IEA Greenhouse Gas R&D Programme

International Developments in CO_2 Storage

What Have We Learnt from Regulatory Developments and from Large-Scale Projects

IEA Greenhouse Gas R&D Programme

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IPCC Guidelines for GHG Inventories

- Apr 2006
- Vol 2 Energy, Chp 5 - *CO_2 Transport, Injection and Geological Storage*
- Each site will have different characteristics
- **Methodology**

  Site characterisation – inc leakage pathways

  ↓

  Assessment of risk of leakage – simulation / modelling

  ↓ ↑

  Monitoring – monitoring plan

  ↓

  Reporting – inc CO_2 inj and emissions from storage site

- For appropriately selected and managed sites, supports **zero leakage** assumption unless monitoring indicates otherwise

CCS Directive and ETS Directive

Launched 23 Jan 2008

Agreed 12 Dec EU Council and 16 Dec EP !

EU CCS Directive (1)

Enabling regulatory framework to ensure environmentally sound CCS (23 Jan 2008)

- Follows IPCC GHG Guidelines and OSPAR
- Objective is permanent storage
- Ocean storage prohibited
- Permits will be required for CCS – exploration and storage
- Storage permit only if “no significant risk of leakage”
- Emphasis on site selection, characterisation, risk assessment, monitoring plan
- Corrective measures plan, and provisional post-closure plan

EU CCS Directive (2)

- Permits - EC has right to review permit decisions – non-binding opinion
- Permits – review by authority after 5 years and then every 10 years
- CO_2 stream acceptance criteria - “overwhelmingly CO_2” – may contain impurities, levels based on risk assessment of integrity – no wastes to be added
- Monitoring plans to include ETS monitoring. Update every 5yrs. Leakage triggers ETS monitoring.
- Reporting and inspections at least once a year

EU CCS Directive (3)

- After closure, liability transfer to competent authority “when evidence indicates completely and permanently contained”. >20 yrs. EC will review. Monitoring will continue but reduced to detect irregularities .

- Financial security from operator – from outset, to cover liabilities including closure, up to transfer of liability. Financial contribution to Competent Authority to cover long-term monitoring for 30 years

- Access to transport networks and storage, unless technical issue or lack capacity

- Removes barriers in other Directives – IPPC, Waste, Water, EIA, ELD, LCPD - Capture-ready

EC Draft CCS Directive - Annexes

- Annex 1 - Site characterisation
  1. Data collection
  2. Static Simulation
  3. Dynamic simulation - security characterisation (ie performance assessment)
  4. Risk assessment
     - Exposure Assessment
     - Effects Assessment
     - Risk Characterisation
- Annex 2 – Monitoring plan
  - For baseline**,** operations, post-closure
  - Criteria, coverage, updating
  - Non-prescriptive on techniques or timescales
- MS bring into force in 2yrs
- Review Directive in 2015 – include mandatory EPS?

ETS Directive

Proposed 23 Jan 2008 - to strengthen, expand and improve the ETS from 2013. Now agreed.

CCS

- CCS fully included from 2013
  - Site and operation will need to comply with CCS Directive
  - Needs **Monitoring and Reporting Guidelines** - underway
- No free allocation to CCS (same as electricity)
- Separate permitting of capture, transport and storage
- If any leakage – surrendering of allowances
- If leakage from storage suspected from monitoring under CCS Directive, then trigger ETS monitoring to quantify
- Biomass and CCS can be opted in

EC's Draft MRG

- By Ecofys with ECN, input from working groups

Leakage from storage:

- CO2 emitted [t CO2] = F_{CO2} * T

  F CO2 = average mass flow of CO2 leaked per day [t CO2/d]

  T = timespan over which leak is estimated to have occurred [d]

  T shall be estimated as the timespan since

  a) the last date when no emissions from the source under consideration were reported;

  b) the date the CO2 injection started; or.

  c) other evidence providing insight into the date the leak started.

