



IEA Greenhouse Gas R&D Programme



# **Commercial Deployment of CO<sub>2</sub> Capture and Storage (CCS)**

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**IEA Greenhouse Gas R&D Programme**

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[www.ieagreen.org.uk](http://www.ieagreen.org.uk)



# IEA Greenhouse Gas R&D Programme



## Programme Members

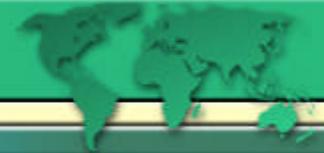


17 Member Countries

10 Industrial Sponsors

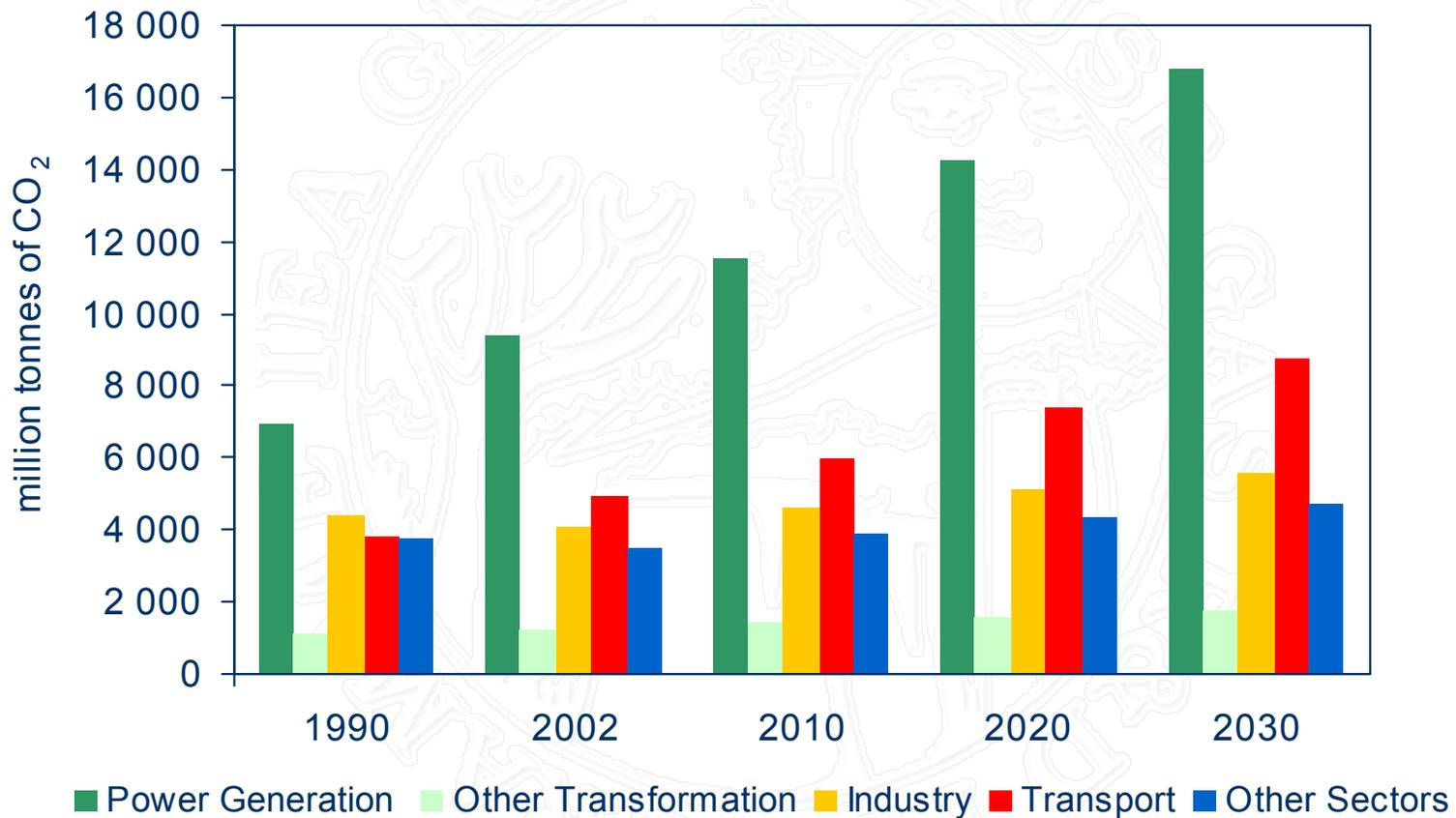


TOTAL



## CO<sub>2</sub> emissions by sector: 1990-2030

(Source: IEA – World Energy Outlook 2004)





## Introduction

- Current international status of CCS.
  - Regional drivers: N America, Europe, Asia-OECD, China, India, Middle East.
- Barriers to CCS commercialisation.
- Research needs.
- Conclusion



