Carbon Dioxide Capture and Sequestration: Managing the Anthropogenic Carbon Cycle

AAAS| Vancouver, BC

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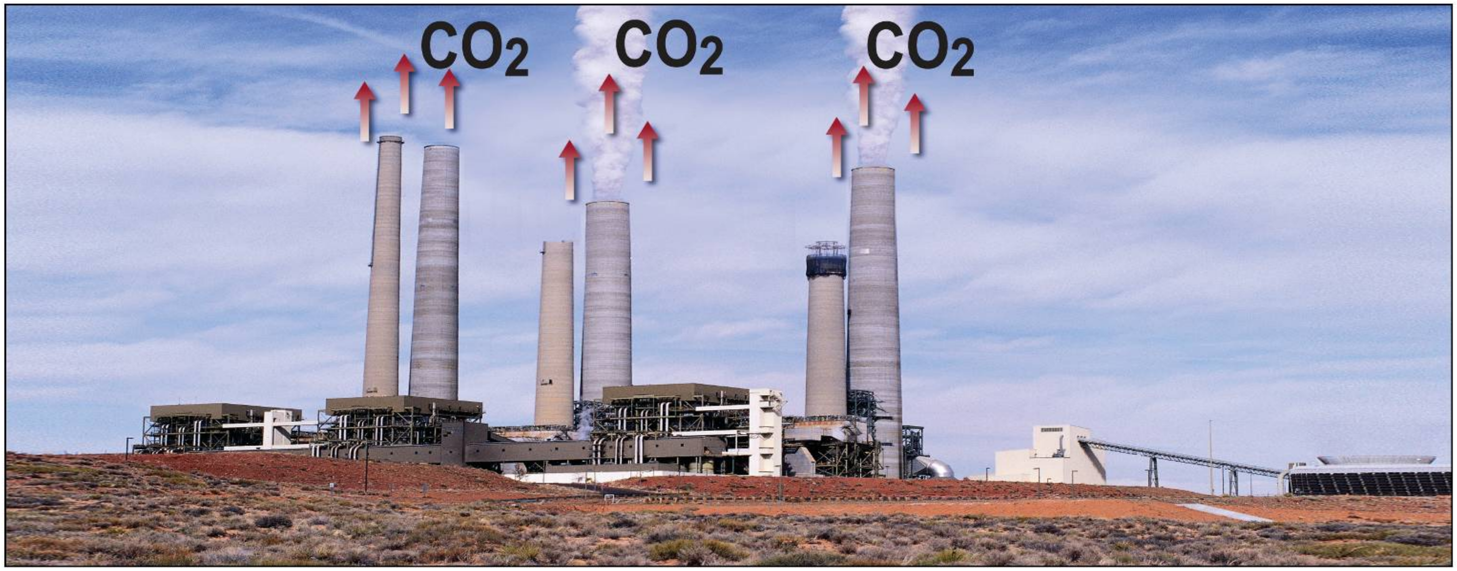
Carbon Dioxide Capture and Sequestration Involves 4 Steps



Capture → Compression → Pipeline Transport → Geological Sequestration

Comparison of Capture Options

Technology	Advantages	Challenges
Post-Combustion	• Mature technology • Retrofit possible • Heat recovery/integration	• High energy penalty (~20-30%) • High cost for capture
Pre-Combustion (IGCC)	• Lower capture costs than post-combustion • Lower energy penalties (10-15%) • H_2 production	• Complex chemical process • Repowering • Large capital investment
Oxygen-Combustion	• Avoid complex post-combustion separation • Potentially higher generation efficiencies	• Oxygen separation • Repowering

