CARBON CAPTURE AND STORAGE

International Energy Agency

Carbon Capture and Storage: A technology overview

29 March 2011

Carbon Capture and Storage Unit
International Energy Agency

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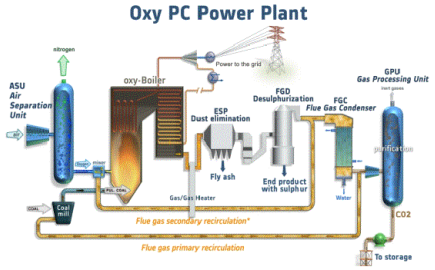
CARBON CAPTURE AND STORAGE

CCS IS A *CHAIN*

Carbon Capture and Storage is a chain/group of technologies and applications that enable:

1. **Capture of CO_2 from large point sources**

   Power plants, steel, cement, refineries, gas processing etc.



Alstom

2. **Its transport**

   Trucks, ships, pipelines

Maersk

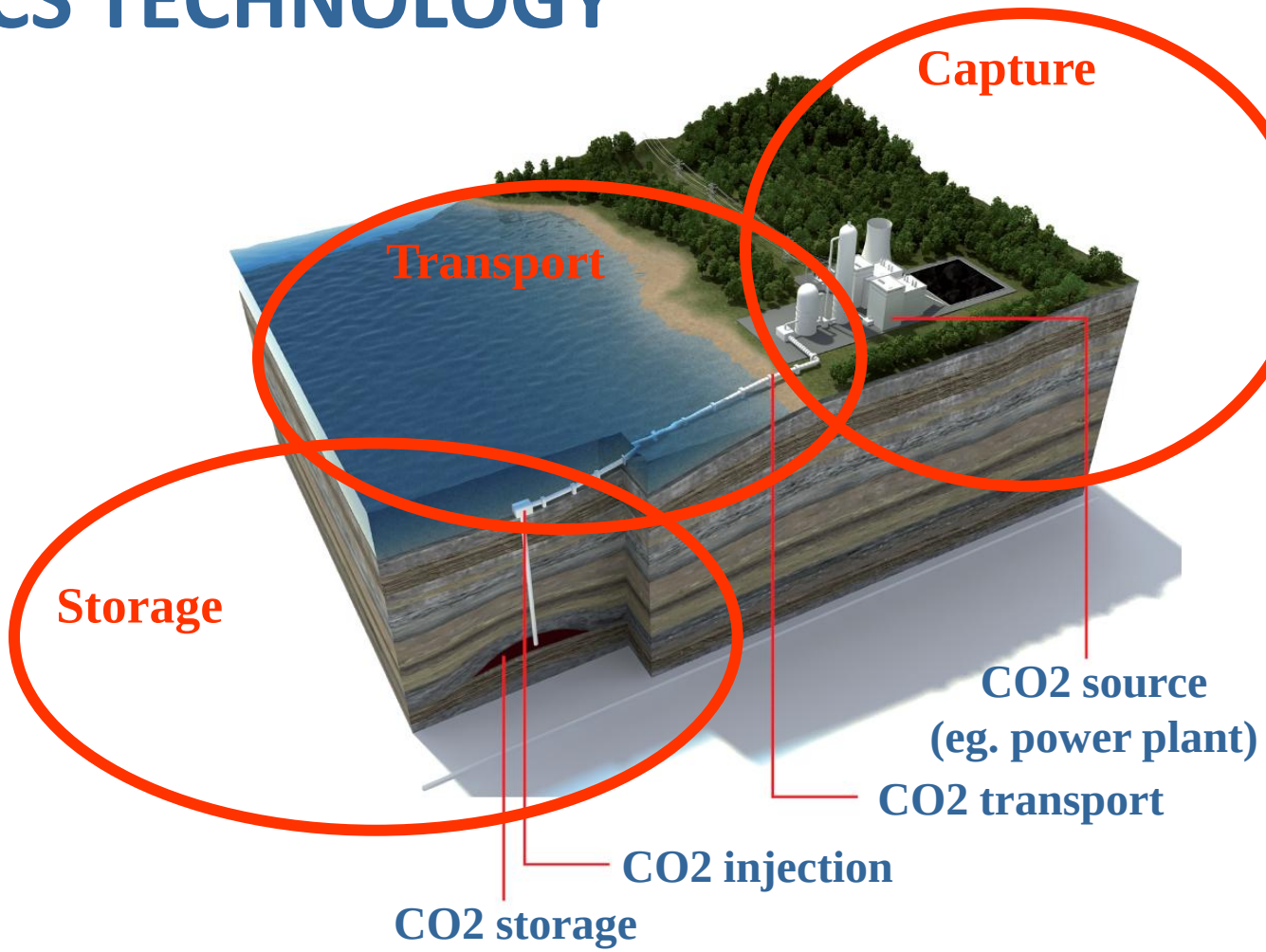
Gassco

3. **Storage of CO2 in geological formations**

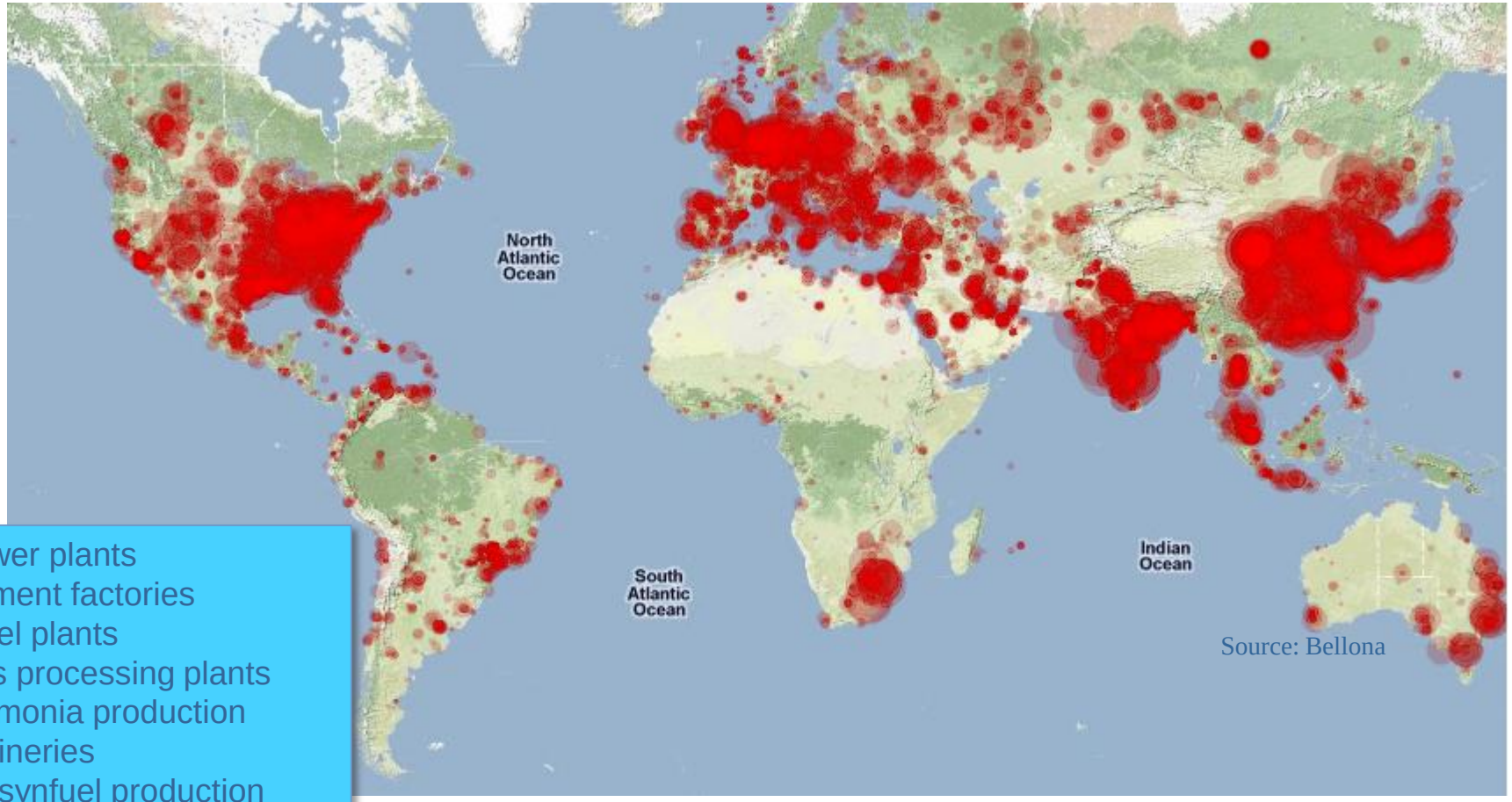
   Depleted oil and gas fields, saline aquifers, EOR, ECBMR etc.

