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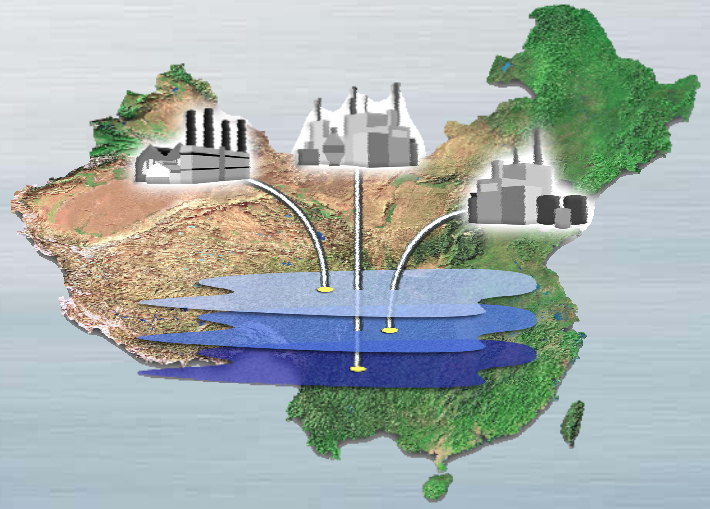

Assessing Market Opportunities for CO_2 Capture and Storage (CCS) in China

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Project Overview

- Assessment of the market potential of CCS in China
  - Identify major existing point sources
  - Examine industrial growth scenarios to understand future point sources
  - Assess CO_2 storage location and capacity
  - Build CO_2 cost curve describing CCS potential versus cost
- Builds on previous studies
- International team established and work is underway
- Preliminary results expected Fall 2006

A Multinational Research Collaboration

- Sponsoring Government Agencies
  - Chinese Ministry of Science and Technology
  - United States Department of Energy
- Participants
  - Battelle
  - Chinese Academy of Sciences
  - Leonardo Technologies, Inc.
  - Montana State University
  - Pacific Northwest National Laboratory
  - PetroChina
  - Tulane University, US/China Energy and Environmental Technology Center
  - Tsinghua University, US/China Energy and Environmental Technology Center

中美能源技术中心
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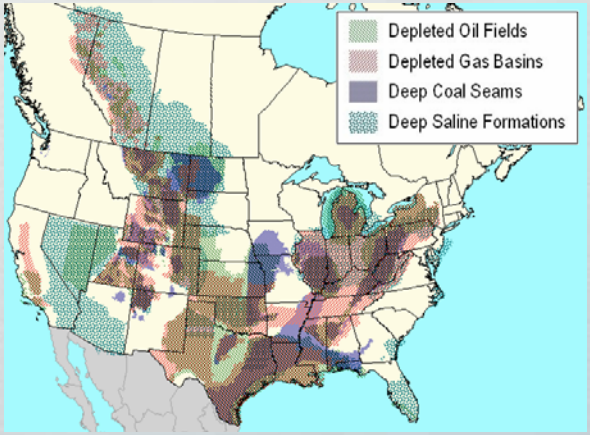
Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Ministry of Science and Technology of the People's Republic of China

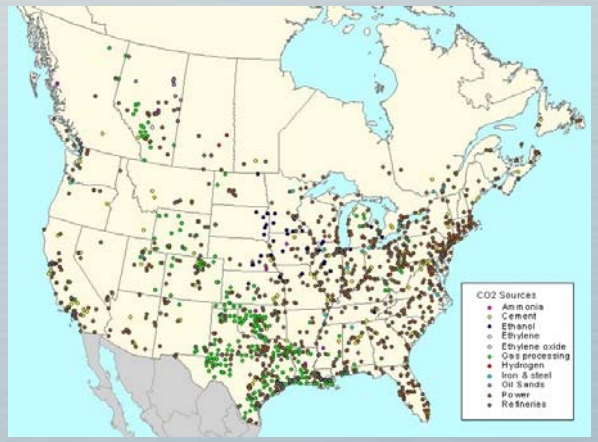
Primary Goal: Assess CO_2 Storage Potential and Large Potential User Market for CCS Technologies within China