# CO<sub>2</sub> Capture AES Warrior Run

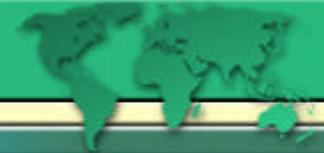




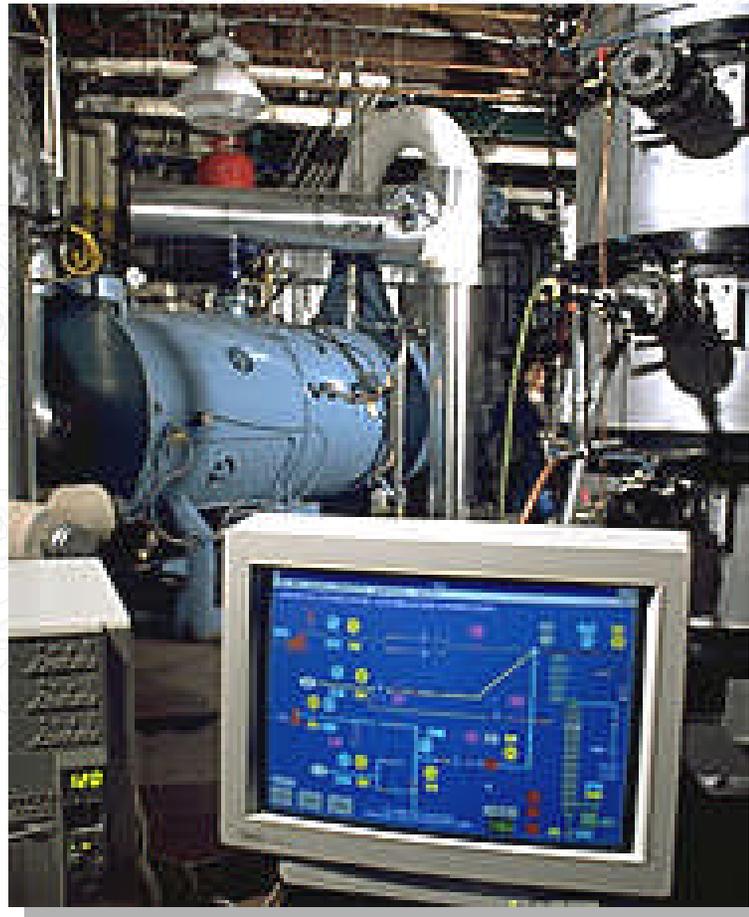
## IGCC without CO<sub>2</sub> capture



Shell gasifier IGCC plant, Buggenum, Netherlands



## O<sub>2</sub>/CO<sub>2</sub>-recycle combustion





## Capture Options

- Post-combustion decarbonisation
  - Proven at industrial scale
  - Needs to be scaled up for deployment at power plants
- Pre-combustion decarbonisation
  - Proven in synthesis gas production
  - IGCC pre-combustion cycle not demonstrated
- Oxy-fuel combustion
  - Currently at developmental stage



# Capture: Potential regional drivers

- ALL: Nuclear – 80% nuclear power in France; 3% in The Netherlands.
- N America
  - USA - fuel security – EOR - indigenous coal
  - Canada - EOR - Oil sands
- Europe
  - Imported fuel - Wider emission reduction portfolio
- Asia-OECD
  - Australia - coal use & export
  - Japan – Imported fuel - increased efficiency
- China & India
  - Now: High efficiency coal plant. Capture-ready plant?
- Middle East
  - Advanced EOR



## China

- Sub-critical PCC
  - **Large numbers of new orders – 87GW in 2003**
- Supercritical PCC
  - **Policy to rapidly deploy the technology**
  - **43GW ordered in 2003, 93% of world supercritical market, ~70 boilers**
  - **Waigaoqiao, 42% efficient (LHV)**
- IGCC
  - **Demonstration plant planned at Yantai**