Vattenfall

CCS TECHNOLOGY



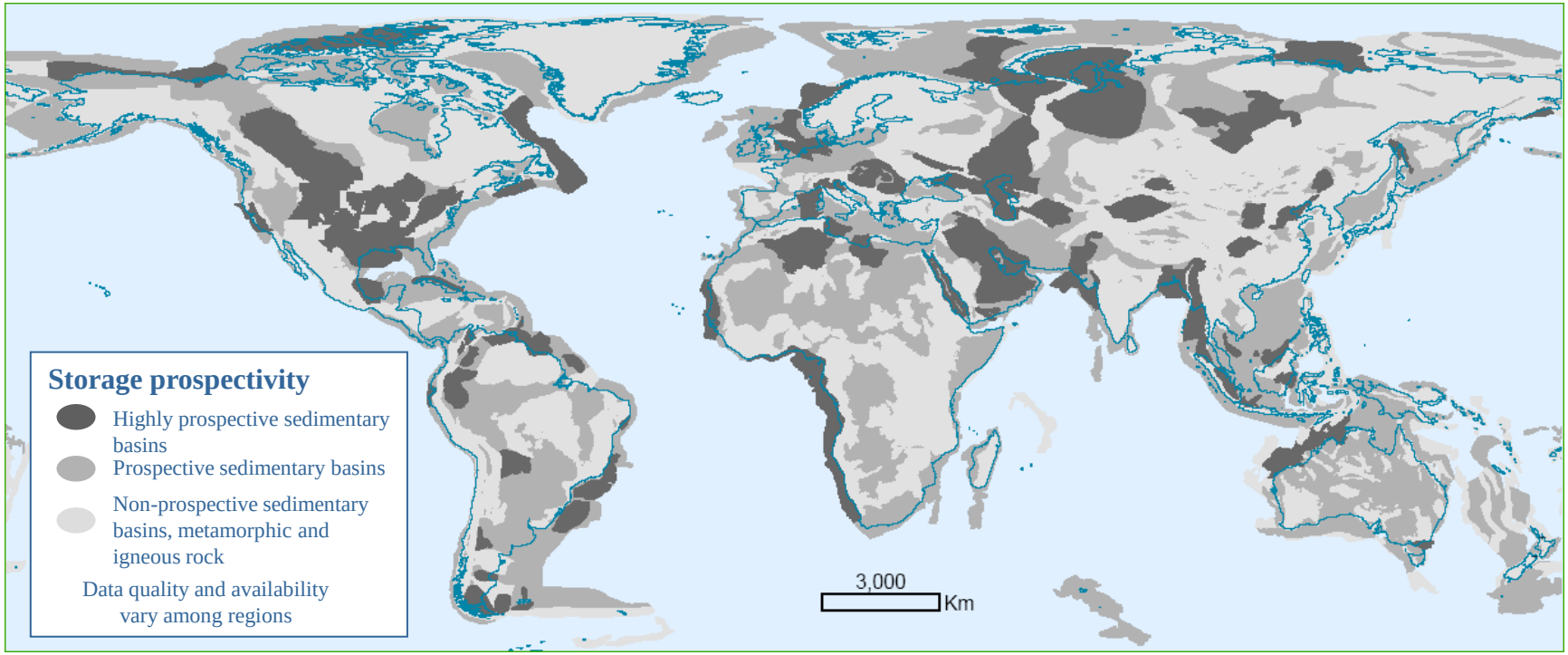
APPLICABLE CO_2 SOURCES



Source: Bellona

- Power plants
- Cement factories
- Steel plants
- Gas processing plants
- Ammonia production
- Refineries
- H2/synfuel production

APPLICABLE STORAGE RESERVOIRS



- Depleted gas/oil fields
- Saline formations
- Enhanced Oil Recovery (EOR)
- Enhanced Coal-bed Methane Recovery (ECBM)

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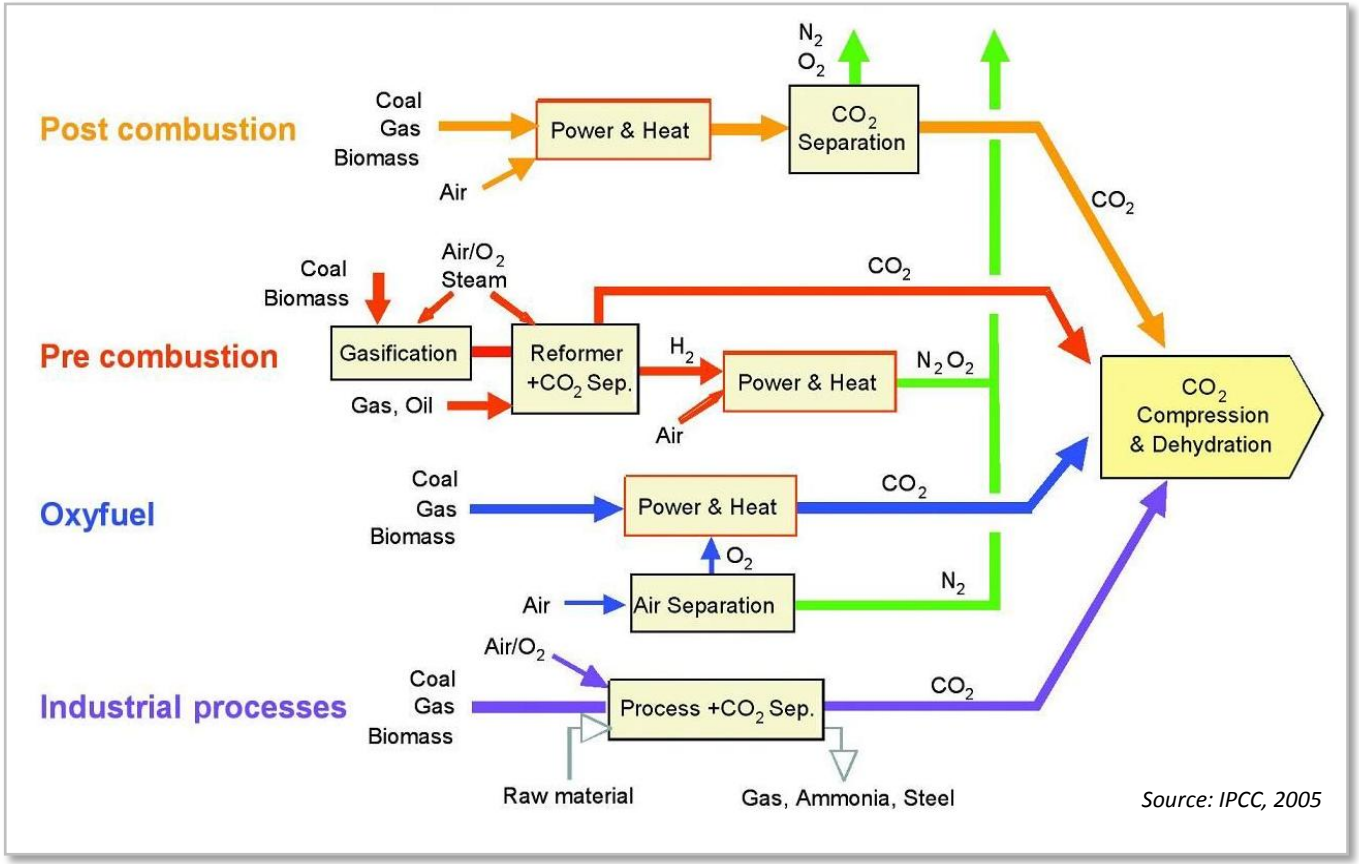
1. CCS in general
2. **Capture technologies**
3. CO2 transport
4. CO2 storage
5. Current and planned projects