- But: necessary level of industrial experience not available for CO_2 storage -> development of MRG approaches for leakage currently not possible

=> EU 'Scientific Body' to evaluate and issue opinion on quantification

London Convention and Protocol

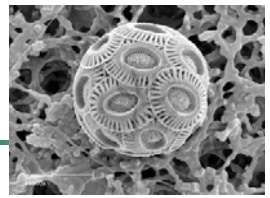
- Marine Treaty - Global agreement regulating disposal of wastes and other matter at sea
- Convention 1972 (83 countries), Protocol 1996 – ratified March 2006 (35 countries)
- Prohibited some CCS project configurations

CCS work

- Assessed by LC Scientific Group
- 2006 - Risk Assessment Framework for CO2

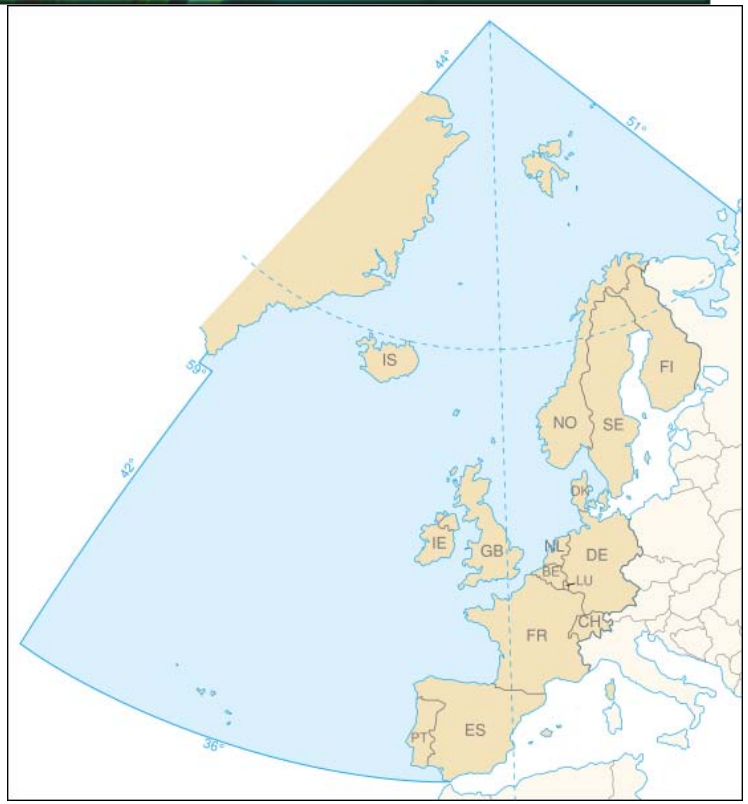
- To allow prohibited CCS Configurations - **amendment adopted** at 28th Consultative Meeting, 2 Nov 2006 - came into force 10 Feb 2007 **to allow disposal in geological formations**

- CO2 Specific Guidelines



OSPAR

- Marine Treaty for NE Atlantic
- 15 nations and EC
- Prohibited some CCS configurations
- Considered CCS and CO_2 impacts on seas



- To allow prohibited CCS configurations - **OSPAR amendments** (to Annexes II and III) for CO_2 storage **adopted June 2007** - but need ratification by 7 Parties

OSPAR Decision – requirement to use Guidelines when permitting.