Technology Overview

In Salah Project, Algeria

Courtesy, Iain Wright

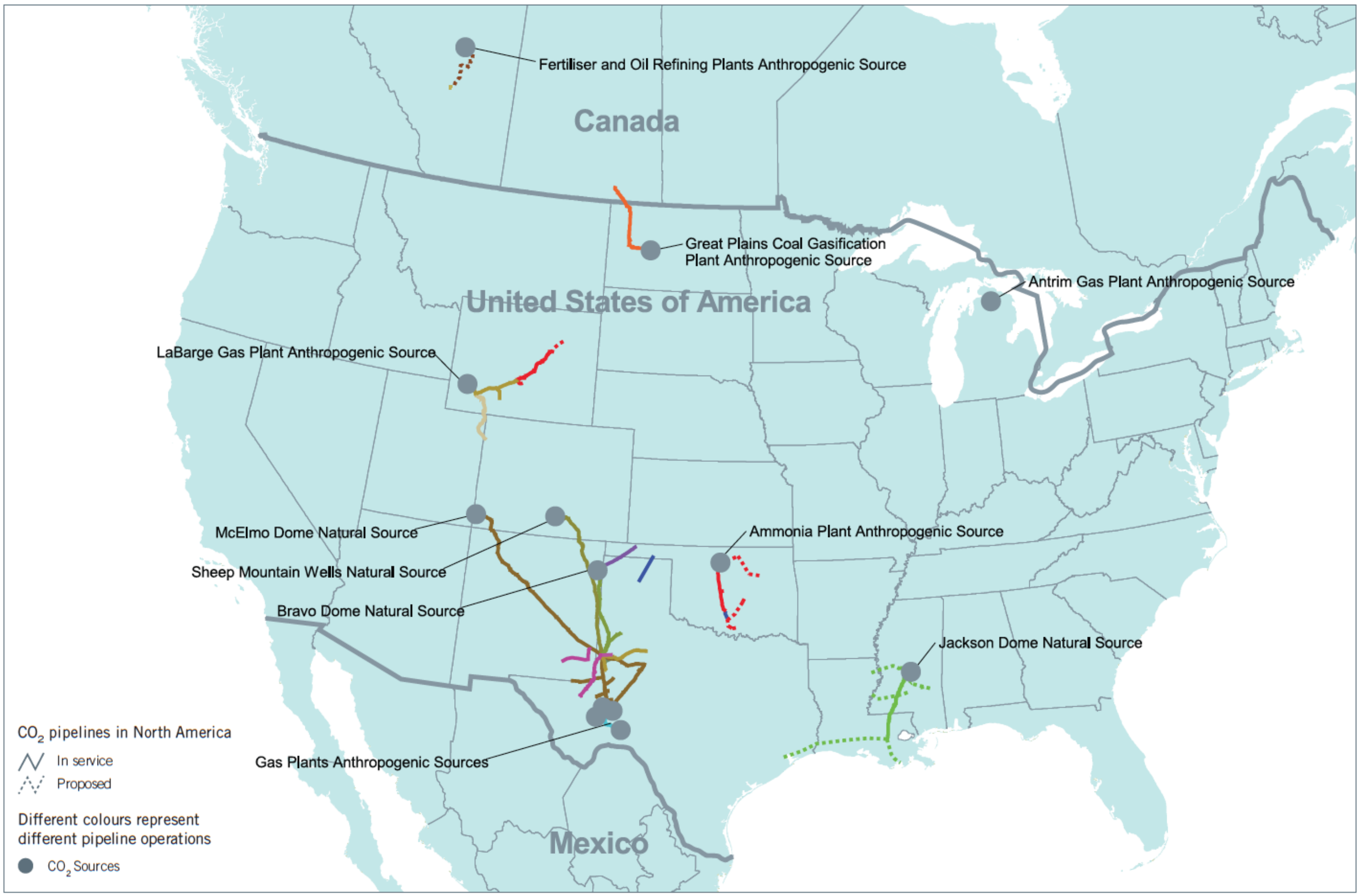
Capture → **Compression** → **Pipeline Transport** → **Geological Sequestration**

- Compression of CO_2 to a liquid state (about 100 bars)
  - Compression is a mature technology
- Transport of liquid CO_2 in pipelines
  - Pipeline transport is a mature technology with over 2,000 miles of pipelines in the U.S.

U.S. Existing and Planned CO_2 Pipeline Network

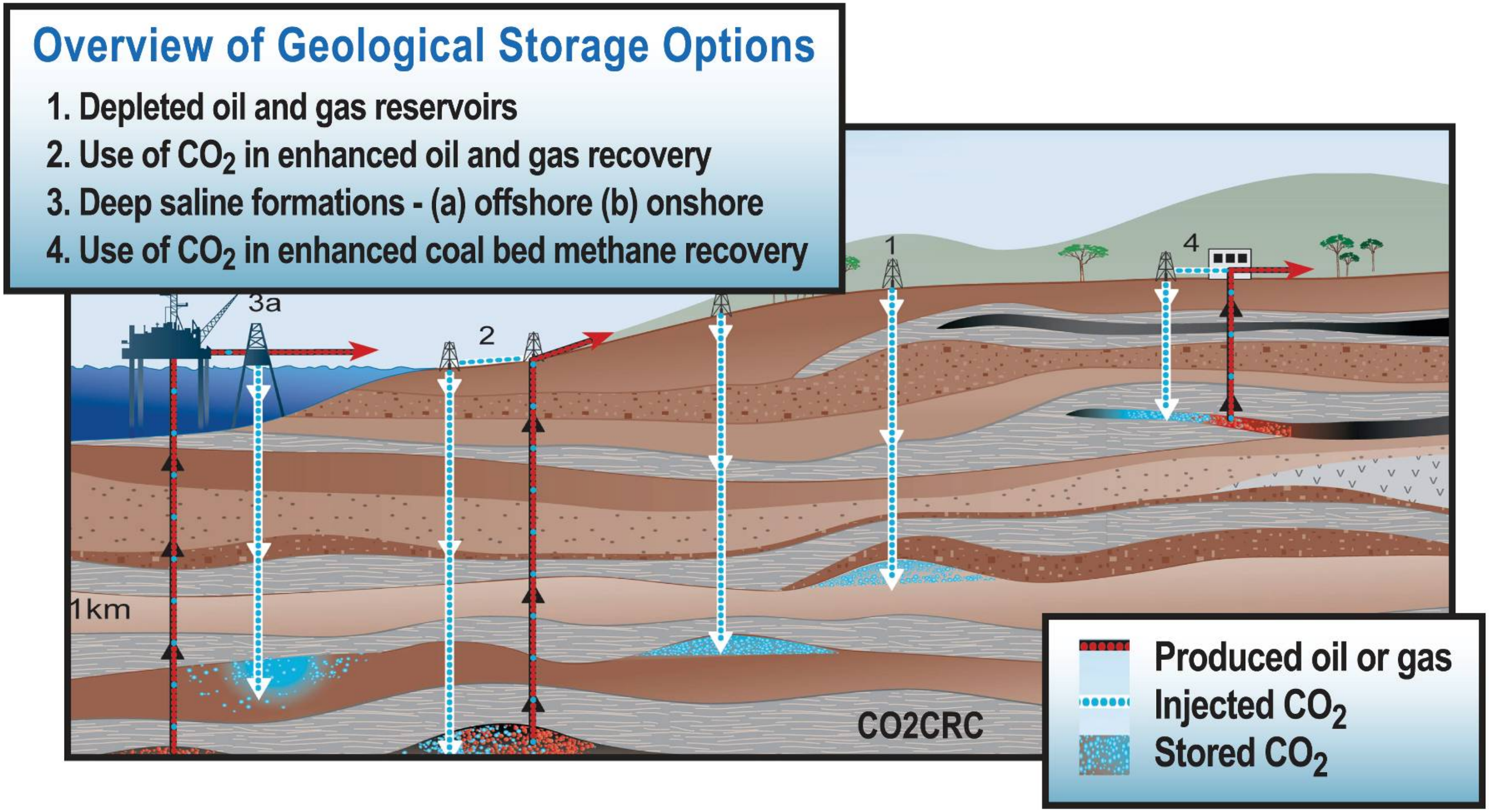
GCEP

Currently transporting about 50 MT/year (equivalent to about 8 1,000 MW coal-fired power plants)