Overview of CO_2 capture processes



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Post-combustion CO_2 capture

Process Layout

Demo plants

Example: 20 MWe Mountaineer demo project, US

Key challenges & development trends

- Scale-up of capture equipment; prove commercial size application at power plants
- Low-cost absorber designs
- Develop solvents with reduced energy penalty & minimized slip to ambient

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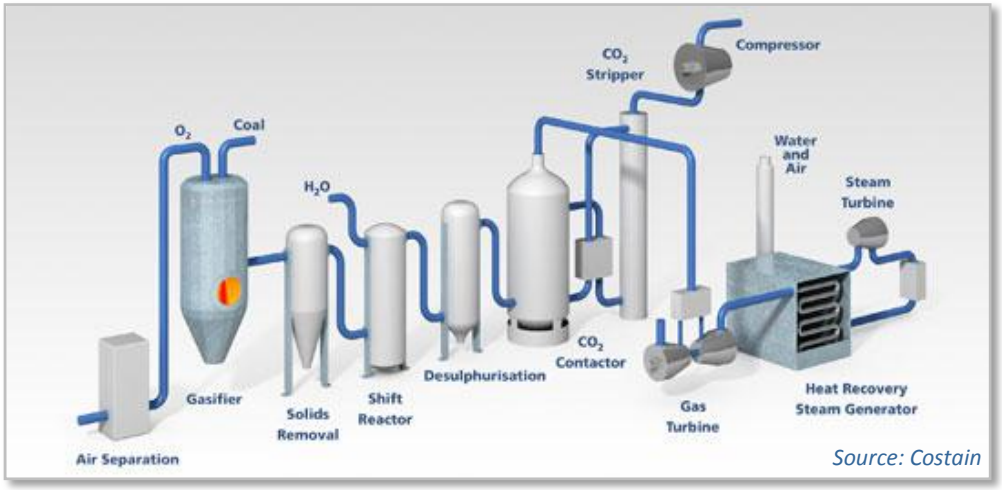
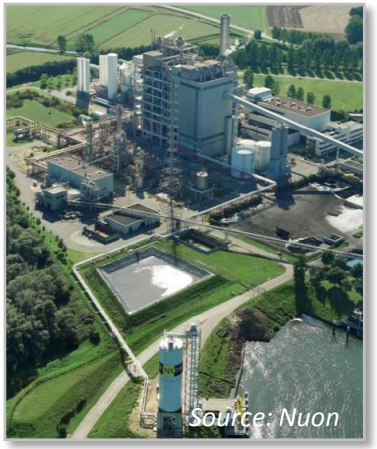
Pre-combustion CO_2 capture

Process Layout



Demo plants



Example: Planned pilot site at Buggenum, NL

Key challenges & development trends

- Prove integration of IGCC power plant with capture technology at commercial scale
- Optimize system design and process availability
- Further improve high hydrogen gas turbines

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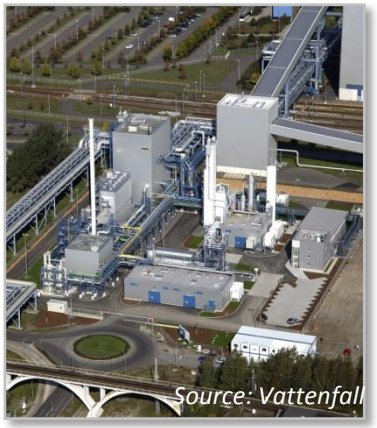
Oxy-combustion CO_2 capture

