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WESTCARB Overview

CO_2 Capture and Storage in Deep Geological Formations: An Overview Drawing on the IPCC Special Report

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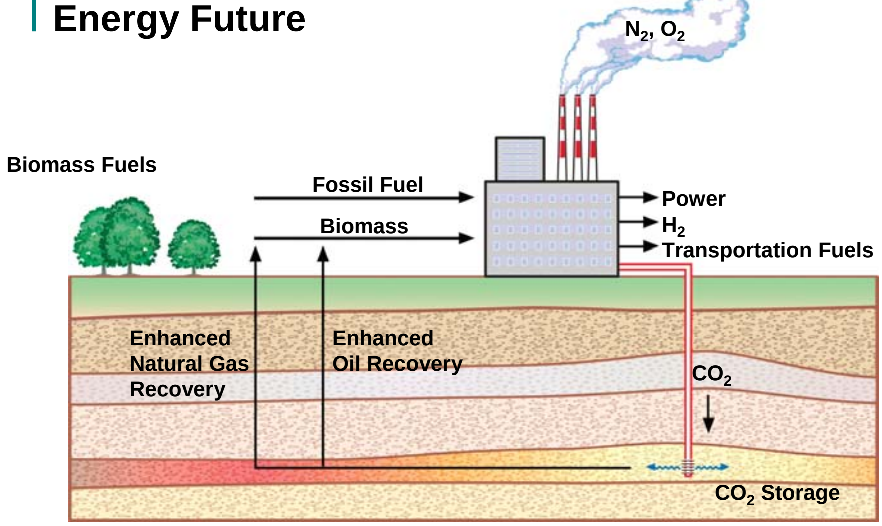
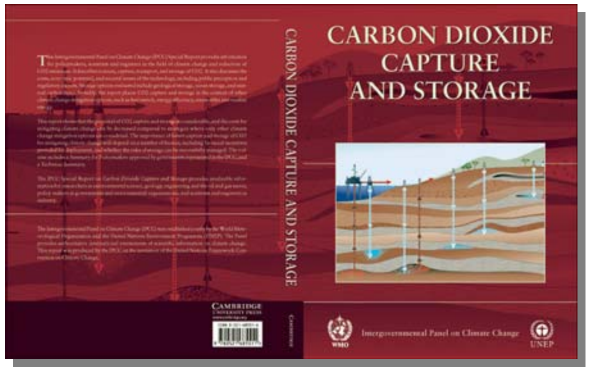
CO_2 Capture and Storage in Deep Geological Formations as a Bridge to a Low-Carbon Energy Future



IPCC Special Report

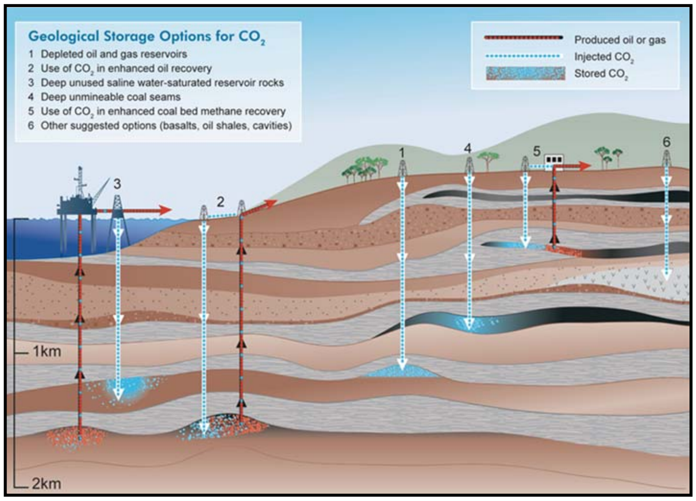


- Three year process to develop report
- Over one hundred authors from thirty-two countries
- Final draft approved September 26, 2005

About the Intergovernmental Panel on Climate Change (IPCC)

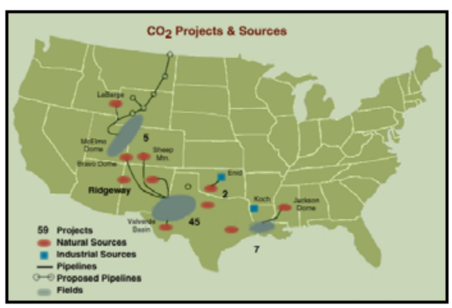
- No research, no monitoring, no recommendations
- Assessment of published scientifically and technically sound information
- Authors are best experts available worldwide
- Covering academic, industrial, and NGO experience
- Thoroughly reviewed by experts and governments
- Policy relevant, but NOT policy prescriptive
- Final approval of summary by governments

