The Future of Coal: Addressing Carbon and Other Environmental Concerns

2006 EIA Energy Outlook and Modeling Conference

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MIT Coal Study

- Interdisciplinary study
- Led by John Deutsch and Ernie Moniz
- Follow-on from the 2003 study “The Future of Nuclear Power”
- Looks out through 2050
- Expected to be completed this spring and released this summer

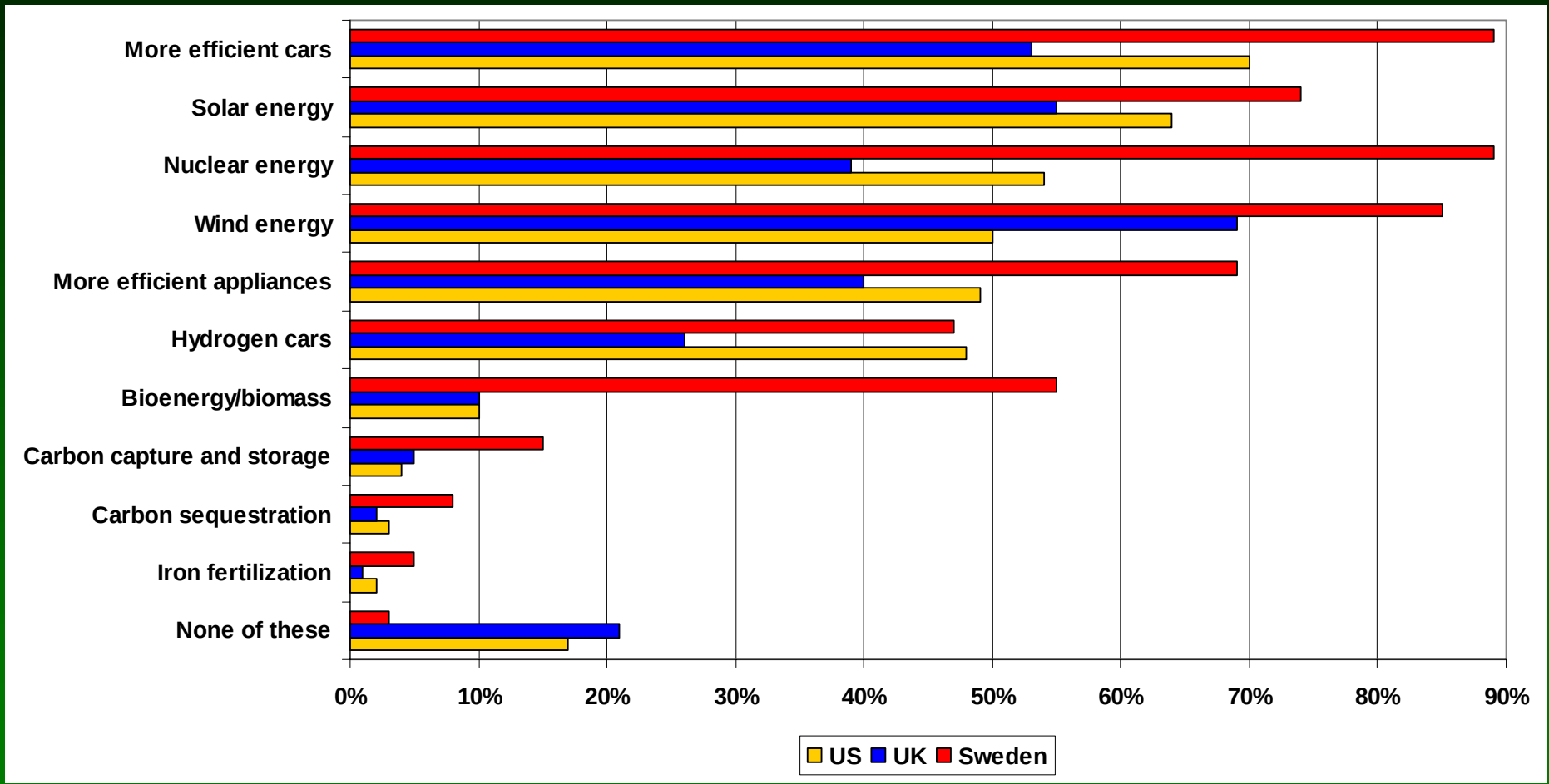
Framing the Issue

- Coal is relatively cheap and abundant
- Criteria pollutant targets (SO_x, NO_x, particulates, Hg) can be met at reasonable costs through at least 2020 and probably well beyond
- Every silver lining has a touch of gray – for coal it is climate change concerns
- CO_2 capture and storage (CCS) is the technology that could allow coal use to expand even in a greenhouse gas constrained world