Based on information from IEA Clean Coal Centre

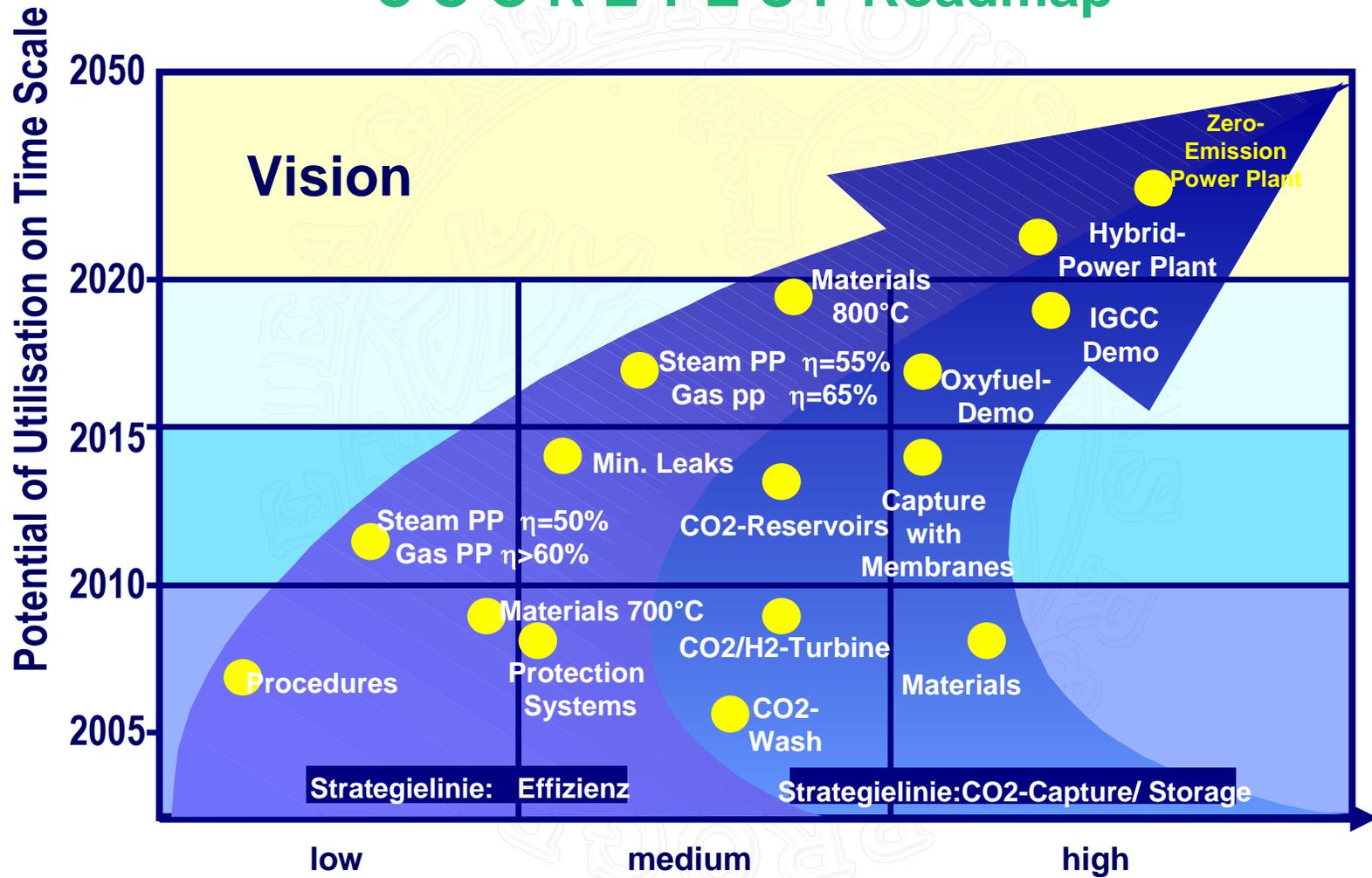


## Capture: International implications

- Can not pick a universally 'preferred' capture technology
  - At least 3 options in serious contention
  - Reduced cost and efficiency penalties critical
  - Cost of demonstrations must be shared
- Look for synergies
  - Technology - NZET, Oxygen production
  - Application – capture-ready power plant, hydrogen, heavy oils/tars