Options for Geological Storage

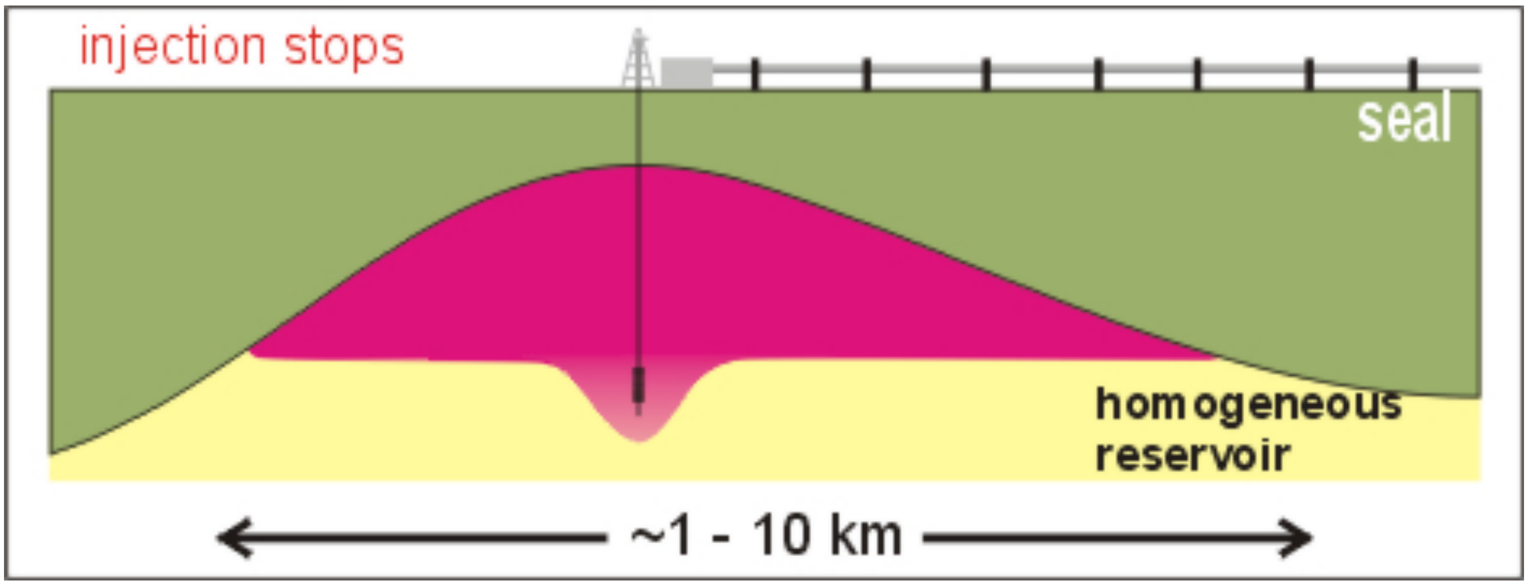
GCEP



Capture → Compression → Pipeline Transport → Geological Sequestration

Basic Concept of Geological Sequestration of CO_2

- Injected at depths of 1 km or deeper into rocks with tiny pore spaces
- Primary trapping
  - Beneath seals of low permeability rocks