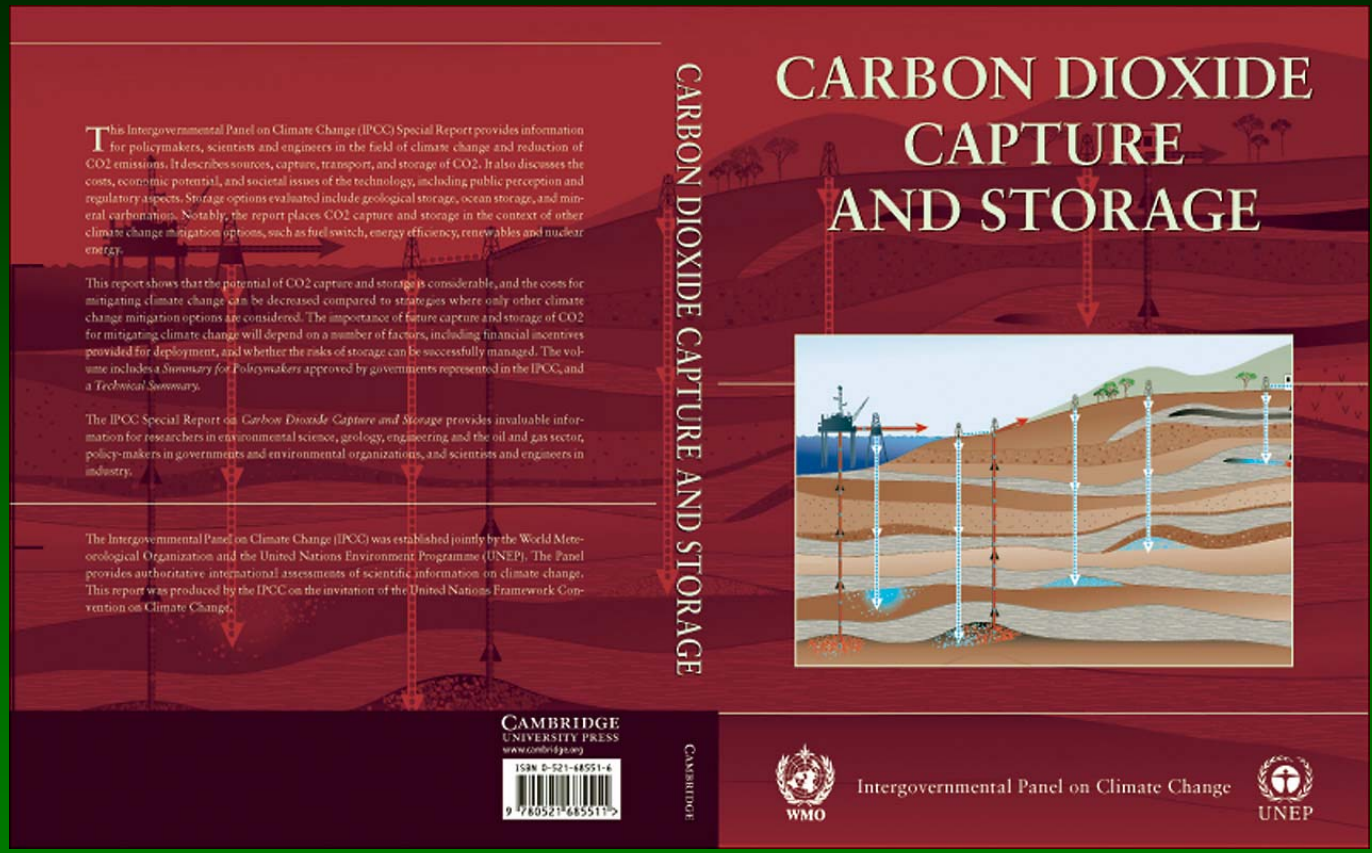
Overview

- What is Carbon Dioxide Capture and Storage (CCS)?
- How does capture work?
- Geological storage – is it safe and effective?
- How much does CCS cost?

Have you heard of or read about any of the following in the past year?



Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage

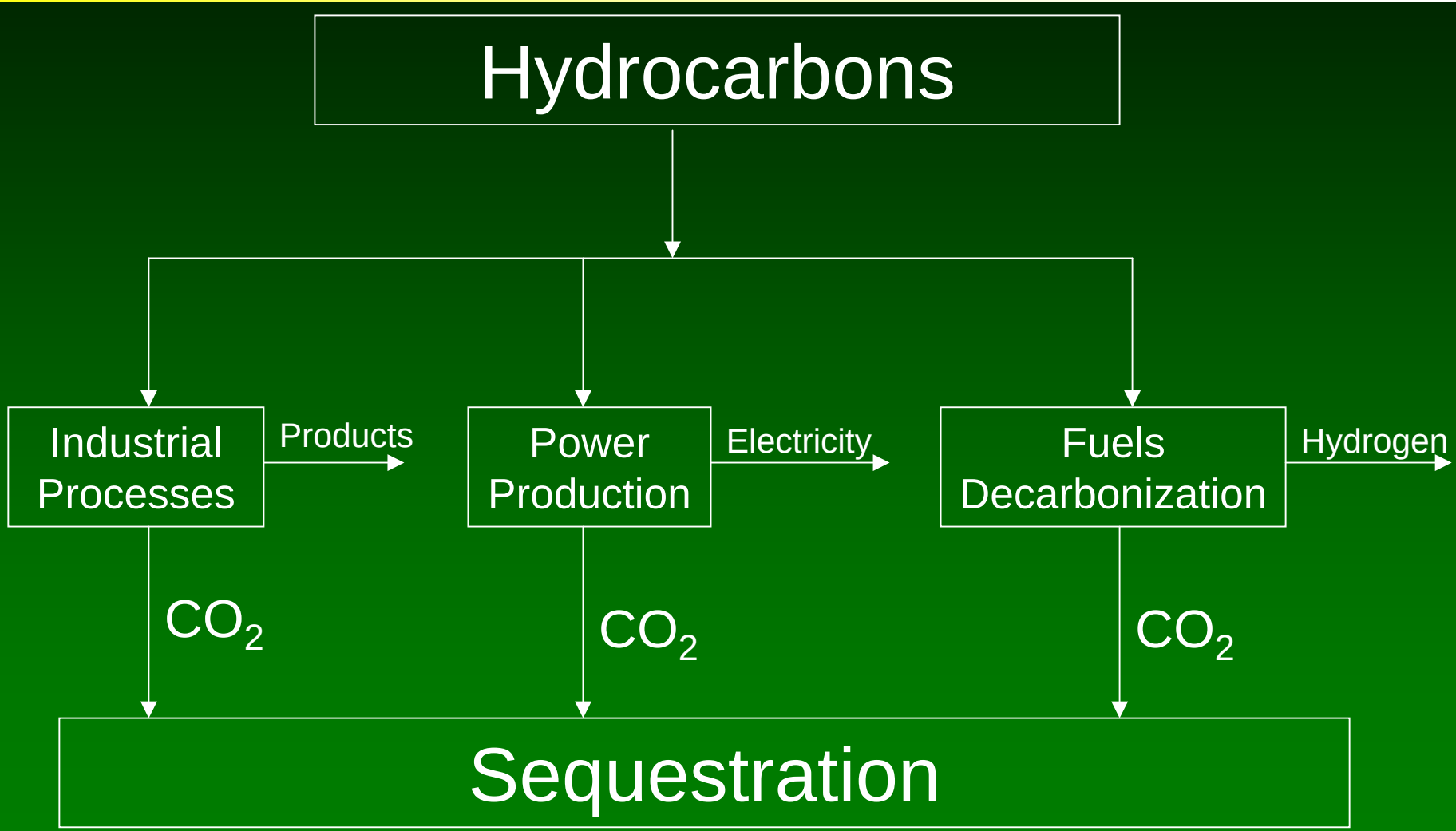


Accepted September 26, 2005 -- www.ipcc.ch

What is Carbon Dioxide Capture and Storage (CCS)?

Carbon dioxide (CO_2) capture and storage (CCS) is a process consisting of separation of CO_2 from industrial and energy-related sources, transport to a storage location, and long-term isolation from the atmosphere.

CCS - Sources


Hydrocarbons
Industrial Processes
Products
Power Production
Electricity
Fuels Decarbonization
Hydrogen
CO_2
CO_2
CO_2
Sequestration

How does capture work?

There are different types of CO_2 capture systems: post-combustion, pre-combustion and oxyfuel combustion.

