CO2 Storage Challenges to the Iron and Steel Industry

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Storage portfolio

- ***Technical studies on key issues***
- ***International research network series***
  - Learning's from R&D projects and pilot injection projects
    - Modelling of injected CO_2
    - Monitoring of injected CO_2
      - Monitoring Tool
    - Well bore integrity
    - Risk Assessment
    - Environmental Impacts/Natural Analogues
- ***What have we learnt from early commercial CCS projects***

Geological Storage Of CO_2

Injection of a supercritical fluid into the pore spaces of permeable rocks (geological reservoirs)

- Reverse of oil and gas production
- Oil industry has been injecting fluids into geological to assist oil production for many years
- CO2-EOR has been practised in North America since the mid 1980's
- Storing natural gas in depleted oil and gas fields and deep saline aquifers since 1990's

What is a Geological Reservoir?

The reservoir comprises a reservoir and seal pair

In general a reservoir / seal pair consist of:

- Porous and permeable "reservoir" rock that can contain (a mixture of) gas and liquid

Rocks with porosity of typically 5-30% of volume of the rock

Overlain by a "seal" (non permeable rock) layer

Typical seal permeability is < 0.001 md

How Does the CO_2 Stay Underground?

Structural Trapping

- CO_2 moves upwards and is physically trapped under the seals

Residual storage

- CO_2 becomes stuck between the pore spaces of the rock as it moves through the reservoir

Dissolution

- CO_2 dissolves in the formation water

Mineralisation

- The CO_2 can react with minerals in the rock forming new minerals

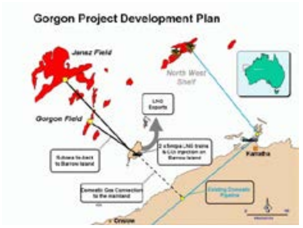
Commercial Application of CCS (to date)

Sleipner
1Mt/y CO_2

Weyburn
2.5 Mt/y CO_2

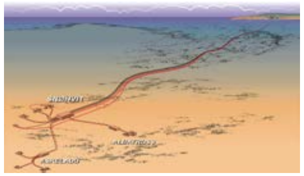
In-Salah
1.2 Mt/y CO_2

Snohvit
0.7Mt/y CO_2



Gorgon
4Mt/y CO_2

350km overland pipeline



160km sub sea pipeline

1996 1998 **2000** 2002 **2004** 2006 **2008** 2010 2012 2014 2016 2018

Industry considerations

- ***Need for CCS in steel industry highlighted in global policy studies***
- ***Core business is making steel***
  - Same dilemma faced by power sector
- ***Is there a business case for CCS?***
  - Probably not – no price on CO_2
- ***Industry has no experience of transport and storage*** *– same as power sector*
- ***Ideally would like a storage company to handle out of gate storage***
  - No market therefore no such companies currently exist