Example from Recent North American Assessment (IEA GHG, 2005):



3,800+ $GtCO_2$ Capacity within 330 US and Canadian Candidate Geologic CO_2 Storage Reservoirs

- 3,730 $GtCO_2$ in deep saline formations (DSF)
- 65 $GtCO_2$ in deep unmineable coal seams with potential for enhanced coalbed methane (ECBM) recovery
- 40 $GtCO_2$ in depleted gas fields
- 13 $GtCO_2$ in depleted oil fields with potential for enhanced oil recovery (EOR)



2,082 Large Sources (100+ $ktCO_2/yr$) with Total Annual Emissions = 3,800 $MtCO_2/yr$

- 1,185 electric power plants
- 447 natural gas processing facilities
- 154 petroleum refineries
- 53 iron & steel foundries
- 124 cement kilns
- 43 ethylene plants
- 9 oil sands production areas
- 40 hydrogen production
- 25 ammonia refineries
- 47 ethanol production plants
- 8 ethylene oxide plants

Cost Curve Methodology, Part 1: Calculating the Full Set of Storage Options

- Develops levelized costs of transport and storage for each possible source-reservoir pair

- Net Storage Cost =

  Cost of Transport (via pipeline from plant gate)

  + Cost of Injection (capital, operating, & MMV costs)

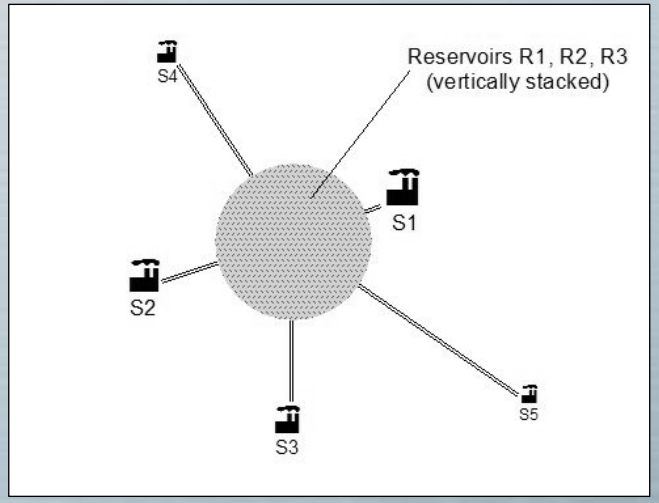
  - Revenue from Value-Added Hydrocarbon Recovery

- The cost curve methodology computes many thousands of source-reservoir cost pairs for these point sources and candidate storage reservoirs, i.e., many CO_2 point sources will have many candidate storage options available within a reasonable distance.

Cost Curve Methodology, Part 2: Identifying the Least-Cost Pairings, Considering Reservoir Capacity Constraints