Process Layout

Demo plants



Example: 30 MWth Jänschwalde demo plant, Germany

Key challenges & development trends

- Reduce air separation energy requirement
- Long-term stability of boiler materials to recycled impurities from combustion process
- Optimize oxygen-firing combustion system

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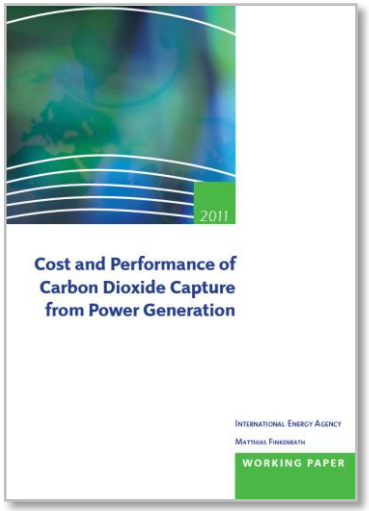
Latest IEA Study

- Reference document for latest information on CO_2 capture cost and performance
- Focus on CO_2 capture from power generation
- In-depth analysis based on major engineering studies



Available for free on IEA webpage

Key average results

Fuel *(capture route)*	***Coal*** *(pre-, post-, oxy-combustion)*	***Natural gas*** *(post-comb.)*
Efficiency penalty (%-pts.)	***10*** *(pre-combustion vs. IGCC: 8)*	***8***
Capital cost increase over baseline without CCS	***74%*** *(vs. PC reference)*	***82%***

Notes: Figures are for OECD countries and include only CO2 capture and compression, but not CO2 transport and storage; capital costs are overnight costs

- Substantial variation in costs across regions and depending on fuel and power plant types

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Capture Summary

- A variety of capture routes is under development:
  - Post-combustion
  - Pre-combustion
  - Oxy-combustion
- For coal-fired power generation, no capture route outperforms alternative routes
- An increase in capital costs of about 70-80% on top of the costs of the baseline power plant without CCS is estimated (this reflects the size of additional equipment required)
- Substantial variation exists in costs across regions and depending on fuel and power plant types

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CO_2 TRANSPORT (1): PIPELINES

- CO_2 can be transported liquid or in gaseous form, but compressed gas the main option, 10-80 Mpa pressures
- Approximately 5600km of CO_2 pipelines exist (mostly in US)
- Currently handling some 50Mt of CO_2 per year
- Existing conventional technology
- Main issues: pipeline economics, permitting, planning
- Risks: potential high concentrations in low-lying areas in case of rupture; however excellent safety record to date

Gassco

Duke University

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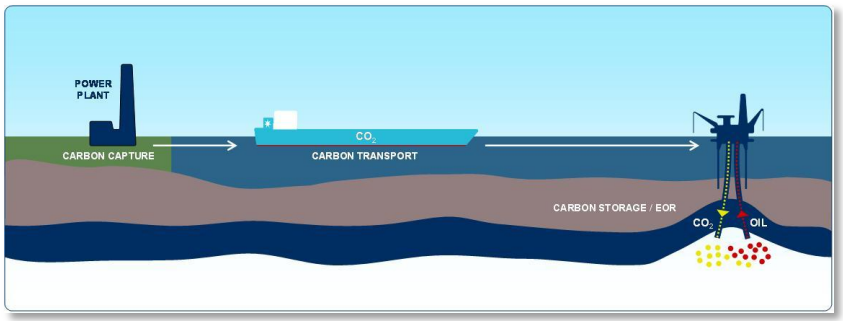
CO2 TRANSPORT (2): SHIPS

- CO_2 in liquid or in gaseous form, liquid the main option
- Current experience: handful of food-grade CO_2 carriers, no large CO_2 carrier fleet
- Liquid CO_2 only under 1) low-temperature and 2) pressure well-above atmospheric → pressure-type or semi-refrigerated tankers (-54°C, 6-7 bar)
- Technology similar to LNG carriers
- Risks: as in shipping overall; asphyxiation if rupture