Courtesy of John Bradshaw

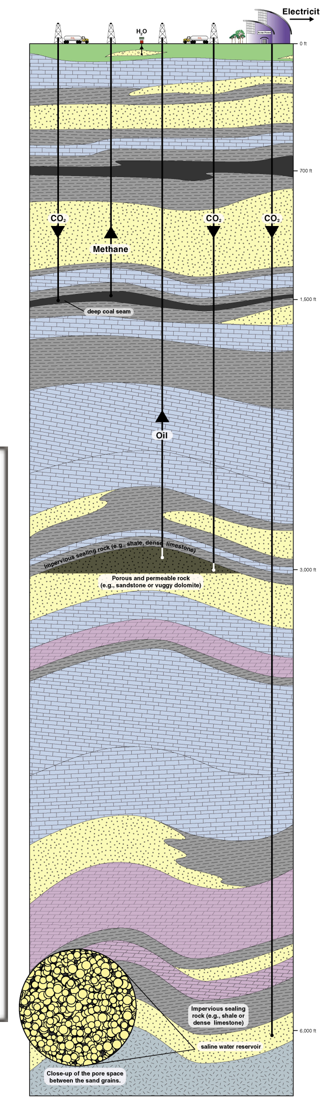
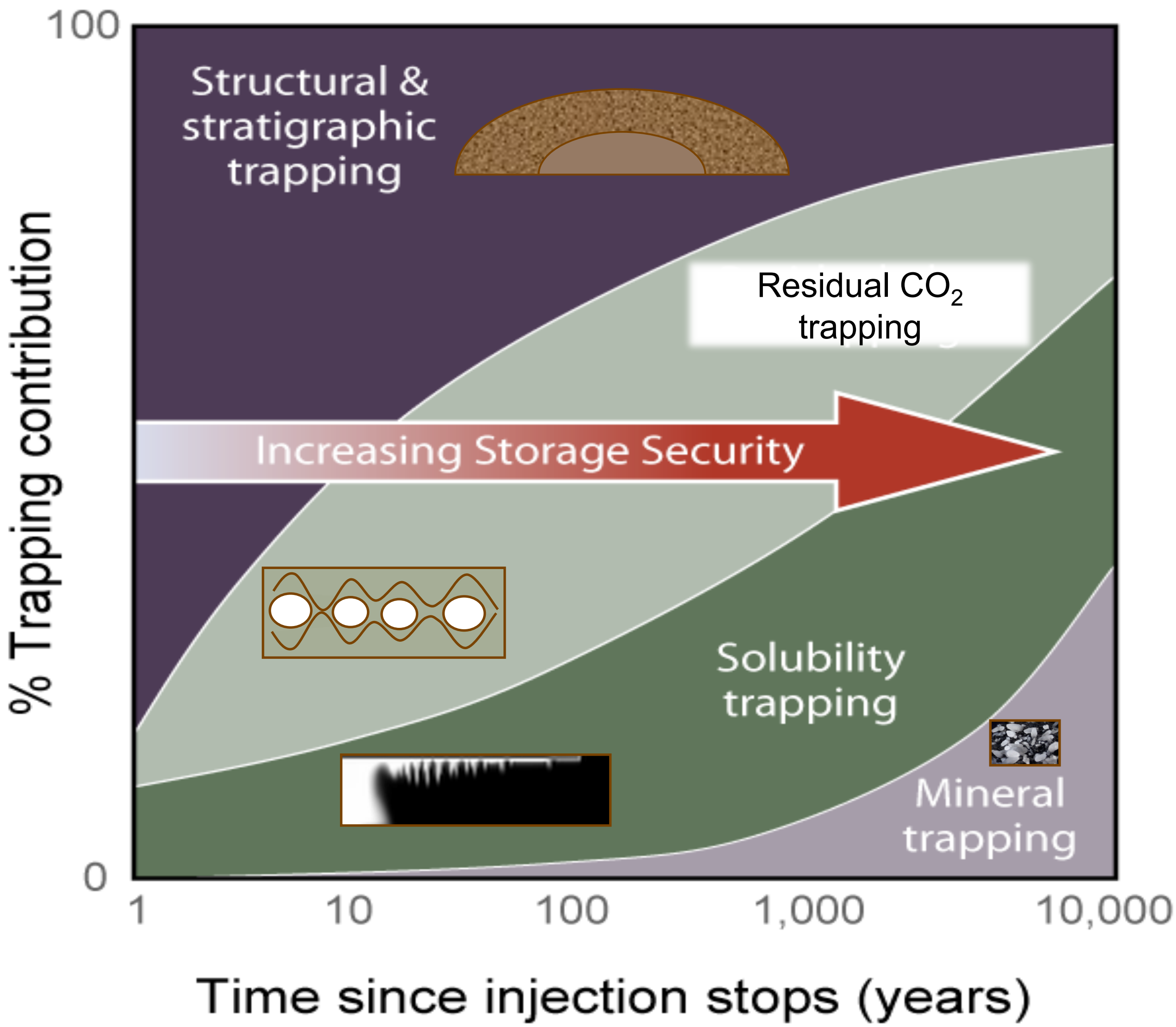
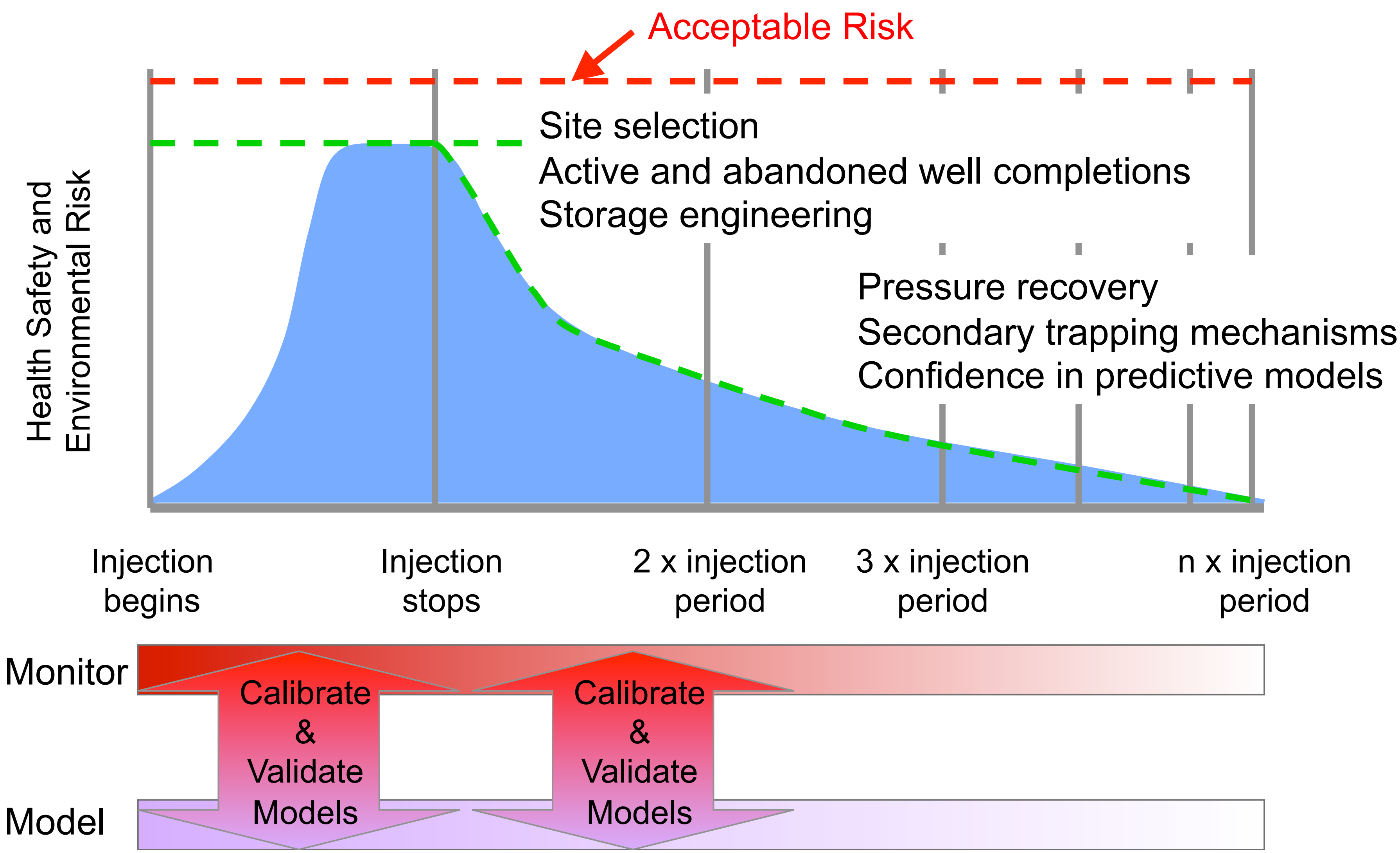