Source-Reservoir Pairing

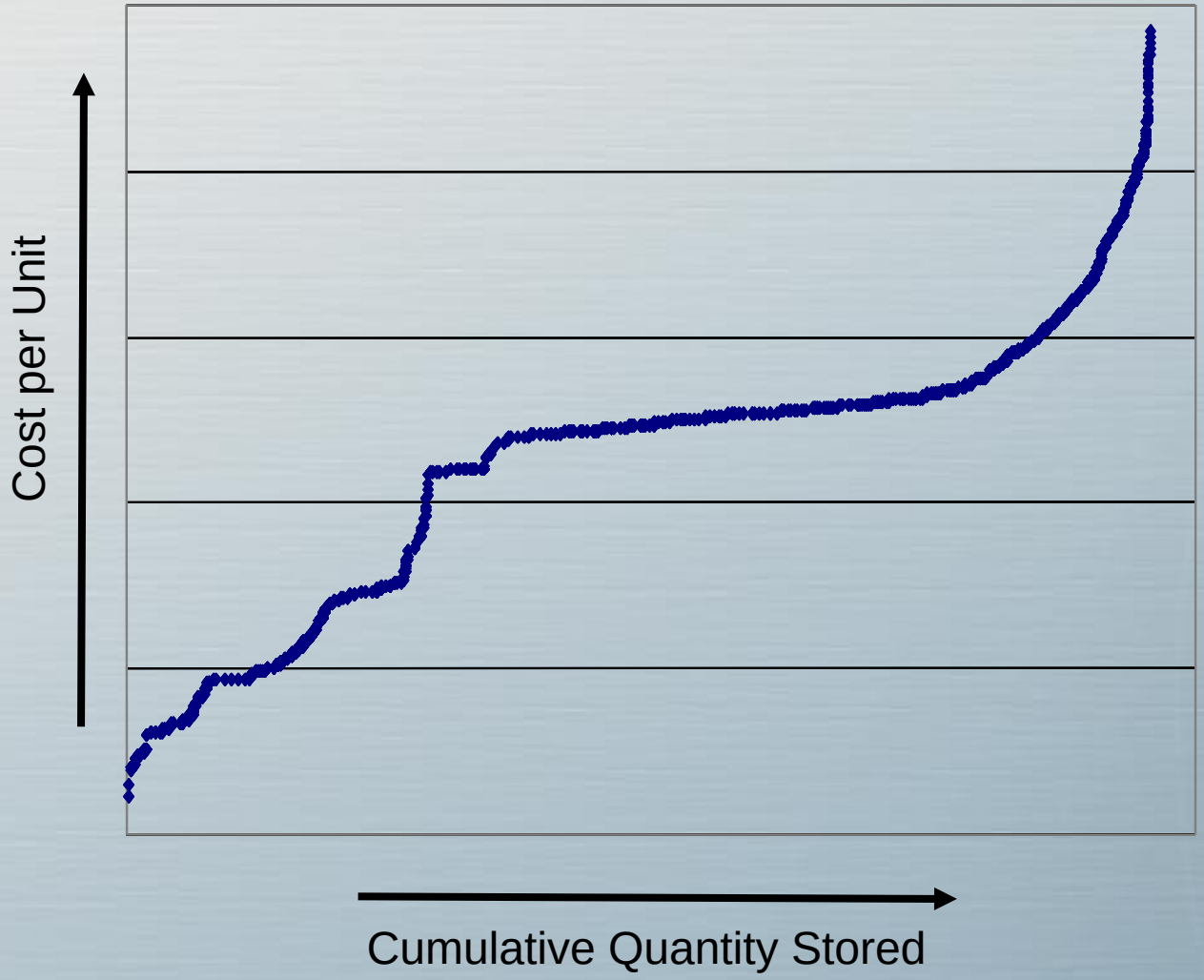
- Cost-minimizing decision process based on:
  - Source characteristics
  - Distance to reservoir
  - Reservoir characteristics
  - Oil and natural gas price
  - Remaining capacity of reservoir and minimum capacity commitment required by source
  - Requirement that reservoir must be able to store at least 10 or 20 years' worth of the point source's CO_2



- Pairing requests are filled in order of net transport & storage cost
- Results in a cost curve of cumulative CO_2 capacity supplied on an annual basis vs. cost ($/t$CO_2$)