Maersk

Arabian Oil & Gas

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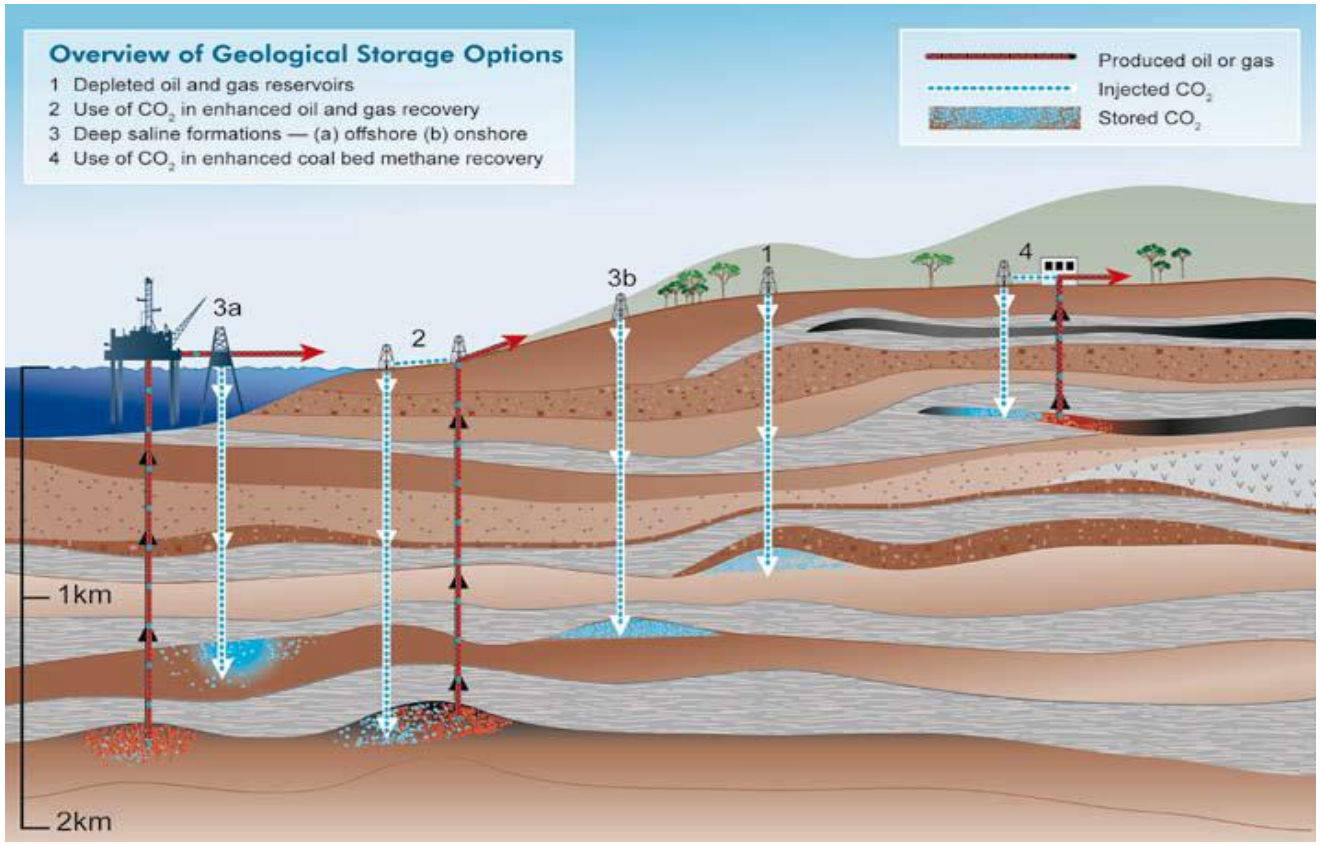
CO2 STORAGE (1)

CO_2 storage solutions (Source: IPCC)



- A variety of storage solutions
- Operating: Deep saline formations, oil/gas fields, EOR

CO2 STORAGE (2)

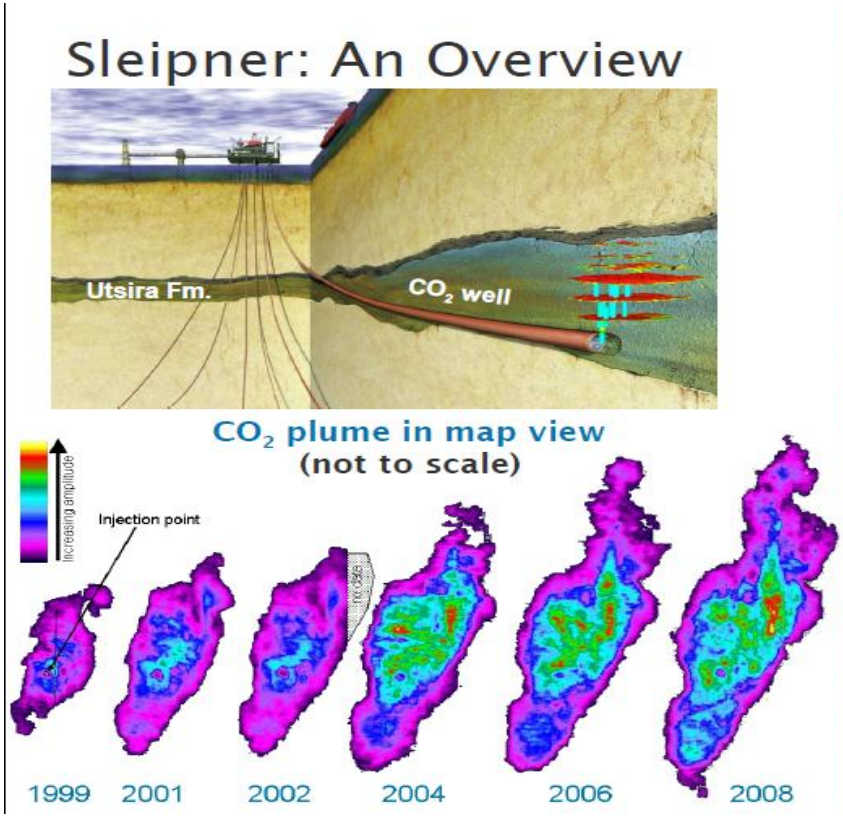
Capacity Estimates (Gt CO2)(Source:GHG)