OSPAR Guidelines for Risk Assessment and Management of Storage of CO_2 in Geological Formations – includes the Framework for Risk Assessment and Management (FRAM)

Storage in water column prohibited

Regulatory developments in other regions

- **USA** – Existing Underground Injection Control programme for ground water protection adapted for Pilot projects
  - US EPA have developed Federal level regulations for CO_2 storage (Jul08)
  - Interstate Oil and Gas Compact Commission has developed recommendations for regulations for CO_2 storage at a State Level
- **Australia**
  - Adapted Commonwealth Petroleum Law for offshore storage
  - State of Victoria has regulation
- **Canada**
  - Canada – acid gas injection and CO2-EOR already permitted in states like Alberta
  - Federal /AlbertaTask Force recommendations for CCS regulations (Apr08)
- **Japan**
  - Adapted marine laws

Regulatory lessons learnt

Regulatory principles for CCS to ensure environmental integrity:

- Site-by-site assessment
- Risk assessment
- Site characterisation and simulation, impacts, supported by monitoring
- Non-prescriptive on monitoring techniques
- CO2 stream impurities determined by impacts on integrity

Development of regulation:

- Use the technical and scientific evidence base
- Learn from existing regulatory developments
- Benefit of having real projects to drive and test regulations

What have we learnt from Large-scale Projects?

- Review current operational large-scale CCS projects
  - Assess learning from projects
  - Identify gaps in the global CCS project portfolio
- Focus on projects relevant to full-commercial scale operation
  - Includes:
    - Large-scale pilot, Demonstration, Commercial
  - Excludes
    - Small and medium pilot, Lab scale
- Define criteria – Identify projects – Collect information - Analyse

Criteria for large-scale operational projects

- Indicative criteria defined for ‘large-scale operational projects’
- Was, or had been, operational by the end of 2008, and either:-
  - Captures over 10,000 tCO_2 per year from a flue gas
  - Injects over 10,000 tCO_2 per year with the purpose of geological storage with monitoring
  - Captures over 100,000 tCO_2 per year from any source
  - Coal-bed storage of over 10,000 tCO_2 per year
- *Commercial CO_2 EOR is excluded unless there is a monitoring programme to provide learning.*
- *Does not need to be fully integrated*

- Added term ‘*large-scale operational*’ to IEA GHG Projects database

Projects identified

Bellingham Cogeneration Facility	IFFCO CO2 Recovery Plant – Aonla
CASTOR Project	Prosint Methanol Plant
Great Plains Synfuel Plant	Rangely CO2 Project
IMC Global Soda Plant	Schwarze Pumpe
In Salah	SECARB - Cranfield II
K12-B	Shady Point Power Plant
Ketzin Project	Sleipner
MRCSP - Michigan Basin	Snohvit LNG Project
Nagaoka	SRCSP - Aneth EOR-Paradox Basin
Otway Basin Project	SRCSP - San Juan Basin
Pembina Cardium Project	Sumitomo Chemicals Plant
Petronas Fertilizer Plant	Warrior Run Power Plant
IFFCO CO2 Recovery Plant - Phulpur	Weyburn
Chemical Co. “A” CO2 Recovery Plant	Zama EOR Project

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- Capture over 100ktCO_2
- Injection over 10ktCO_2 for storage
- Monitored EOR over 10ktCO_2
- Capture over 10ktCO_2 from flue gas
- Coal bed storage over 10ktCO_2