# COORETEC: Roadmap





## Transporting CO<sub>2</sub> - pipelines

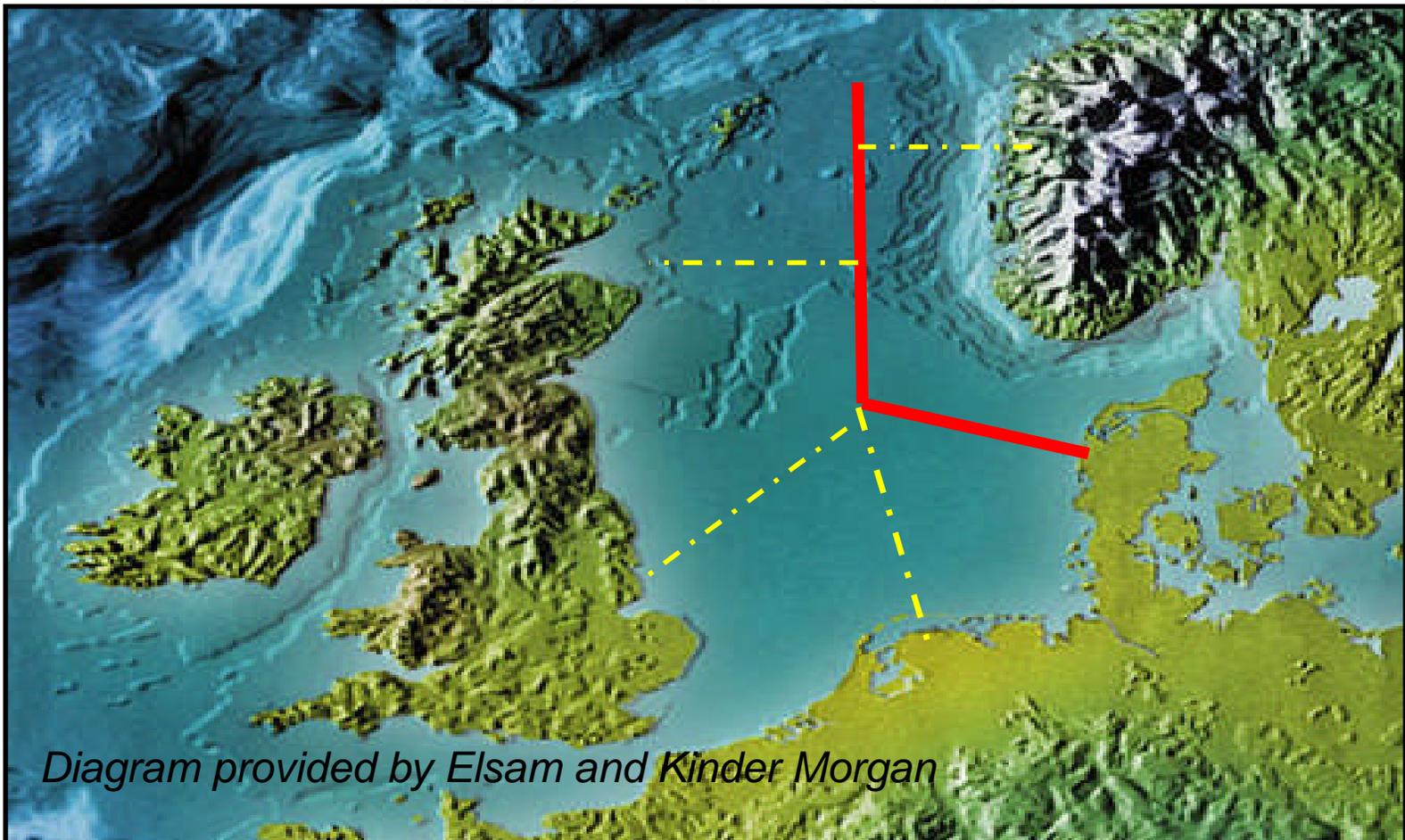


- CO<sub>2</sub> pipelines:
  - 3100 km in use today
  - Capacity > 45 Mt/y
- Weyburn
  - Pipeline length 325 km
  - 19 MtCO<sub>2</sub> over 15 years of EOR.

***Photo: Dakota Gasification***



## The CENS Project



*Diagram provided by Elsam and Kinder Morgan*



## Transmission Options

- Pipelines
  - Technically proven
  - Extensive network of CO<sub>2</sub> pipelines in North America carrying 45 million t/y CO<sub>2</sub>
- Ships
  - Small volumes of CO<sub>2</sub> already carried by ships
  - Likely only to be used for long distance transport
  - Less difficult than LNG



## Transporting CO<sub>2</sub>: Regional drivers

- N America - sources and sinks matched – international and geographical boundaries not a major problem
- Europe - pipeline backbone ?
- Asia-OECD
  - Japan – underground storage may be limited
- China & India - limited data
- Middle East – could import CO<sub>2</sub>



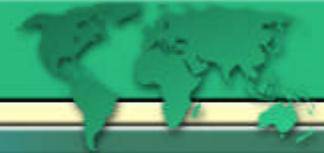
## CO<sub>2</sub> transport : International implications

- Potentially a major industry – similar in size to the Oil industry
- Cost is highly dependant on scale
- Inter-regional transport systems likely to be needed
- Shipping an option



## Storage Options

- On the ground - mineralisation ( $\text{CaCO}_3$ )
- Underground – oil and gas fields, deep saline aquifers, etc
- Ocean – dispersed or liquid pool