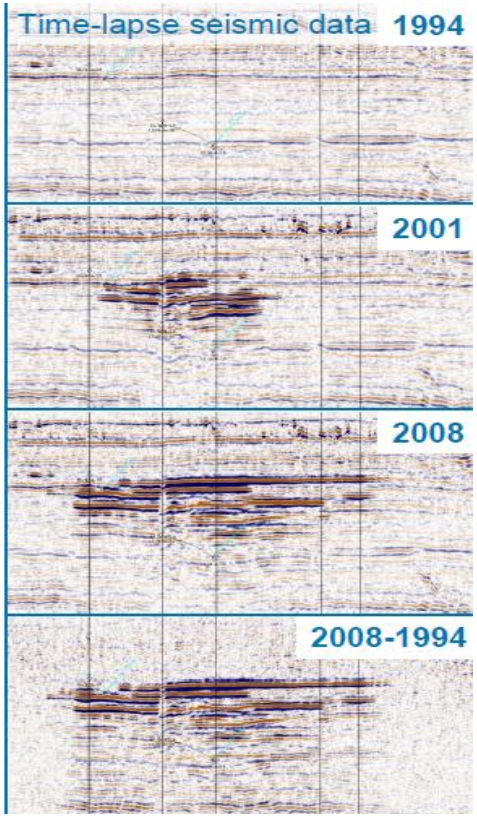
Storage Type	Global (IPCC 2005)	Global (IEAGHG)	USA	Europe	Russia (IEA2008)
DSF	1,000 – 10,000		3,300 – 13,000	90 – 330	2000
Depleted Gas	680 – 900	160	140	20 - 32	150-200
CO2-EOR		65			

- Significant uncertainty and different estimation methods
- Standardization for CO2 storage capacity estimation

CO2 STORAGE (3)

Monitoring : Seismic Survey(Source: STATOIL)





- Various methods for monitoring
- Best practice guidelines for storage monitoring

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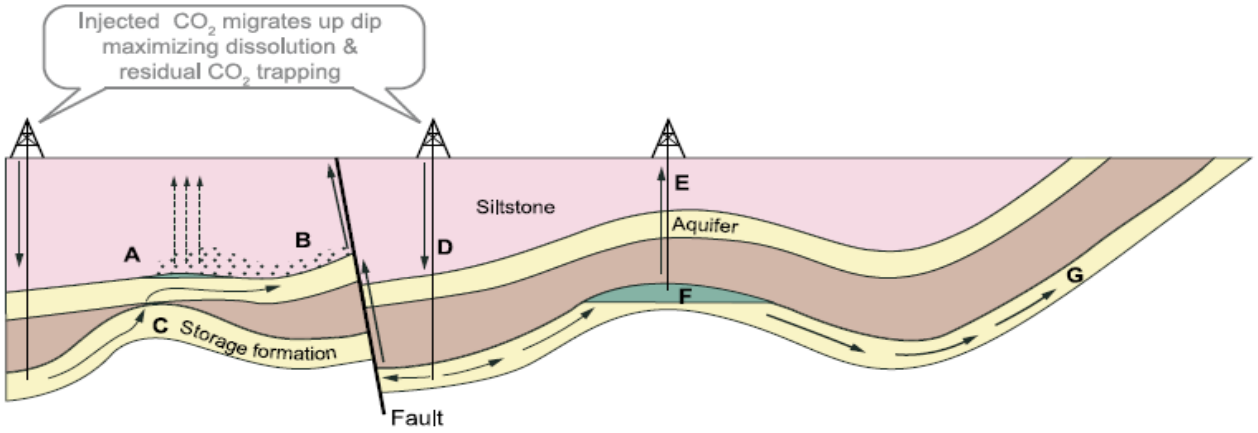
CO2 STORAGE (4)

Potential Escape Mechanism(Source: IPCC)



Potential Escape Mechanisms

A. CO_2 gas pressure exceeds capillary pressure & passes through siltstone	**B.** Free CO_2 leaks from A into upper aquifer up fault	**C.** CO_2 escapes through 'gap' in cap rock into higher aquifer	**D.** Injected CO_2 migrates up dip, increases reservoir pressure & permeability of fault	**E.** CO_2 escapes via poorly plugged old abandoned well	**F.** Natural flow dissolves CO_2 at CO_2 / water interface & transports it out of closure	**G.** Dissolved CO_2 escapes to atmosphere or ocean