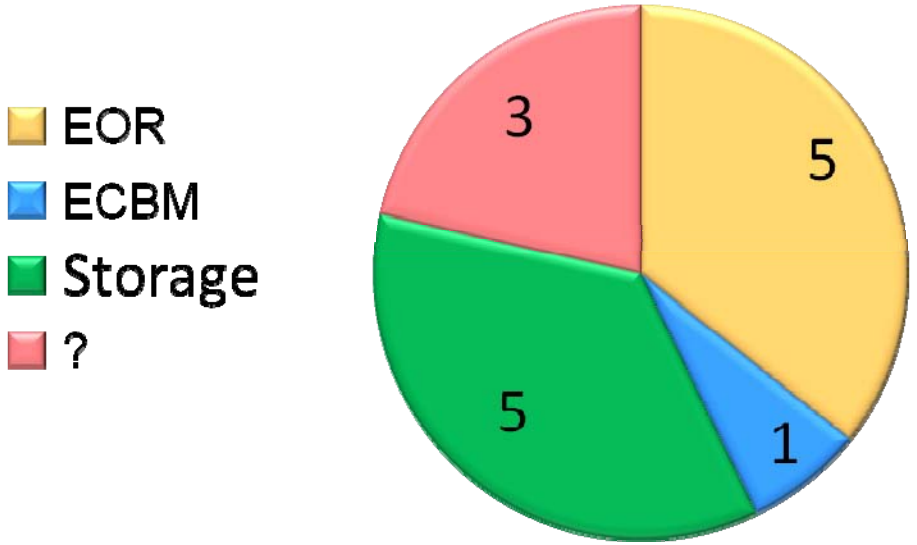
Information Gathering

- 28 large scale operational projects identified
- Each project has been asked to provide information using a questionnaire
- 18 Responses so far (6th March 2009)

- Analysis of projects in 2 parts:
  - Extent of project coverage
  - Key learning from projects

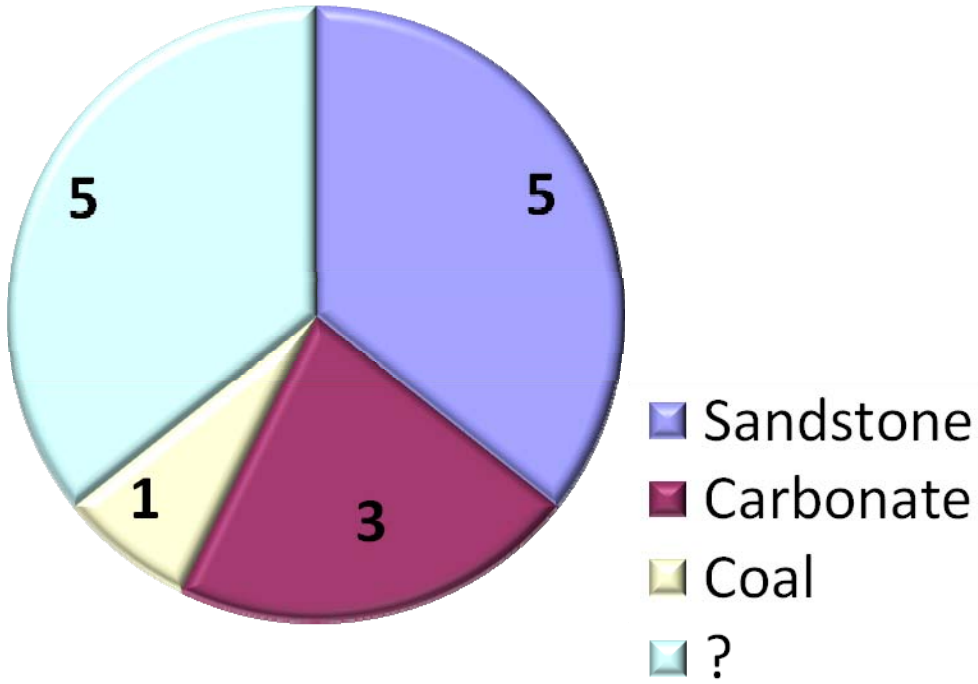
Extent of coverage – Injection

- Over 10Mt injected per year
- Multiple purposes for injection
  - Storage
  - EOR
  - ECBM