Assessing CCS Market Opportunities
The Outcomes

- Example CCS Cost Curve

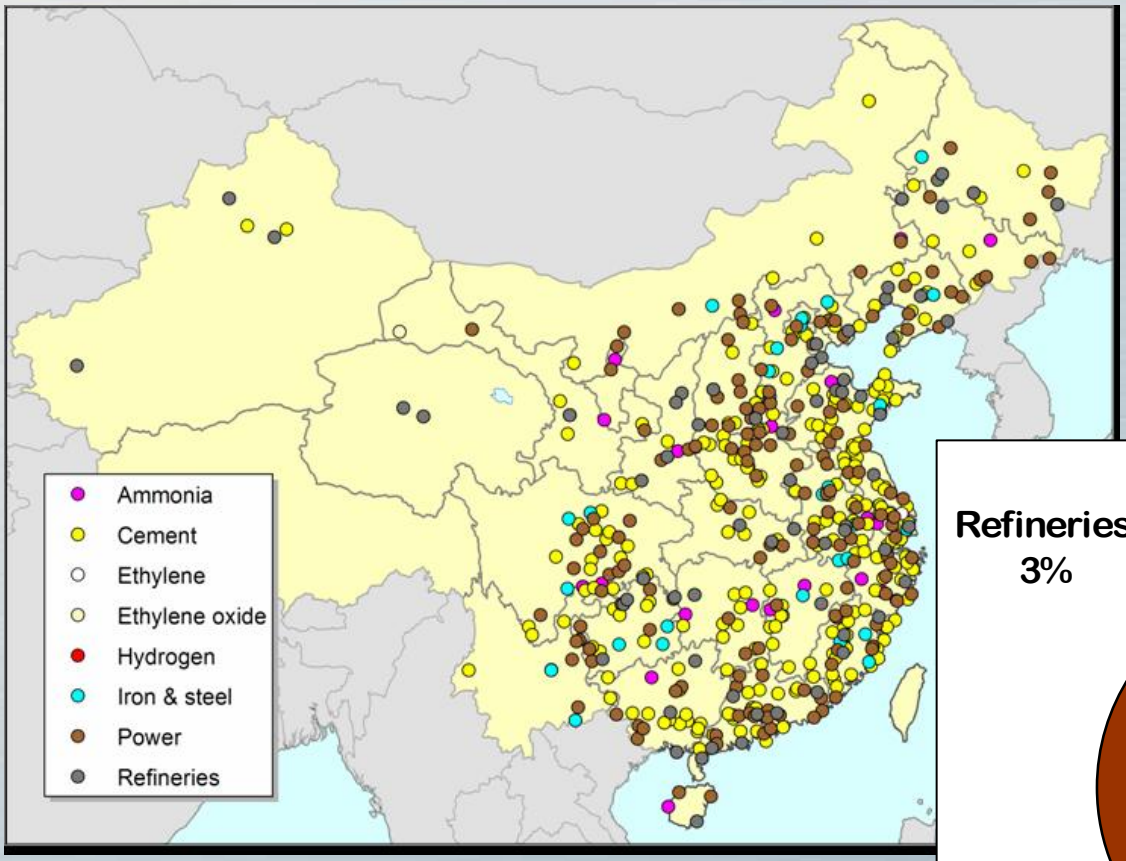


Such curves are useful as they enable us to:

- Describe the graded (heterogeneous) nature of the "CCS natural resource" for the region
- Identify whether the region's opportunities are constrained by lack of accessible storage capacity
- Assess expected levels of costs to implement CCS technology options
- Compare value with other regions as well as other potential CO_2 mitigation options