Remedial Measures

A. *Extract & purify ground-water*	***B.*** *Extract & purify ground-water*	***C.*** *Remove CO_2 & reinject elsewhere*	***D.*** *Lower injection rates or pressures*	***E.*** *Re-plug well with cement*	***F.*** *Intercept & reinject CO_2*	***G.*** *Intercept & reinject CO_2*

- Various potential leakage mechanisms
- Develop safety regulations and criteria

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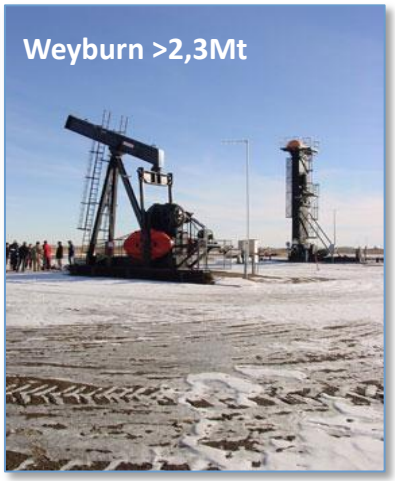
CURRENT AND PLANNED PROJECTS (1)



Five large-scale projects are currently storing >5Mt CO_2 per year

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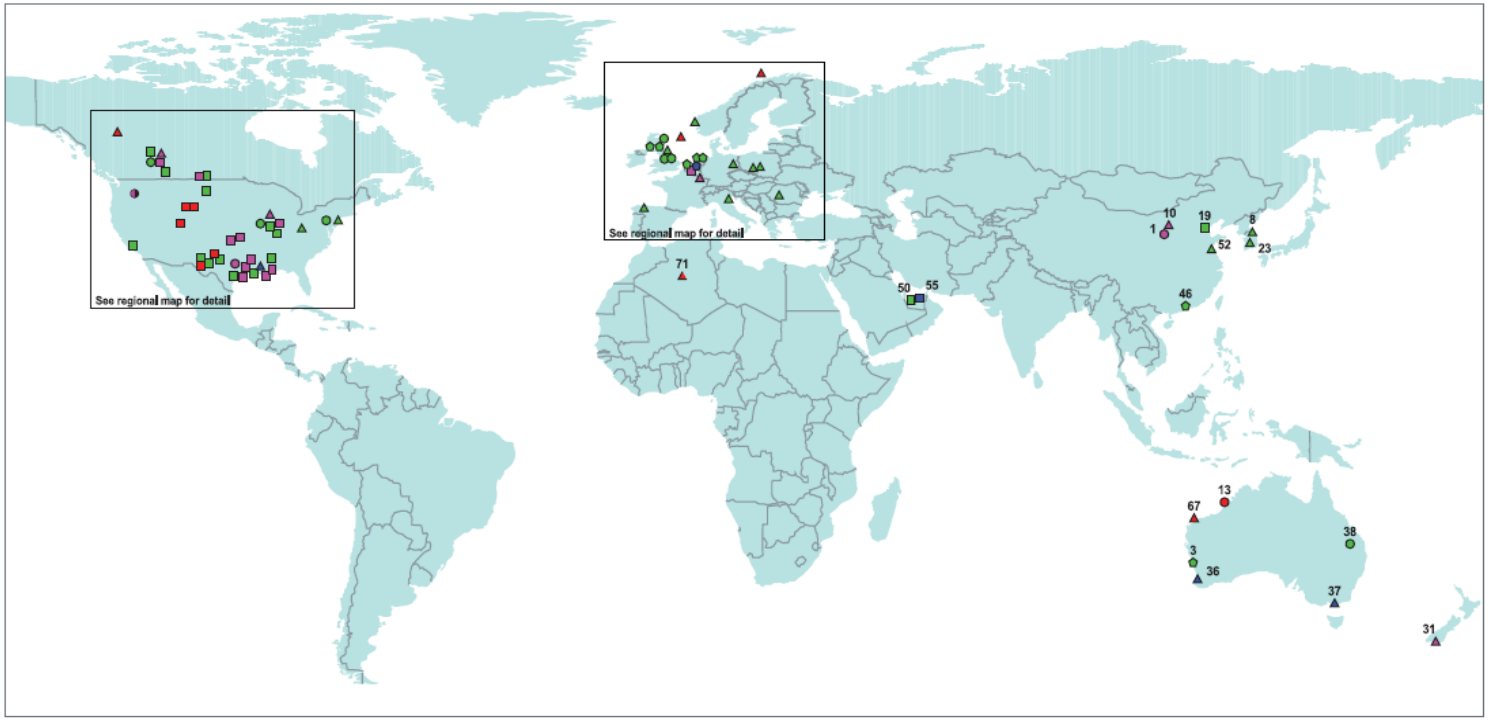
CURRENT AND PLANNED PROJECTS (2)

72 other integrated large-scale projects in various stages of development



Source: GLOBAL CCS INSTITUTE

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