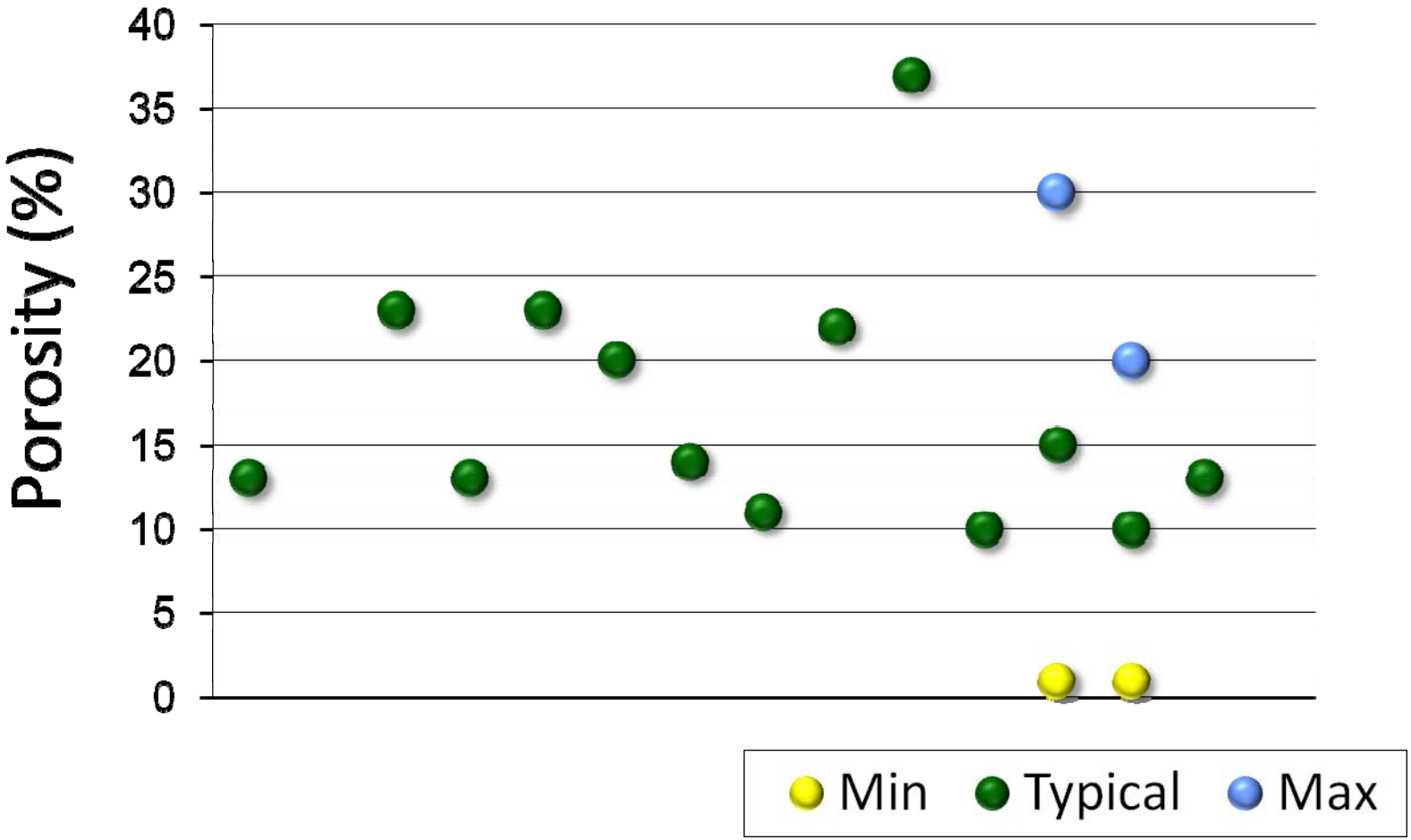


Extent of coverage – Storage Formations