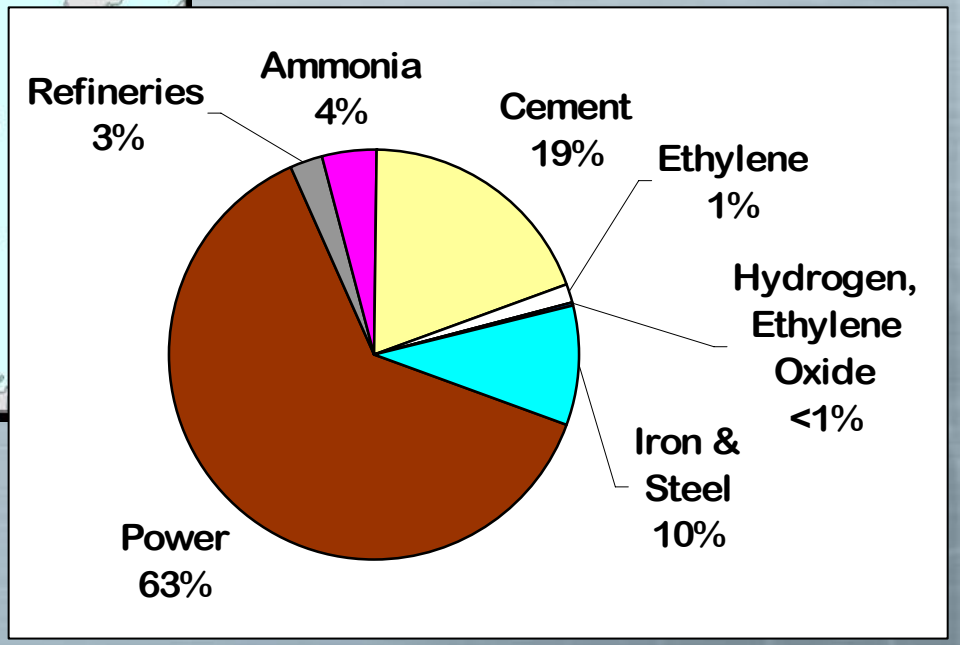
Stationary CO_2 point sources in China

Sources by type (Preliminary)

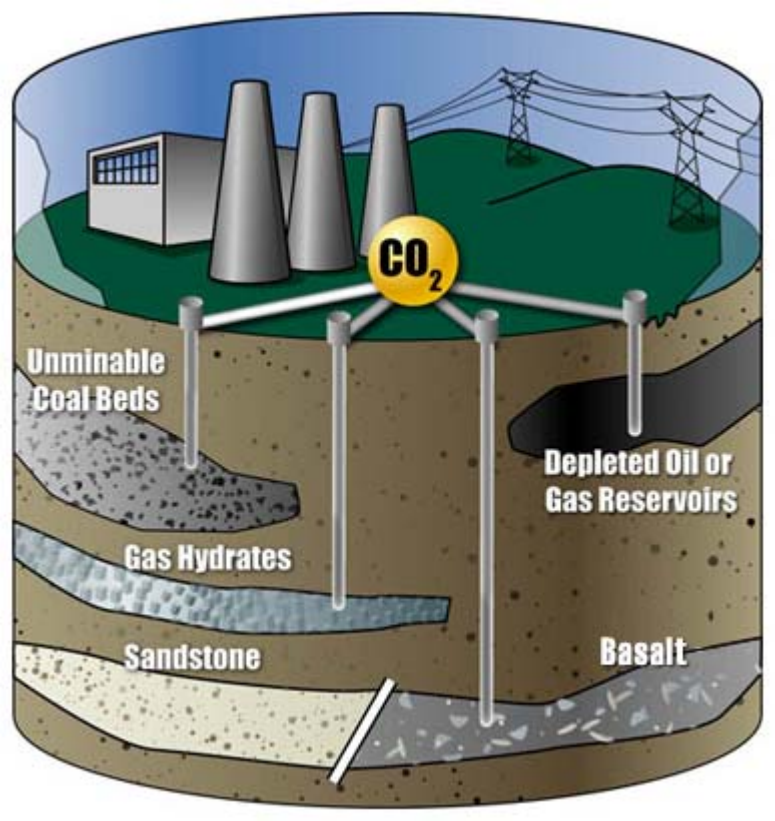


Large CO_2 Point Sources (100+ $ktCO_2$/yr):

- 1561 Locations
- 2961 $MtCO_2$/yr
- ~180 high purity sources (4% of emissions)



Candidate Geologic CO_2 Storage Reservoirs in China



Estimates of CO_2 storage capacity within the following reservoir types are underway:

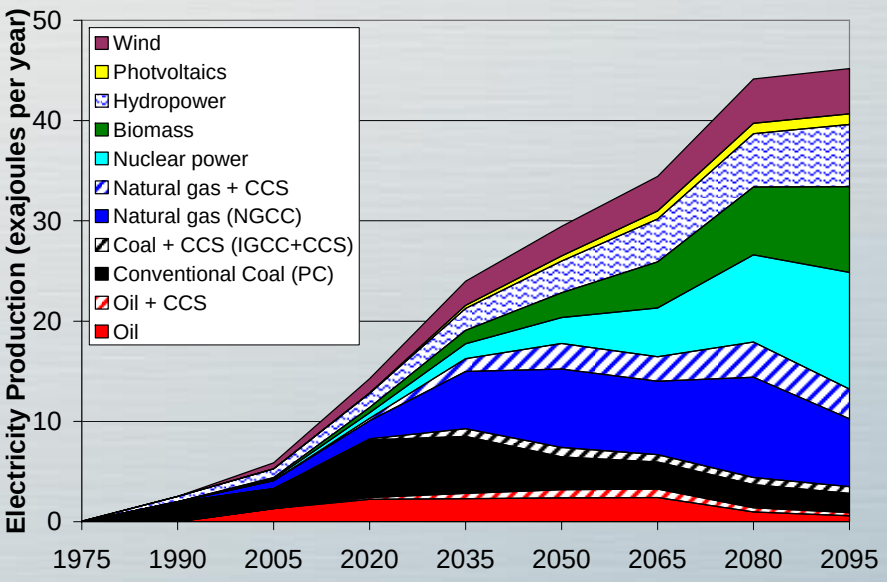
- Deep saline formations
- Deep unmineable coal seams (and potential for enhanced coalbed methane (ECBM) recovery)
- Depleted gas fields
- Depleted oil fields (and potential for CO_2-flood enhanced oil recovery (CO_2-EOR))

These will be mapped along with the large CO_2 point sources to enable spatial and economic analyses

Assessing CCS Market Opportunities

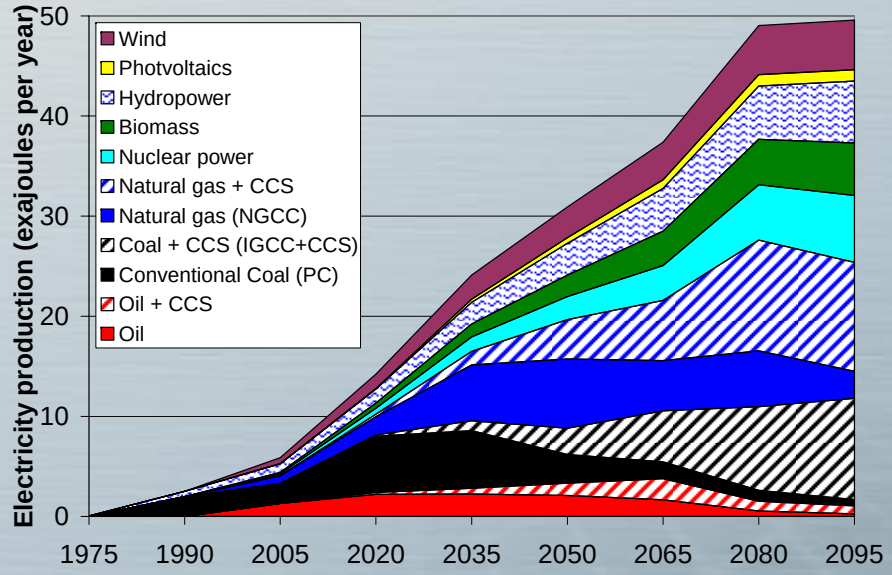
Final Thoughts: The Potential Benefits of CCS in China

CCS Deployment in China is Limited



- The use of fossil fuels is severely curtailed in carbon-constrained world
- Nuclear power and biomass must be pushed beyond cost-effective limits to meet energy demand
- These combine to result in high energy prices

CCS Allowed to Deploy to Full Potential



- Fossil fuel use increases while emissions are curtailed
- A balanced, stable electricity generation portfolio is maintained
- Lower energy prices
- $100s of billions to a $1 trillion in economic benefits

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The Benefits

- If we can establish the ability to broadly deploy CCS within China, that has tremendous potential economic value: $100s of billions to $1 trillion
- Essential to the deployment of “zero-emission” coal technology
- Preserves the societal benefits of fossil fuels in a carbon-constrained world
- These kinds of national/regional assessments of CO_2 storage potential have previously been identified as a high technical priority by the Carbon Sequestration Leadership Forum

Thank you