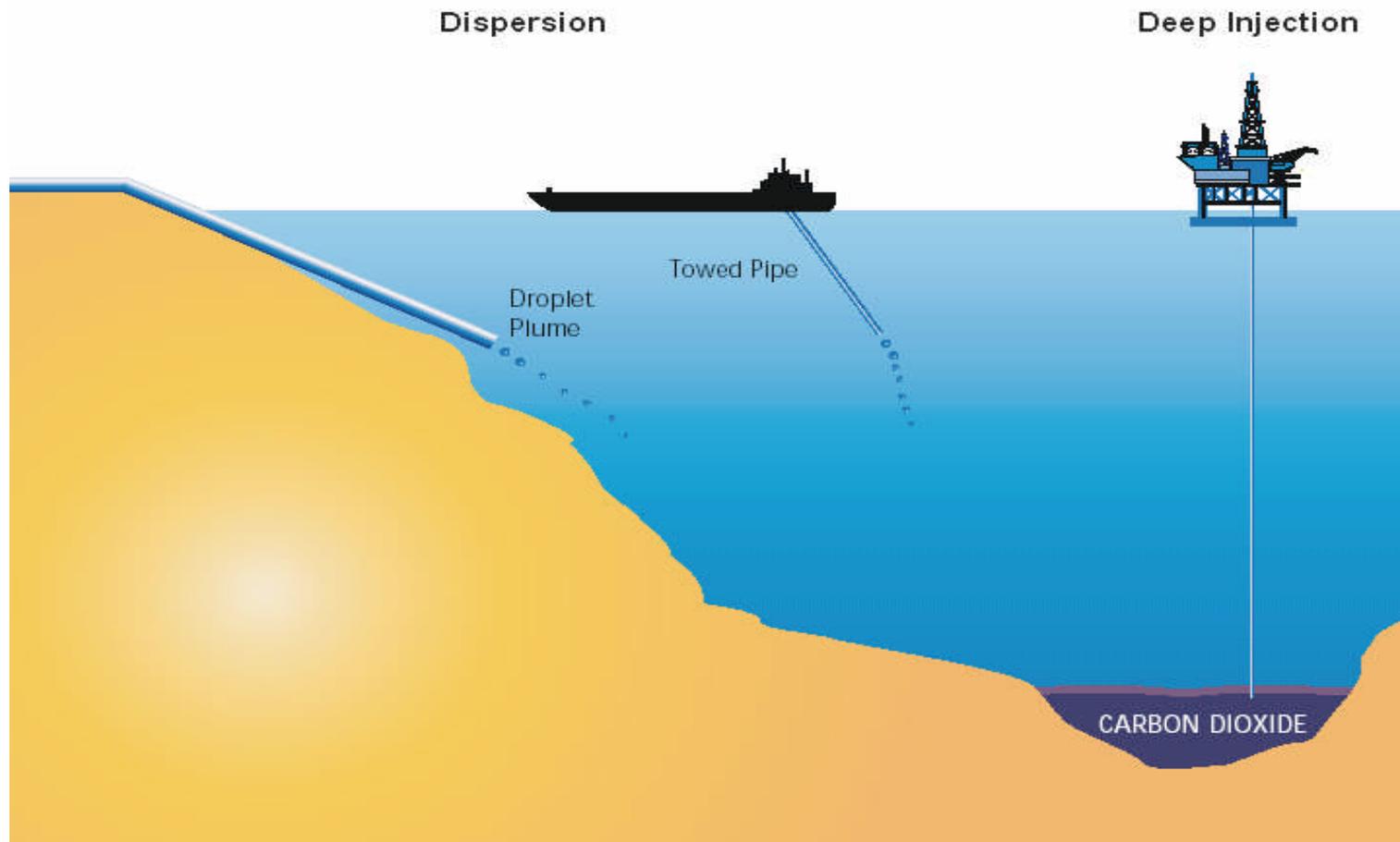


Time Magazine,  
May 17<sup>th</sup>, 2004

1 million tonnes  
CO<sub>2</sub>/year



# Ocean Injection of Liquid CO<sub>2</sub>



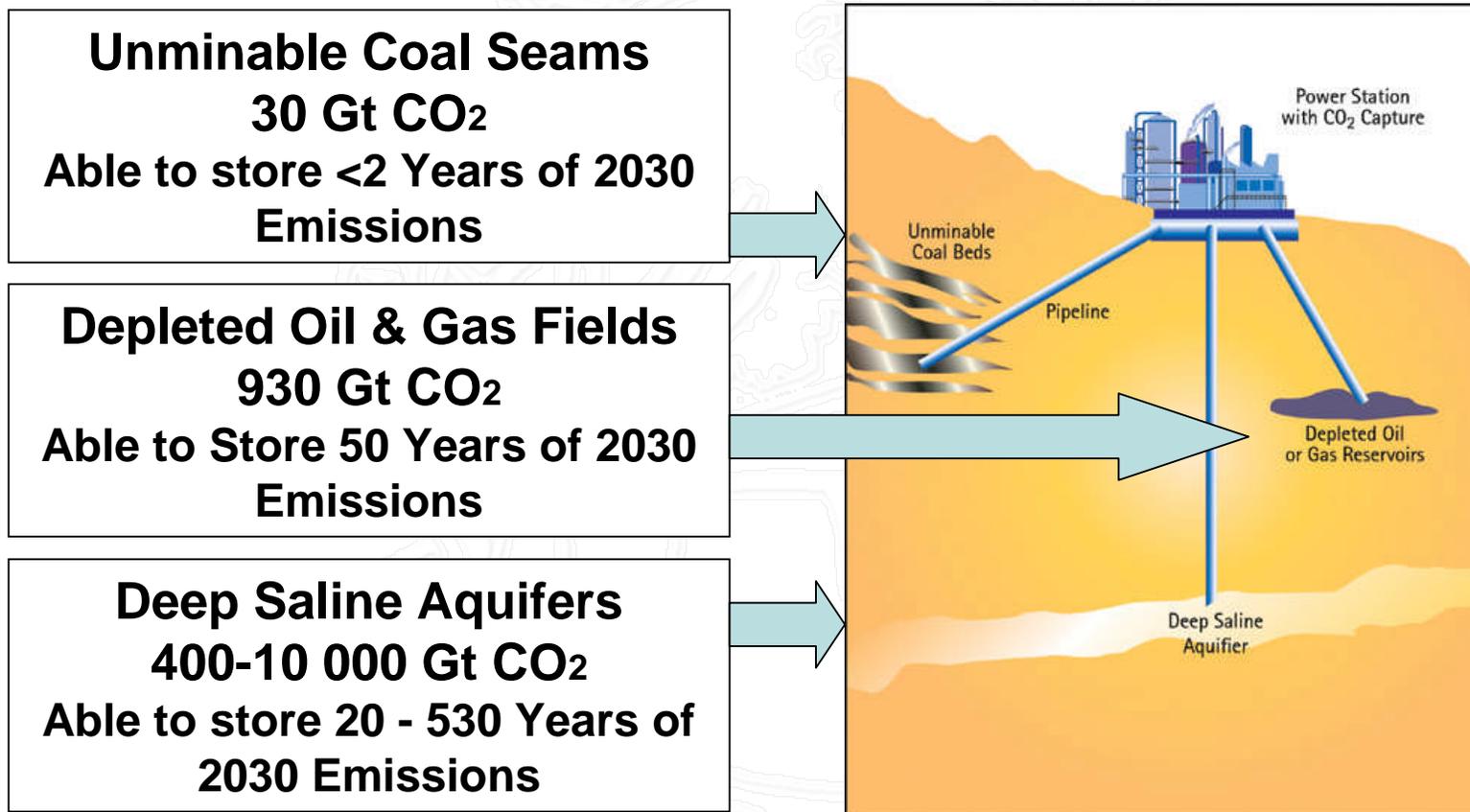


## Storage Options

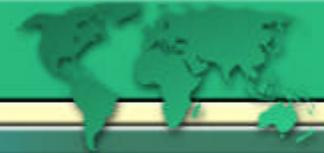
- Ocean
  - Scientific concern about impacts on marine ecosystems
  - Possibly illegal under existing international treaties
  - Resistance from environmental pressure groups
- Geological
  - Technology demonstrated