Options for Storing CO_2 in Deep Underground Formations



Multiple Lines of Evidence Indicate Storage Can Be Secure and Effective

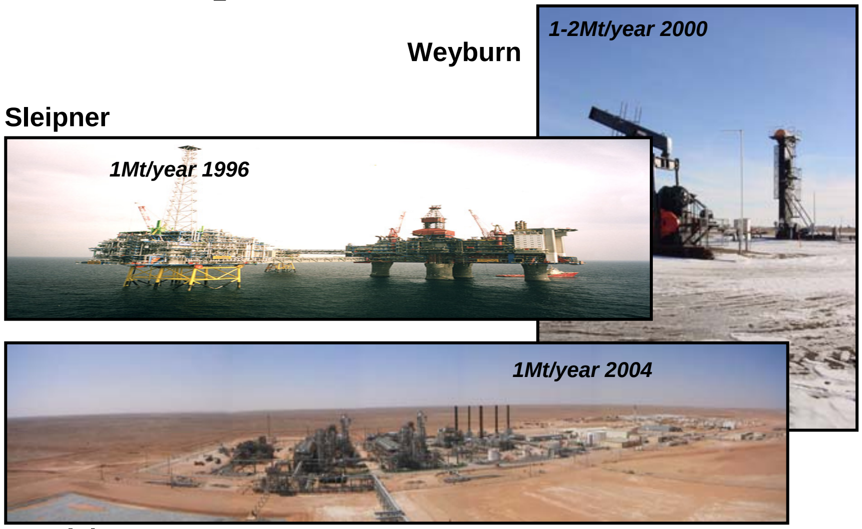
- Natural analogues
  - Oil and gas reservoirs
  - CO_2 formations
- Industrial analogues
  - CO_2 EOR
  - Natural gas storage
  - Liquid waste disposal
- Fundamental physical and chemical processes
- Numerical simulation of long-term performance
- Monitoring existing projects



Existing CO_2 Storage Projects

Weyburn

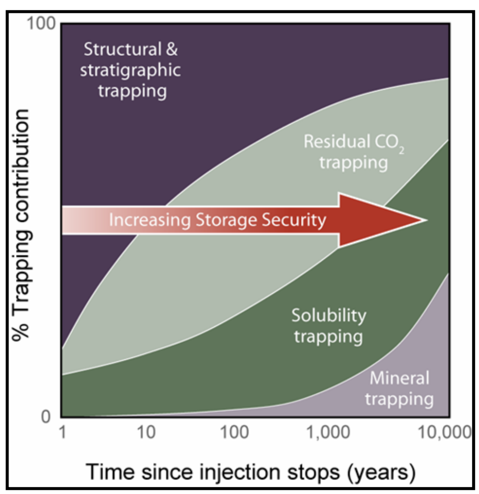
Sleipner



In Salah

Trapping Mechanisms and Increasing Storage Security with Time

- Structural and stratigraphic trapping beneath caprock
- Capillary trapping (residual CO_2 trapping) in storage formation
- Geochemical trapping
  - Solubility trapping
  - Mineral trapping



Fraction Retained

" Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years, and is likely** to exceed 99% over 1,000 years."*

* "Very likely" is a probability between 90 and 99%.
** Likely is a probability between 66 and 90%.

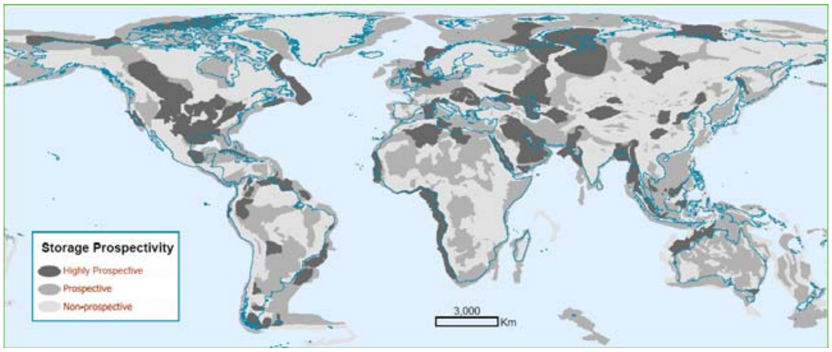
Capacity of Storage Formations

Reservoir Type	Lower Estimate of Storage Capacity ($GtCO_2$)	Upper Estimate of Storage Capacity ($GtCO_2$)
Oil and gas fields	675[a]	900[a]
Unminable coal seams (ECBM)	3–15	200
Deep saline formations	1000	Uncertain, but possibly 10^4

a. Estimates would be 25% larger if undiscovered reserves were included.