Infrastructure considerations

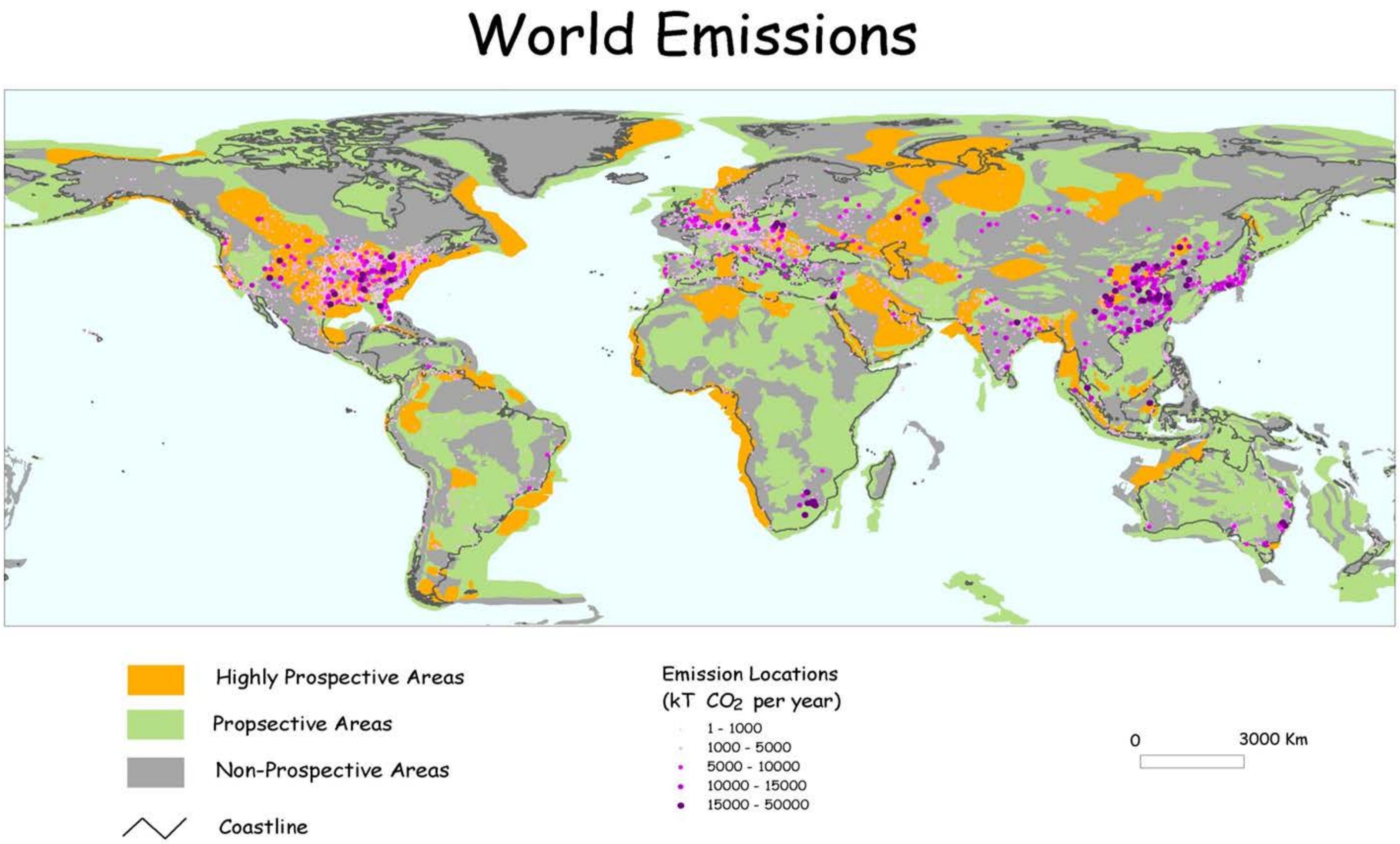
- ***Each site will be site specific***
- ***Need a gas gathering system?***
  - More than one stack
  - Central capture plant or multiple?
  - Experience from refining industry
- ***Shipping versus pipelines***
  - Site approximate to harbours
  - Experience from projects like ROAD in Rotterdam

Experience to date

Experience from demonstration projects in power sector

- Need to start storage assessments early
- Highest source of project risk
- Large up front cost, which you may lose
  - Who pays for those costs and takes the risks?
- Who undertakes work? – geological surveys or geoengineering contractors
- Biggest issue regarding public acceptance
  - Security of storage issues

Storage Resource



Storage Resource Issues

USA & Europe

- *Good storage potential*
- *Europe – off shore*
- *USA – on shore*
- *Competition from other sectors – power sector*
- *Need to consider transmission network to reservoirs*
- *Are there suitably large reservoirs?*

Asia

- *Limited storage potential in region*
- *Transport to other regions – shipping*
- *Competition from other sectors – power sector*
- *Need to consider transmission network to distribution terminal*
- *Are there suitably large reservoirs?*