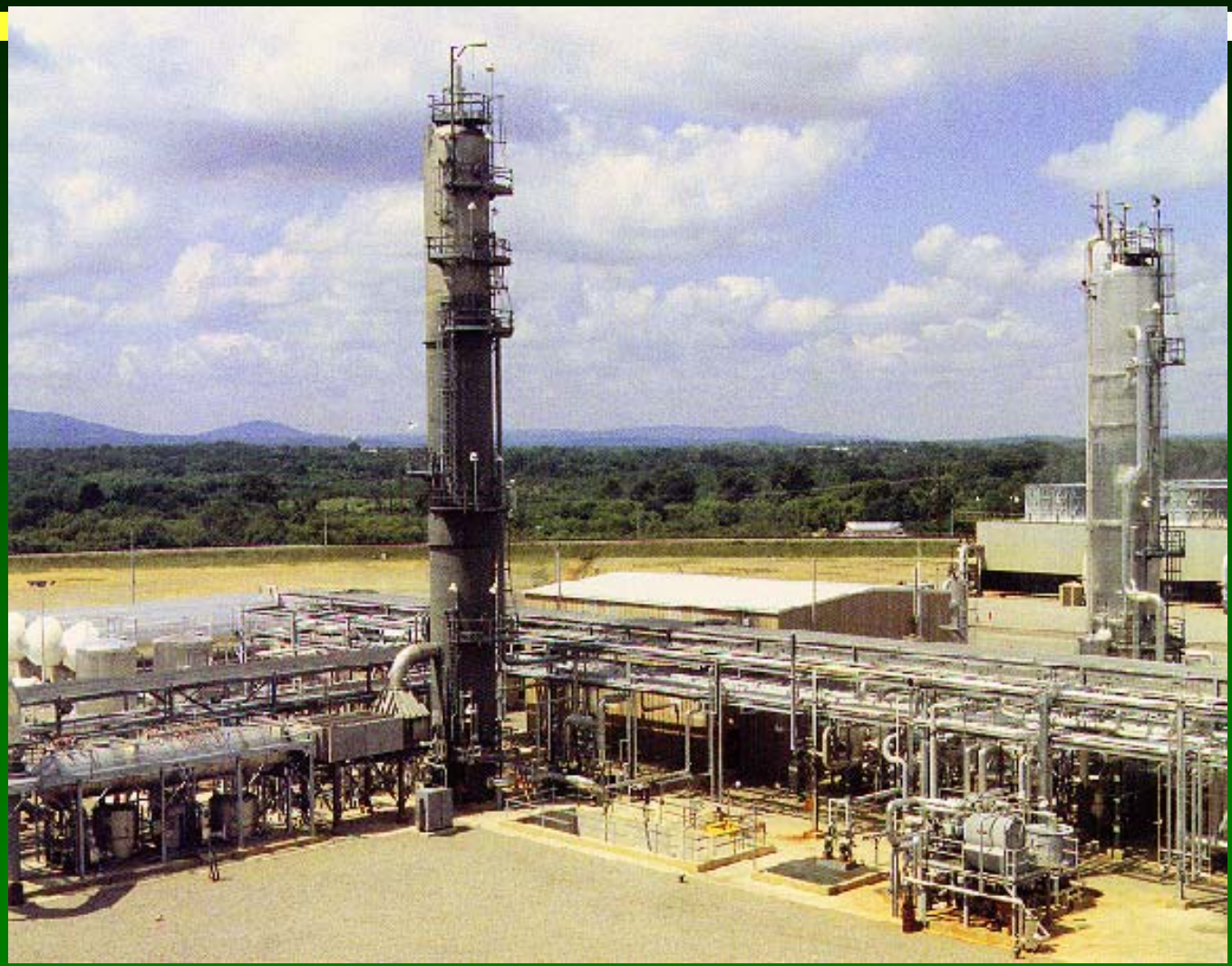
Approaches to CO_2 Separation Pilot/Commercial Activities

Approach	Coal	Gas
Post-combustion	Exists for Slip Streams CO_2 for Commercial Markets	Exists for Slip Streams CO_2 for Commercial Markets
Oxygen	Vattenfall's 30 MW_{th} pilot near Berlin (approved)	Total's retrofit of existing boiler in southwest France (approved)
Pre-combustion	FutureGen (275 MWe) in US (under study)	BP's DF1 in Scotland (under study)