"Available evidence suggests that worldwide, it is likely that there is a technical potential of at least about 2,000 $GtCO_2$ (545 GtC) of storage capacity in geological formations."

Prospectivity for Storage Around the World

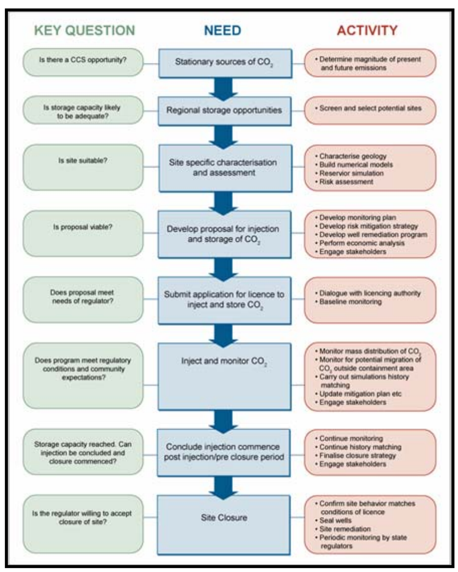


From Bradshaw and Dance 2005

"It is likely that the technical potential for geological storage is sufficient to cover the high end of the economic potential range (2200 $GtCO_2$), but for specific regions, this may not be true."

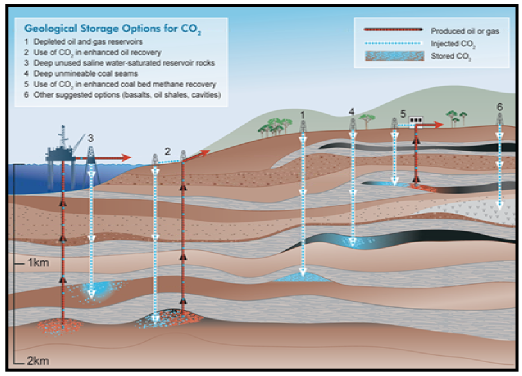
Well Selected and Managed Sites Are the Key to Success

" With appropriate site selection informed by available subsurface information, a monitoring program to detect problems, a regulatory system, and the appropriate use of remediation methods to stop or control CO_2 releases if they arise, the local health, safety, and environment risks of geological storage would be comparable to risks of current activities such as natural gas storage, EOR, and deep underground disposal of acid gas."



Site Selection

- Sedimentary basins
- Caprock characteristics
  - Low permeability
  - Large thickness
  - Lateral continuity
- Storage formation characteristics
  - High permeability
  - Large thickness
  - Areally extensive
- Geological stability
  - Tectonically stable
  - Favorable stress conditions on faults and fractures
- Knowledge about geological setting
- Well field infrastructure and know-how



Monitoring Is Needed to Ensure that Geologic Storage Is Safe and Effective

Requirements for Geologic Storage

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Worker and Public Safety | Local Environmental Impacts to Groundwater and Ecosystems | GHG Mitigation Effectiveness

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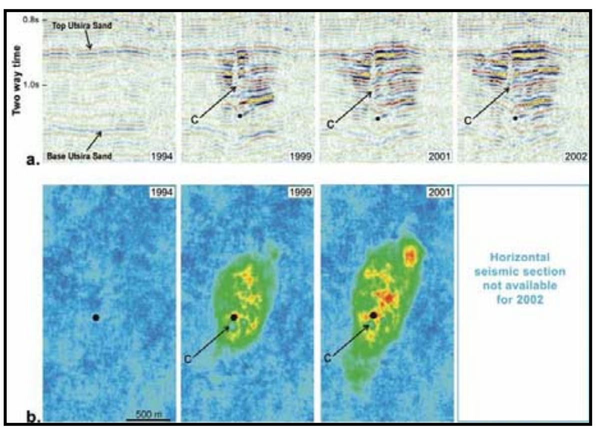
Monitoring Needs