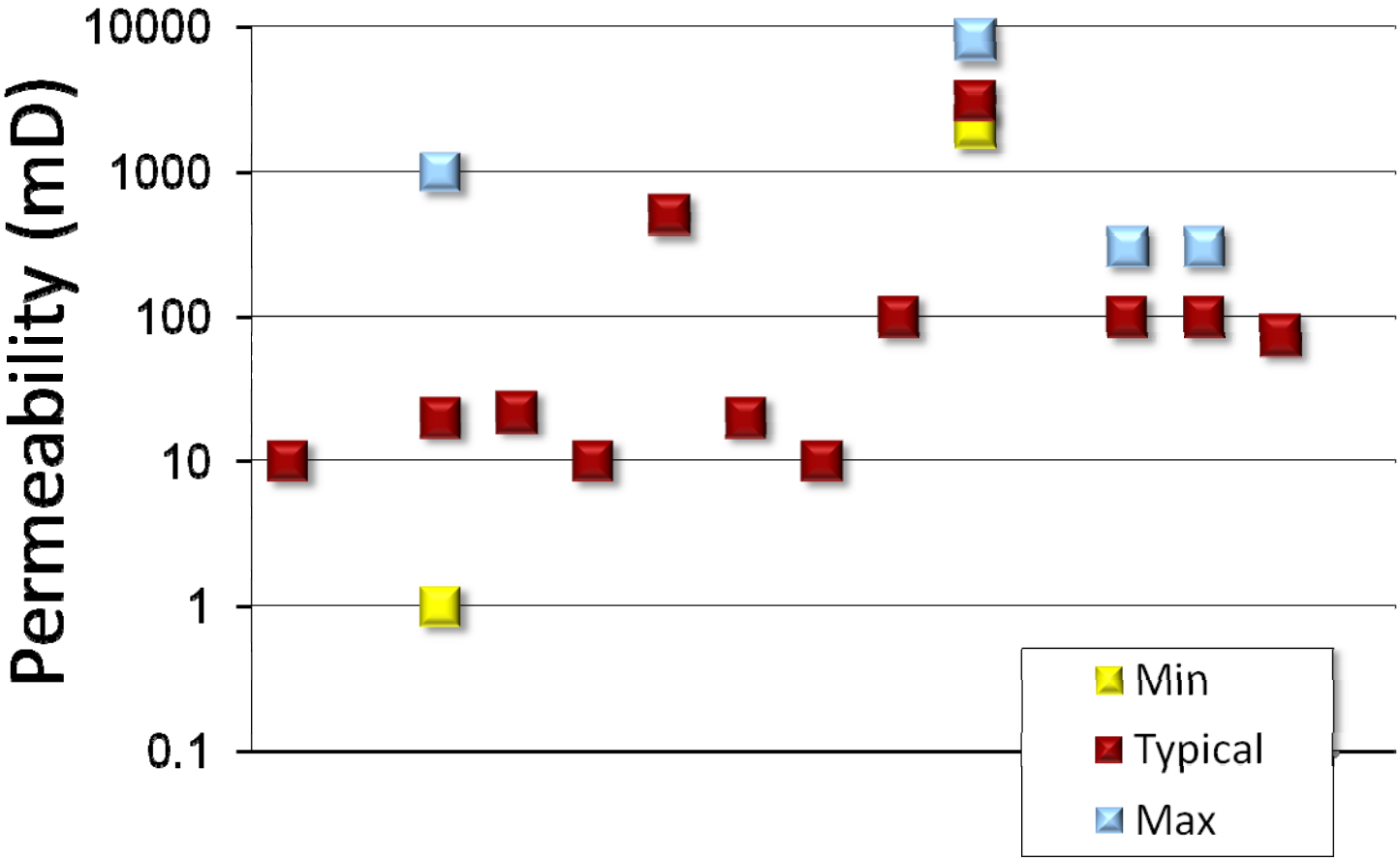
- A variety of storage formations
  - Sandstone
  - Carbonate
  - Coal