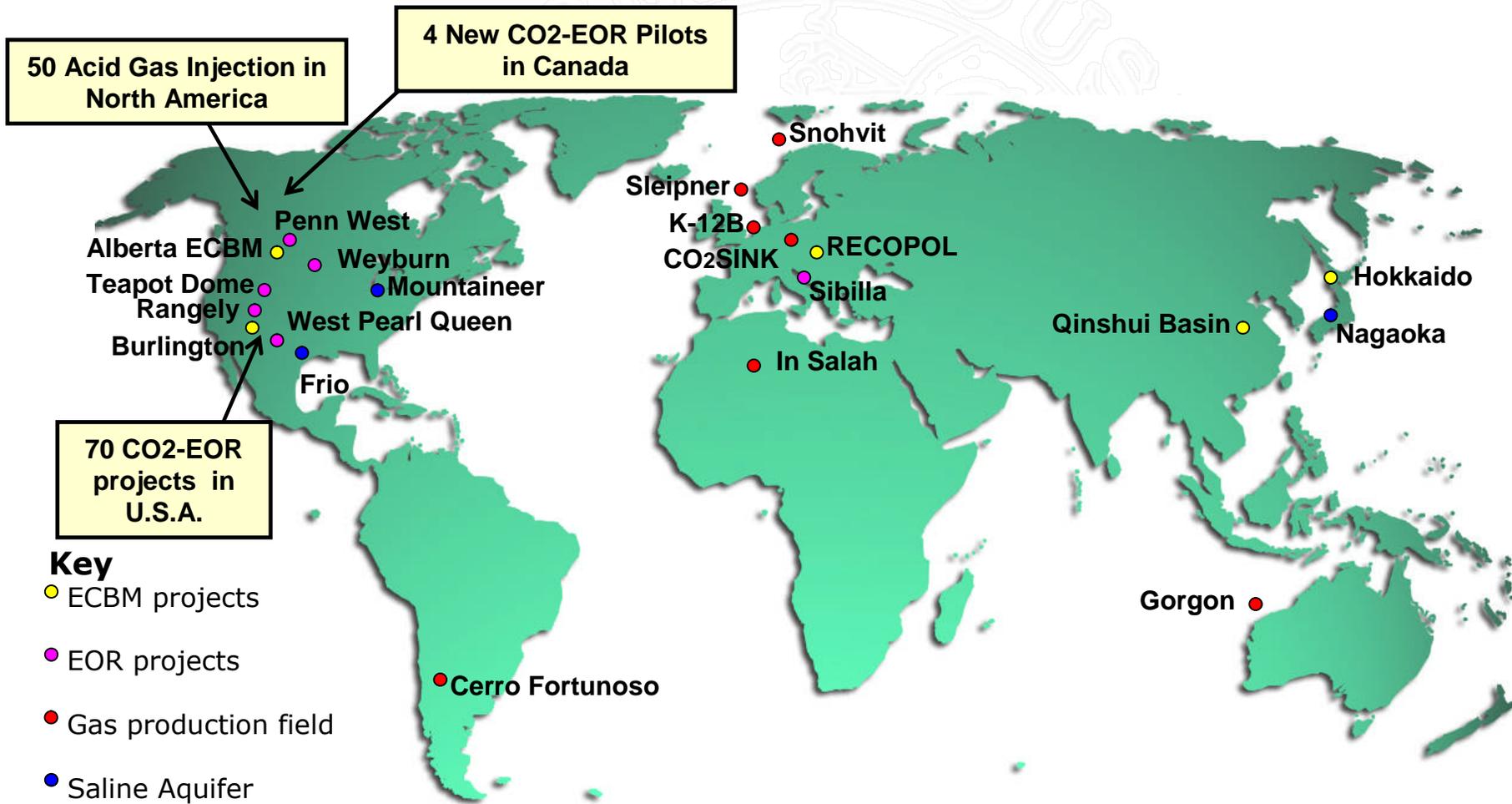
## Geological Storage Options



Note: CO<sub>2</sub> Storage capacity at cost of 20 US \$ per tonne of CO<sub>2</sub>

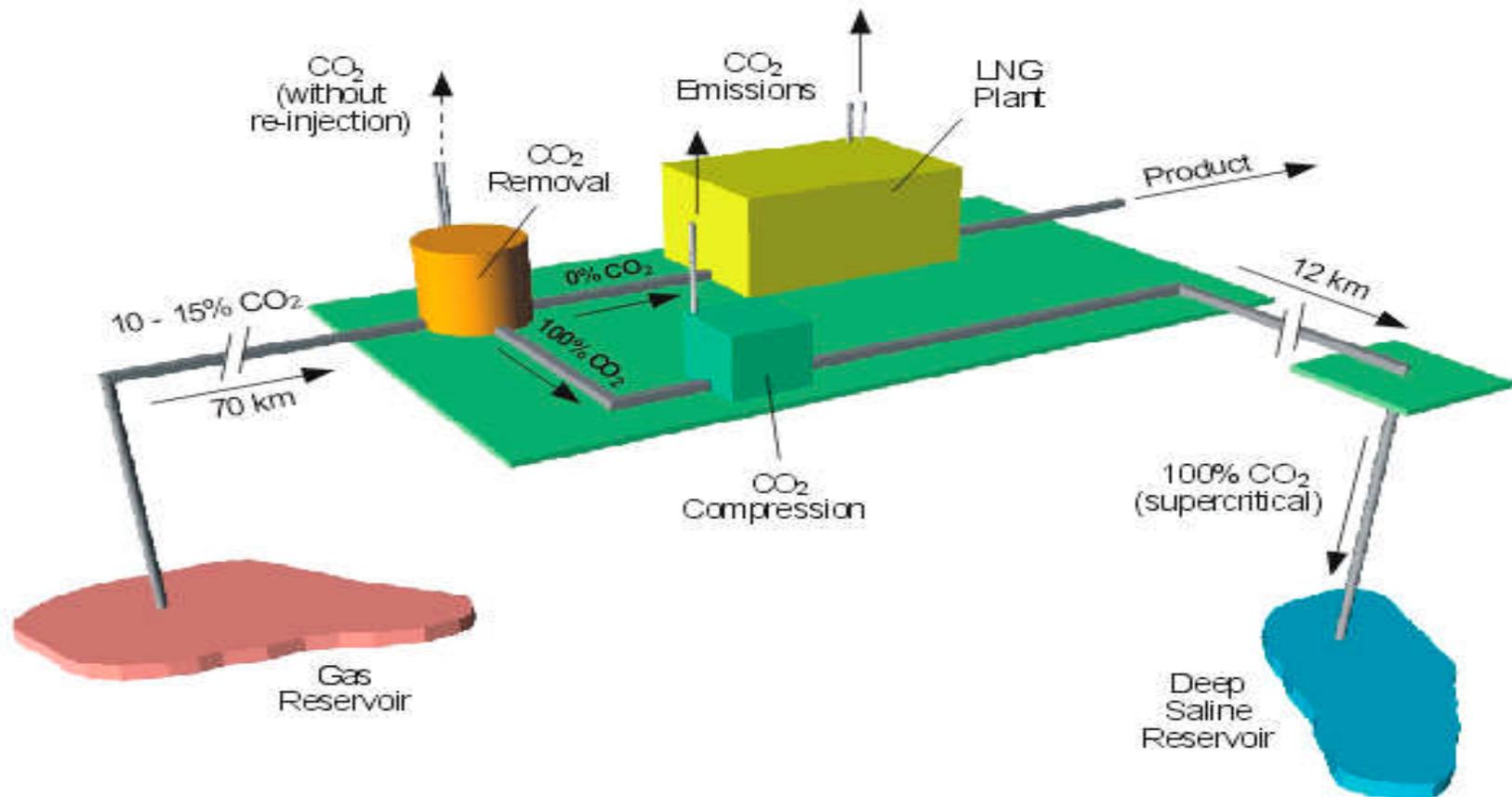


# CO<sub>2</sub> Storage Demonstration Projects





## Gorgon LNG plant with CO<sub>2</sub> capture



Courtesy of ChevronTexaco



## CO<sub>2</sub> Storage: regional drivers

- N America - experience with EOR, inland aquifers.
- Europe - Potential of EOR to extend N Sea – N Sea aquifer.
- Asia-OECD - no match of sources and sinks
- China & India - limited data
- Middle East – large potential in oil& gas fields.