Image courtesy of ISGS and MGSC

Secondary Trapping Mechanisms

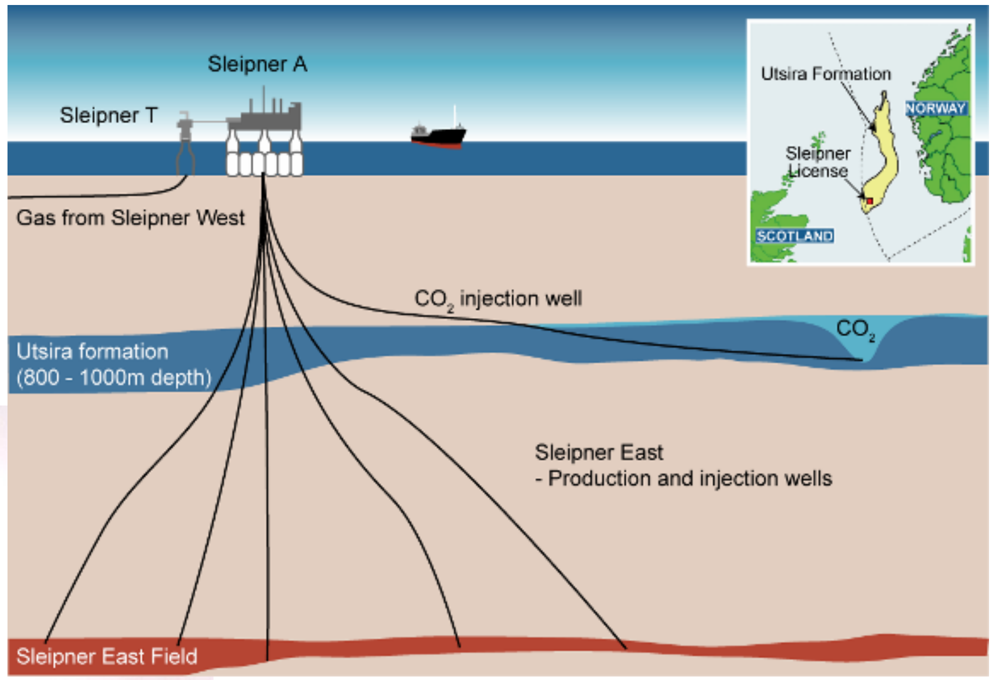


Risk Evolution and Management



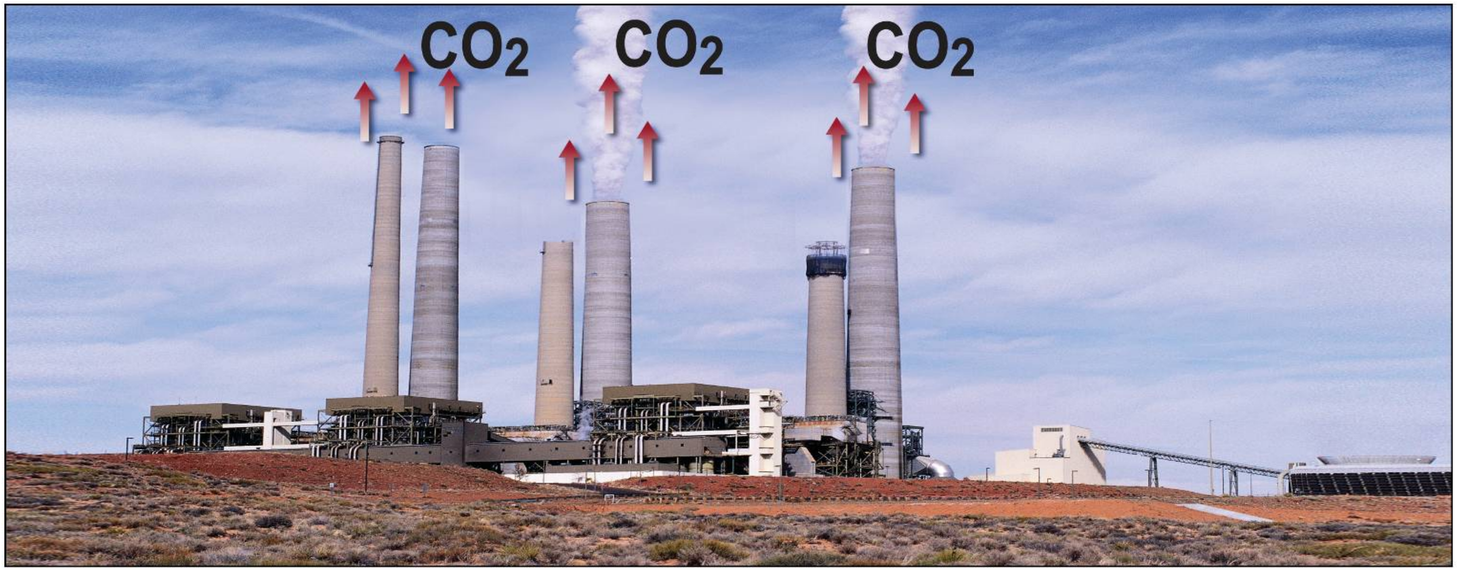
Sleipner Project, North Sea

- 1996 to present
- Avoid CO_2 tax of $50/tonne
- 1 Mt CO_2 injection/yr
- Seismic monitoring



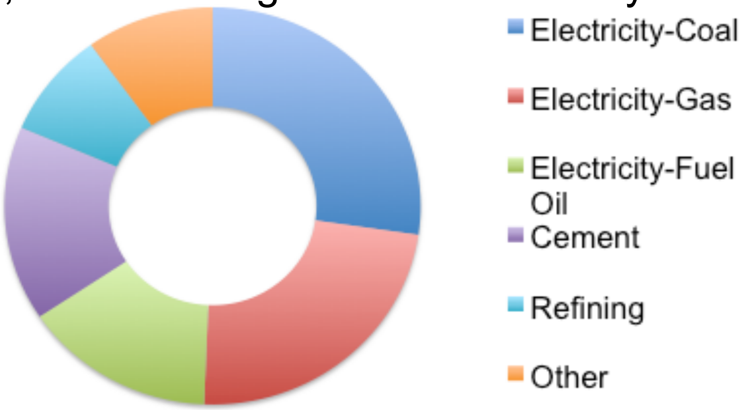
Courtesy *Statoil*

Why CCS: CCS is Applicable to Many Emission Sources



CCS is applicable to the 60% of CO_2 emissions which come from stationary sources such as power plants, cement plants and refineries.

7,400 sources greater than 0.1 Mt/yr



CCS has broad application across many sectors of the economy

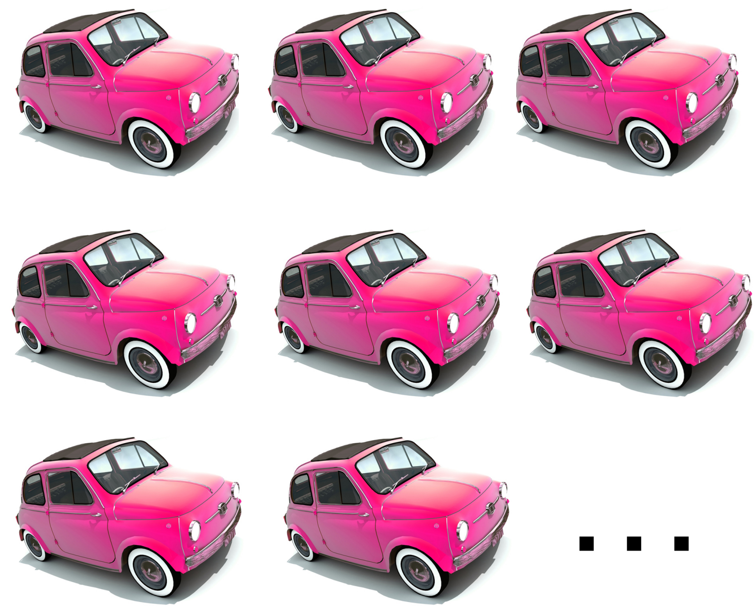
Why CCS: Large Emissions Reductions with Few Projects

CCS with 90% capture

One 1,000 MW coal-fired power plant
(6.5 MT CO_2/year)