CO_2 Capture at an Industrial Process

Source: Mitsubishi

CO_2 Capture at a Coal-Fired Power Plant

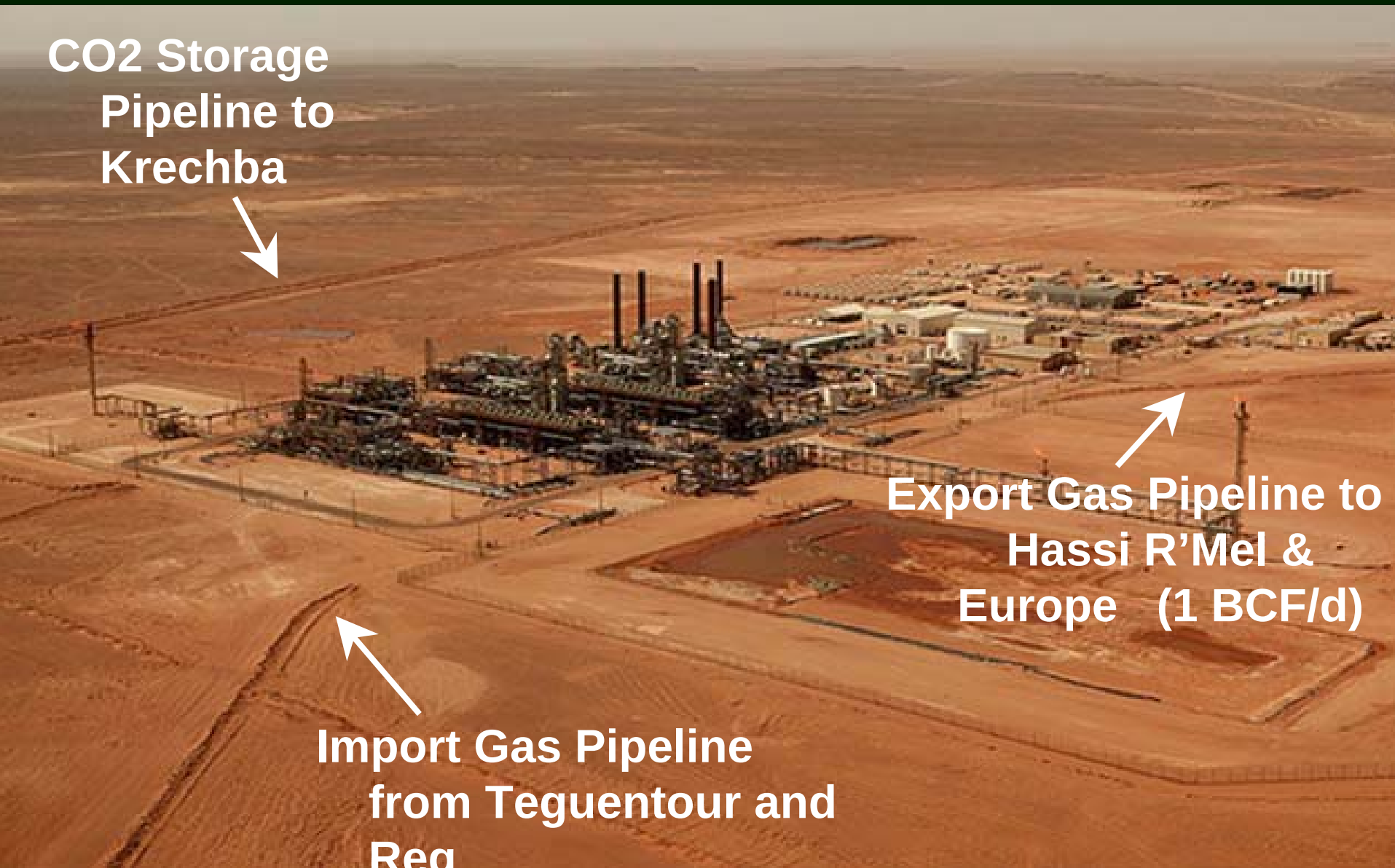


Source: ABB Lummus

Geological storage – is it safe and effective?

Storage of CO_2 in deep, onshore or offshore, geological formations uses many of the same technologies that have been developed by the oil and gas industry and has been proven to be economically feasible under specific conditions for oil and gas fields and saline formations, but not yet for storage in unminable coal beds.

