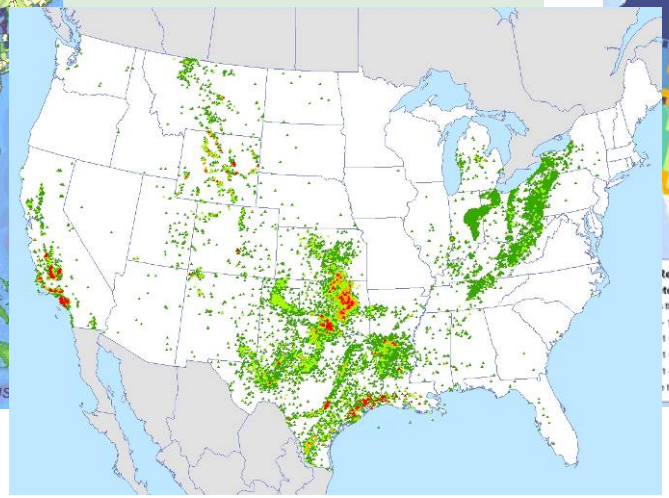
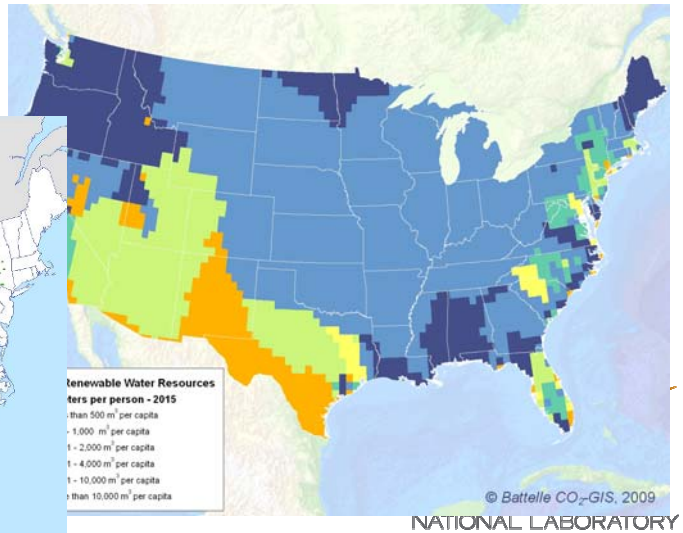
Examining Potential Constraining Factors

- Seismic hazards
- Existing deep well penetrations
- Groundwater resource protection & use impacts
- Threatened / endangered species habitat
- Culturally / ecologically sensitive areas and protected lands









Thank You

Regional Opportunities for Carbon Dioxide Capture and Storage in China

Report Now Available at:

http://energyenvironment.pnl.gov/pdf/roccs_china_pnnl_19091.pdf

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