=

Increase efficiency from 25 to 50 mpg

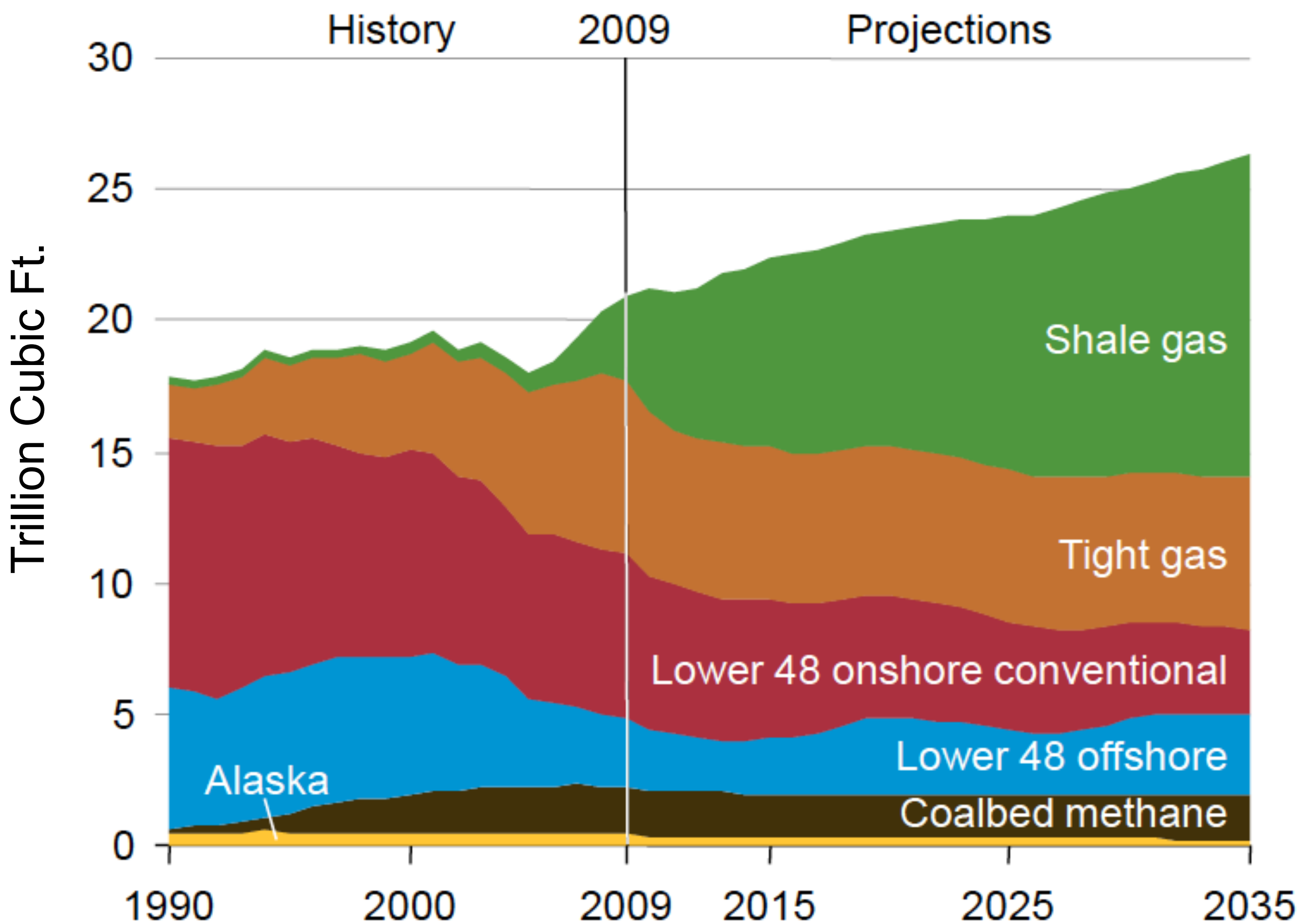


2.8 Million Cars
(10% of California Fleet)

Dramatically reduce the number of actors needed to achieve large emission reductions.

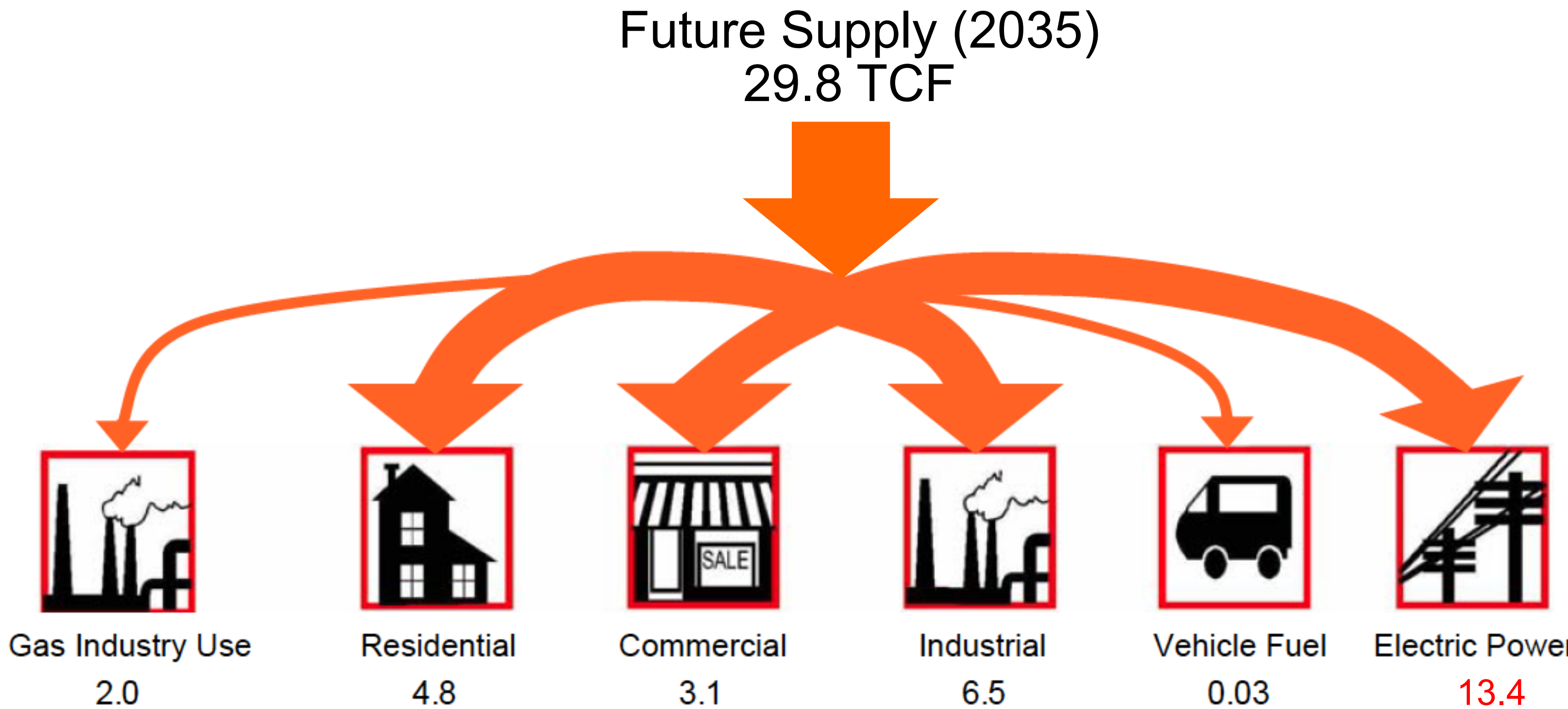
Competition with Natural Gas for Power Generation