Moving up in scale

- **Injection rates on the order of 10 MtCO_2/year for many sites;**
- **CCS infrastructure will need to be of the same scale as that of the current petroleum industry;**
  - **Management of reservoir pressures (water production) to avoid fracturing, seismic events and impact on resources (both groundwater, petroleum).**
  - **Need to optimise storage process by:**
    - **Multi-well injection schemes;**
    - **Enhancement of dissolution and residual trapping mechanisms to maximise effective storage capacity (co-injection of brine/CO_2).**

Injection Strategy – Parameters 1

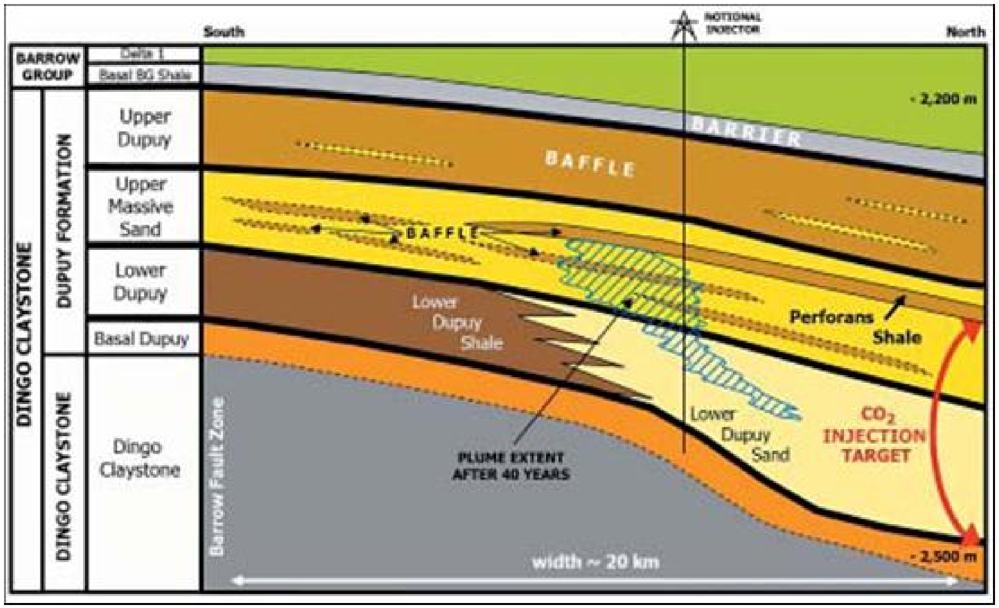
- Definition of Injectivity:
  - The ability of a geological formation to accept fluids by injection through a well or series of wells.
- Many factors effecting injectivity, but primary is bottom-hole pressure, surpassing this pressure limit is likely to lead to migration and leakage.
  - Bottom-hole pressure influenced by:
    - Injection rate,
    - Permeability,
    - Formation thickness,
    - CO_2 / brine viscosity,
    - Compressibility.