- Well field and surface facility safety
- Monitoring well integrity
- Detection of CO_2 location in the subsurface
- Surface monitoring for seepage detection and inventory verification

Monitoring Well Integrity

- Injection and production rate
- Wellhead and formation pressure
- Casing and annulus pressure testing
- Temperature
- Well logs

Monitoring: Detection of CO_2 Location in the Subsurface

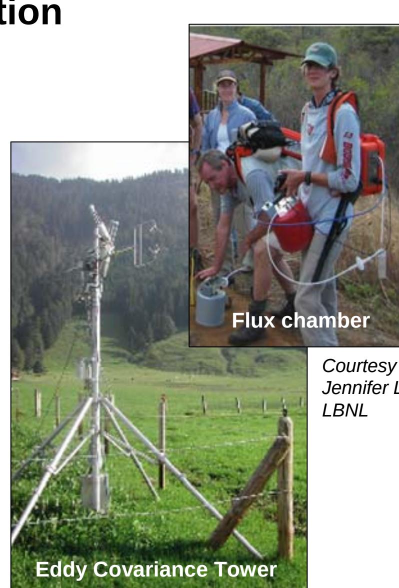


From Chadwick et al., 2005

- Seismic images collected from Sleipner Project, North Sea
- 1Mt/year CO_2 storage since 1996

Surface Monitoring for Seepage Detection and Inventory Verification

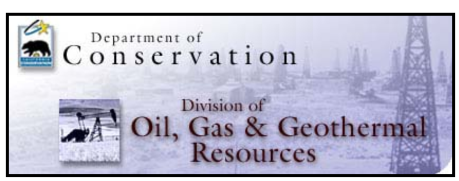
- Soil gas and vadose zone monitoring
- Fluid and gas phase tracers
- Eddy covariance flux monitoring
- Flux chamber monitoring
- Atmospheric CO_2 concentration



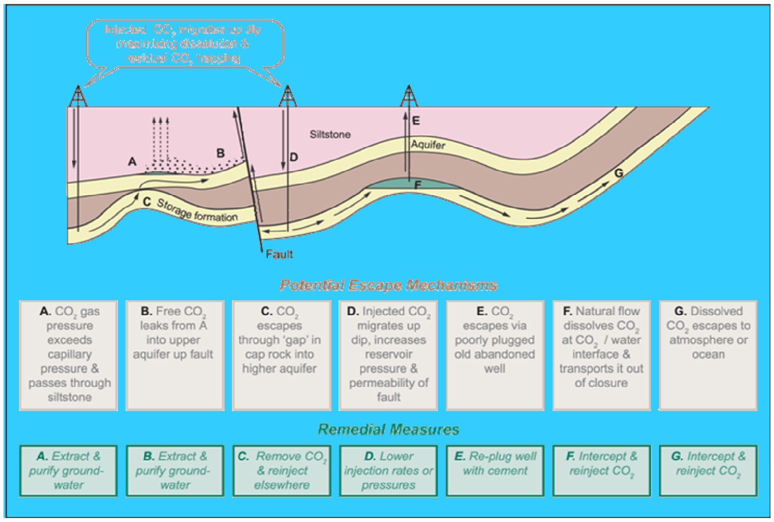
Courtesy of Jennifer Lewicki, LBNL

Regulatory Oversight

- Permits for operating storage projects
  - Site selection
  - Operating parameters
  - Monitoring plans
- Monitoring oversight
  - Adequacy of data collection
  - H, S & E review
- Transparency of health, safety, and environmental data collection and analysis



Potential Release Pathways and Remediation Measures



Costs for CO_2 Capture and Storage

Ways of expressing costs:	***Ranges found:***
▪ Additional electricity costs – Energy policymaking community	▪ \$0.01–0.05/kWh
▪ CO_2 avoidance costs – Climate policymaking community	▪ \$20–70/tCO_2 avoided
▪ Cost of geological storage including monitoring	▪ 10–20% total project costs

Conclusions

- CCS is an emerging technology for creating low-C energy from fossil fuels
- Many components are technologically mature
- More experience is needed to establish cost and performance data for integrated systems
- Pilot and demonstration projects for geological storage are needed to gain confidence in the security of geological storage