Why not forget about CCS and simply replace coal fired generation with natural gas?



EIA, 2011. Annual Energy Outlook.

Why CCS: Fuel Switching to Natural Gas is Not Enough



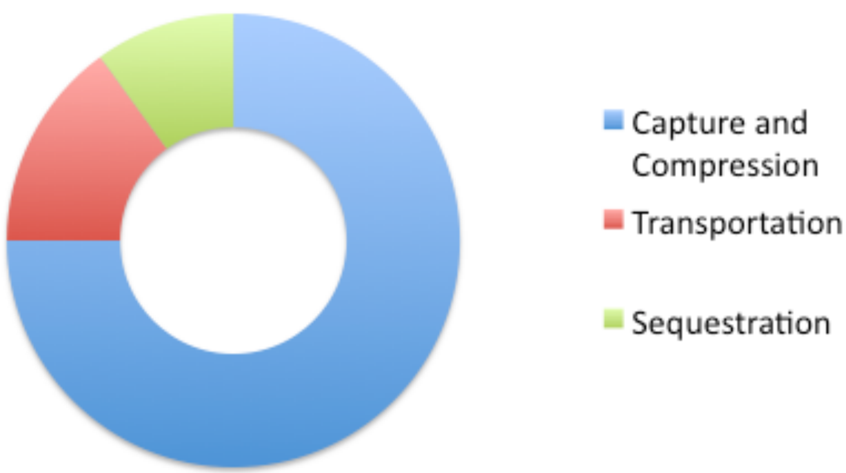
Assume:

1. All incremental gas production (~6 TCF by 2035) is used to generate electricity
2. Power generation efficiency of 48.8% (combined cycle gas power generation)

→ Replace about 45% of existing coal-fired generation (2010 baseline)
Good, but more needed to reduce emissions to safe levels.
EIA predicts a maximum of 20% replacement of by 2035.

Major Challenges Going Forward

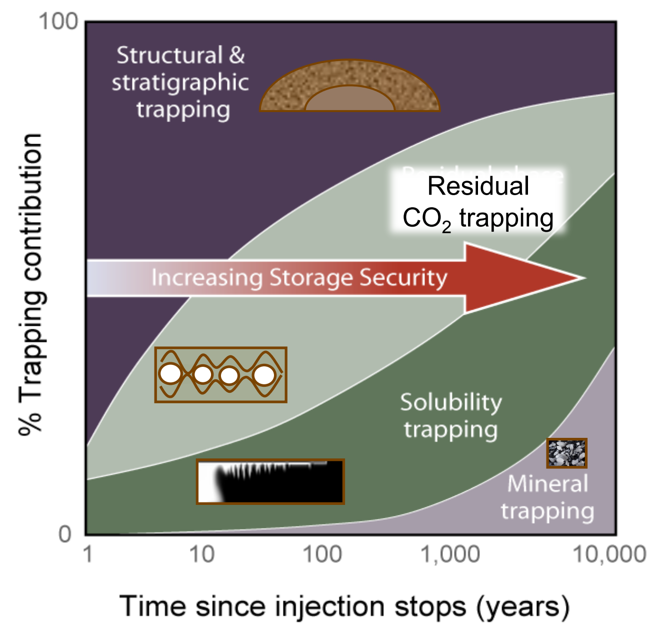
Reducing the cost cost of CO_2 capture (~50%)



Incremental cost of CCS

- Capture R&D
- Learning by doing

Increasing confidence in CO_2 storage



- Demonstration projects
- Monitoring
- R&D

Major Trends: Good News, Bad News

- Global government investment stable for now at $23.5 B
- Large R&D community making good progress
- Capture from industrial sources gaining momentum
- Use of CO_2 for EOR
- Progress on regulatory issues
- Approval for use of CCS in the Clean Development Mechanism (CDM)

- Lack of progress toward local, national, and global CO_2 reduction commitments has thwarted private investment
- Cost of early projects higher than expected
- Local public reaction is mixed, especially in Europe

Concluding Remarks

- CCS is an important part of managing the anthropogenic carbon cycle
  - Needed for large and rapid emission reductions
  - Large per project emission reductions (e.g. 2.5 million cars)
  - Switching to natural gas is not sufficient
- Progress on CCS proceeding on all fronts
  - Industrial-scale projects
  - Government support
    - *Demonstration plants*
    - *Research and development*
- Research is needed to support deployment at scale
  - Capture: Lower the cost of capture
  - Sequestration: Increase confidence in storage permanence
- Serious commitment to CO_2 emission reduction needed to sustain progress and fully re-engage industry