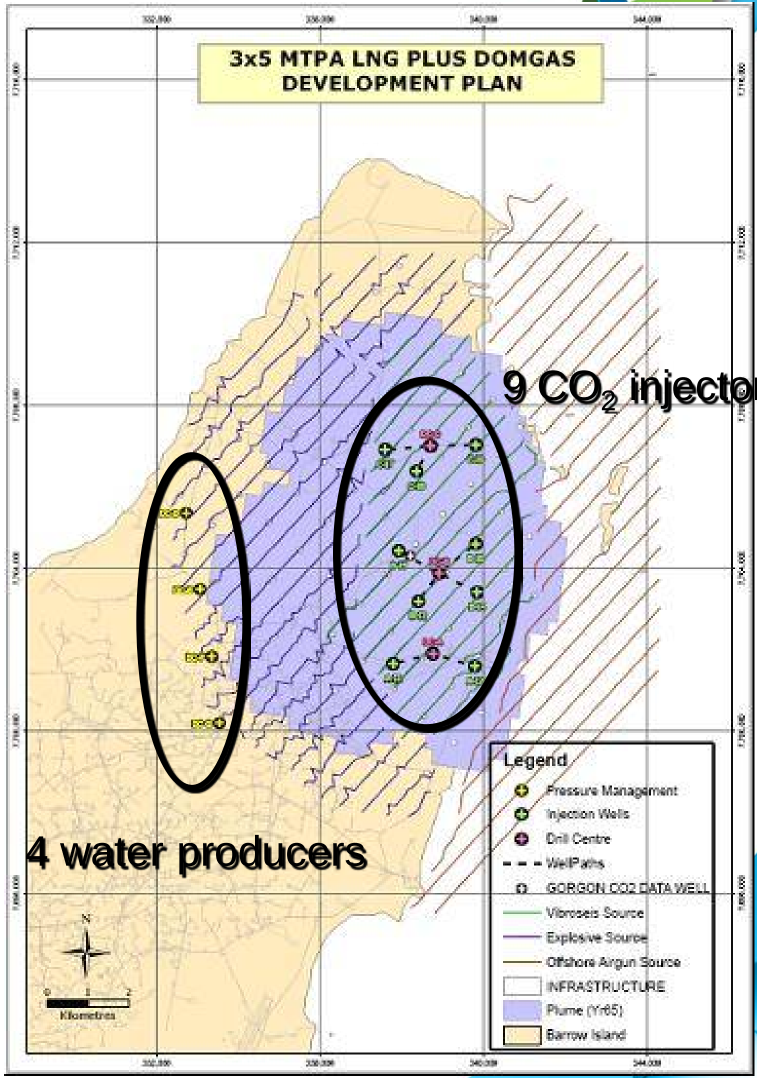
Existing Injection Strategies

- Snøhvit, Norway, LNG Project.
  - 0.75 Mt/yr CO2 injected through single well into DSF below Jurassic gas reservoir
  - Single well injection, considerable upscale necessary to analogise with commercial CCS projects of the future

- Gorgon, Australia, Offshore Natural Gas Production,
  - Produced gas approx. 14% CO_2, removed from gas stream, compressed and transported via 12km pipeline to storage site.
  - Anticipated 9 injector wells, in 3 groups
  - Budget contingency allows for additional wells if necessary.
  - 4.9 Mt/yr CO_2 injected, with total projected storage of 125 Mt CO_2
  - Water production wells also planned to maximise control of plume, and manage reservoir pressures

Pressure Maintenance - Gorgon Proposal





Conclusions to date

- **Pressure build-up is most influential factor on injectivity and storage potential,**
- **Pressure management will therefore prove a vital element of injection strategies,**
- **Large scale demonstrations will enhance knowledge and understanding.**
- **The pure size of future CCS projects might provide unexpected new challenges.**

Largest on shore project in planning

Bełchatów CCS Project

- **250MW post combustion capture slip stream**
- **Storage in onshore deep saline formation**

858MWe Power Plant near Lodz in Poland

Bełchatów issues

- ***Site characterisation programme, 5 years and €7 million***
- ***Proposed reservoir is a deep saline aquifer***
  - Area of Karst on top causing seismic issues
  - Inject and monitor in flanks
- ***Public opposition to seismic acquisition***
- ***Plume could extend 20km***
  - Need a compensation mechanism to cover plume spread

Summary

- *Technology development issues*
  - 10 - 20 years to introduce new technology into industry sectors
  - Technical issues to resolve with oxy firing
    - Pilot testing underway
- *Transmission*
  - Steel facilities near sea shore/estuaries
    - Large volumes of gas to be transported
    - Multiple stacks, collection/distribution infrastructure required
    - Pipeline or ship transport?
- *Scale*
  - We could be looking at 8 to 30 Mt/CO2/y produced
  - Need large reservoirs to accept this volume of CO_2
  - Largest CCS injection so far Gorgon, Australia 4 Mt/y
  - Looked at potential for injection up to 10Mt/y so far

Thank You

Further details can be found at:

www.ieaghg.org

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