## CO<sub>2</sub> storage: International implications

- Geological storage preferred to ocean storage
- EOR early opportunity
- Depleted oil & gas wells potentially significant stores
- Widespread CCS needs storage in deep saline aquifers.



## Barriers to commercialisation(1)

- Policy
  - Kyoto Protocol now ratified
  - CCS not defined as a mitigation option under Kyoto
  - IPCC Special report will be presented at COP 11 in November 2005
  - CCS likely to then become a recognised mitigation option



## Barriers to commercialisation (2)

- Technical
  - Capture
    - Demonstrations s required
  - Transport
    - Non technical
  - Storage
    - Leakage - safety
    - Leakage – carbon accounting



## Barriers to commercialisation (3)

- Acceptance
  - OSPAR & London conventions may prevent 'dumping' of CO<sub>2</sub> at sea and under the sea bed
  - CO<sub>2</sub> injection as part of EOR operations is acceptable
  - Public Acceptance
    - NGOs against ocean storage; more open to implementation of CSS
    - Will not gauge real public response until projects are set up in their 'backyards'
    - General public largely unaware of the technology



## Barriers to commercialisation (4)

- **Regulatory Regimes**
  - Currently no international standards
  - Development of national standards in progress
    - Netherlands - adapted Mining Act for K-12B Project
    - Regional partnerships and EPA in USA are looking at modified existing regulations for CO<sub>2</sub>-EOR
    - Canada has looked at modifying natural gas storage standards
    - EC - establish national standards to allow CCS to take part in European Trading System



## Barriers to commercialisation (5)

- Fiscal Incentives
  - Lacking commercial business architecture
    - No financial incentive to capture
    - Storage business does not exist
  - Emissions taxes e.g. in Norway are not replicated elsewhere
  - Tax exemptions being considered for CO<sub>2</sub>-EOR in North Sea
  - Trading Schemes will generate a price for CO<sub>2</sub> that will assist CCS



## International R,D&D needs

- We need to prove the following:
  - That CCS is safe and affordable.
  - That there are no significant environmental effects
- Demonstration projects will play a critical role.
- Fate CO<sub>2</sub> stored underground will not be demonstrated for many years – will need to be modelled with confidence.



## Conclusions

- Climate Change is a global problem requiring international cooperation.
- The establishment of CCS technology at scale requires a major investment even by the standards of OECD countries.
- Multi-national agreements and initiatives will be necessary.
- The preferred CCS option will not always be the same and will depend on many factors.



# IEA Greenhouse Gas R&D Programme



[www.co2captureandstorage.info](http://www.co2captureandstorage.info)

A screenshot of the IEA CO2 Sequestration website displayed in a Microsoft Internet Explorer browser window. The browser title is 'CO2 Sequestration - Microsoft Internet Explorer'. The address bar shows 'http://www.co2sequestration.info/'. The website content includes a navigation menu on the left with links like 'Home', 'What is CO2 Sequestration?', 'Research Programmes', 'Search Projects', 'Send Us Your Feedback', 'Contact Us', and 'Login'. The main content area features a 'CO2 Sequestration' header, an 'Introduction' section with text about the role of CO2 capture and storage, and a search box for projects. There is also a small image of a power plant and a green box with text about evaluating geological carbon sequestration.

IEAGHG maintains a database of practical R,D&D projects.

This and other reference material on CCS can be found on our website

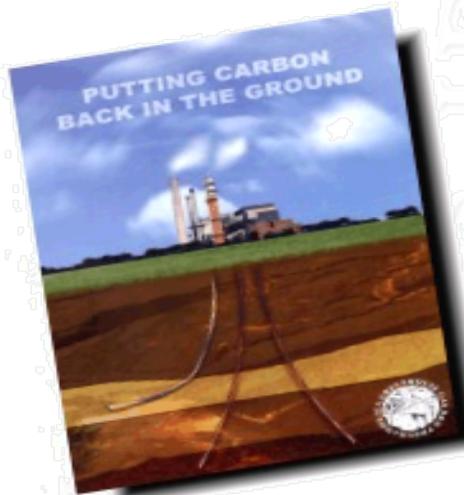
[www.ieagreen.org.uk](http://www.ieagreen.org.uk)



## Some of our deliverables

Quarterly newsletter

Topical Reports



**GHGT-8**  
**19<sup>th</sup>-23<sup>rd</sup>**  
**June 2006,**  
**Trondheim, Norway**