In Salah Gas Processing Plant



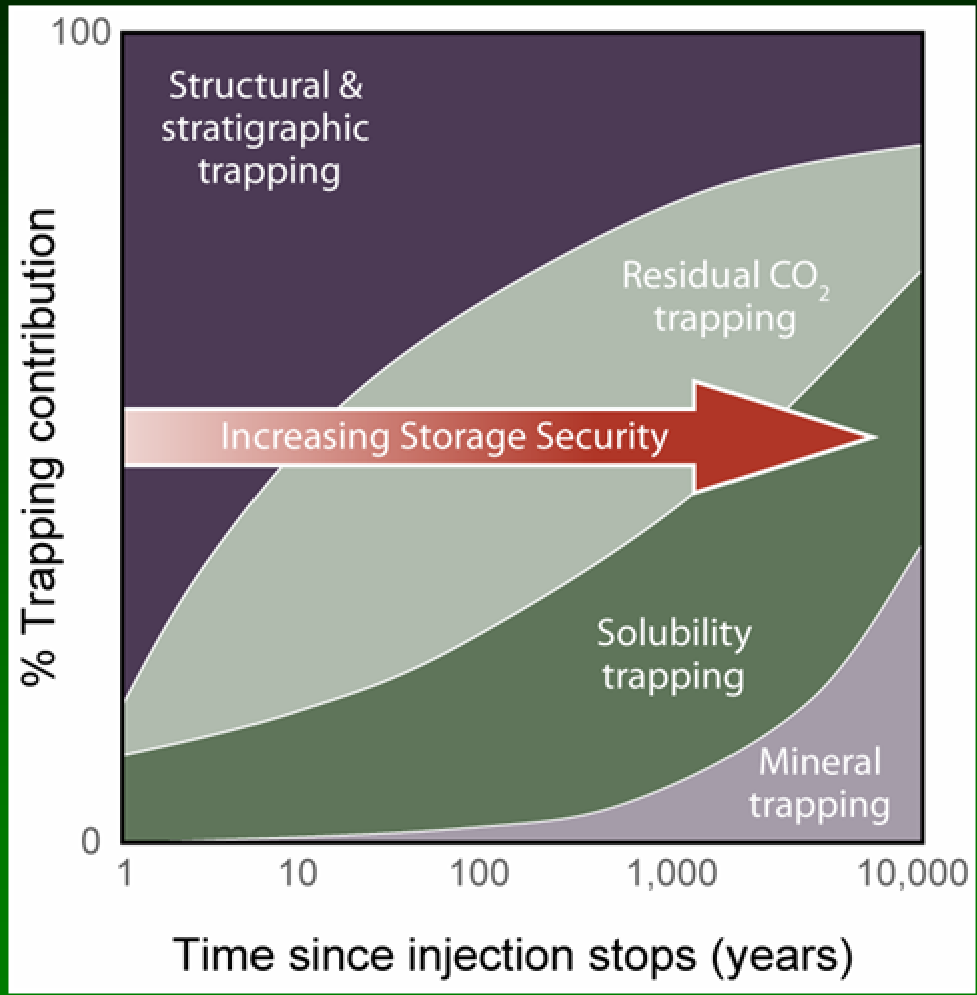
Geological storage – is it safe and effective?

- *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.*

- *For well-selected, designed and managed geological storage sites, the vast majority of the CO2 will gradually be immobilized by various trapping mechanisms and, in that case, could be retained for up to millions of years. Because of these mechanisms, storage could become more secure over longer timeframes.*

Trapping Mechanisms and Increasing Storage Security with Time

- Storage security depends on a combination of physical and geochemical trapping
- Over time, residual CO_2 trapping, solubility trapping and mineral trapping increase



Courtesy Sally Benson, LBNL

How much does CCS cost?

- Carbon capture and storage technologies exhibit significant penetration in the electric power sector at carbon prices above \$30/tCO_2 (>\$100/tC).
  - 80% associated with capture/compression
  - 20% associated with transport/injection
- Targets of opportunity exist today at lower costs
  - Low/no capture costs (industrial by-product)
  - Commercial value for CO_2 (e.g., EOR)

How much does CCS cost?

Type of Capture Plant	Cost ($/tCO$_2$avoided)
Post-combustion Supercritical PC	45
Oxyfuel Supercritical PC	35
Pre-Combustion IGCC	29

Assumptions:

- Uses technology available today
- Assumes an nth plant (versus 1st of a kind)
- Transport/storage cost is $5/tCO$_2$

PC = Pulverized Coal; IGCC = Integrated Coal Gasification Combined Cycle

Moving Forward

- Two biggest challenges for CCS:
  - Reducing capture costs
  - Addressing the regulatory and associated issues of storage
- CCS is not a silver bullet, but should be thought of as part of a portfolio of climate change mitigation options

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