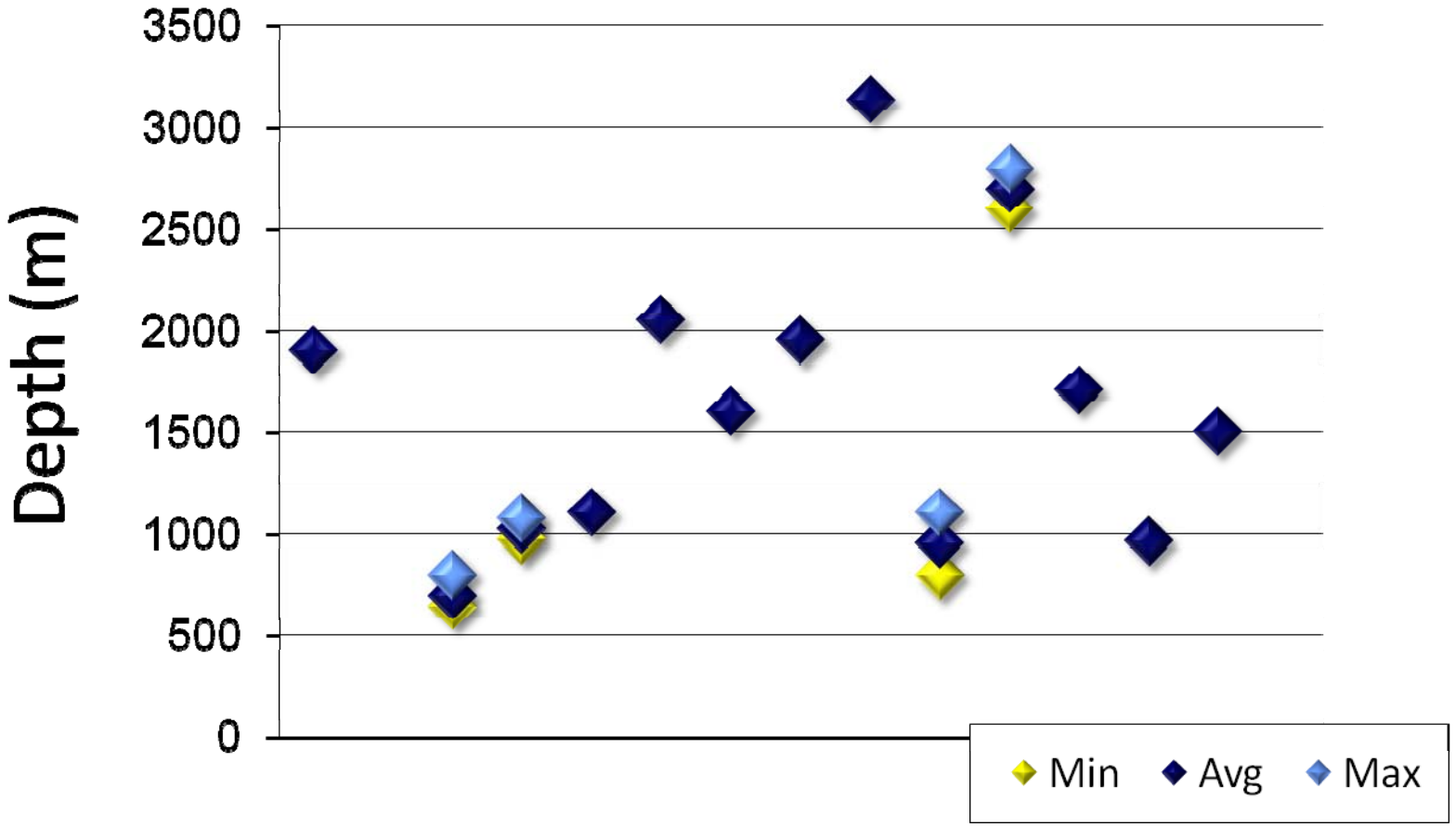
Porosity



Permeability



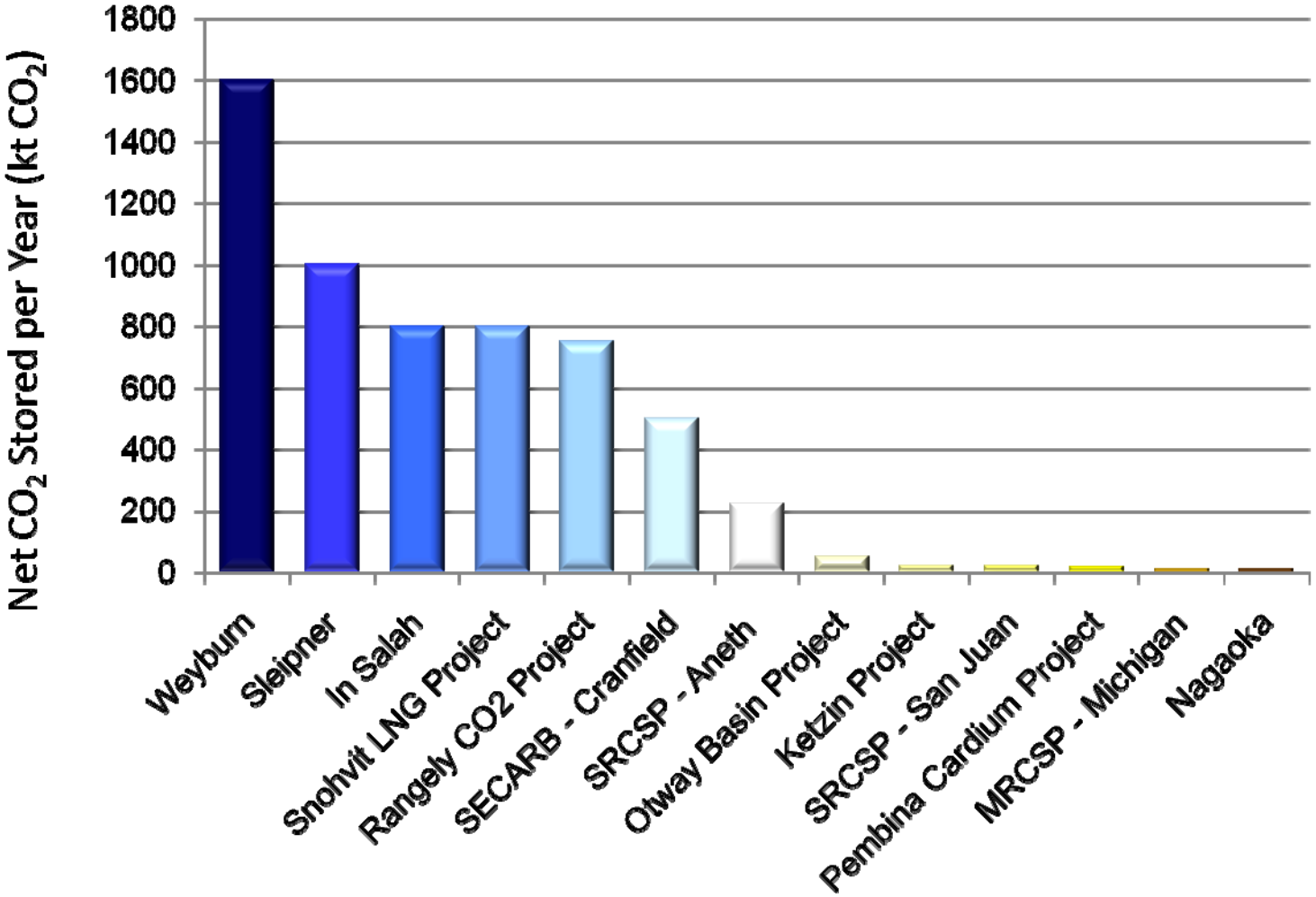
Reservoir Depth



Extent of coverage – Storage amounts

- There are six projects that store over 40,000t CO_2 per year
- All projects combine store almost 6Mt per year
- Total of 57 project years of CO_2 storage experience
- Over 40Mt of CO_2 stored

Net CO_2 Storage per Year



Extent of coverage – Monitoring

- 2D seismic
- 3D seismic
- 4D seismic
- Vertical seismic profiling
- Cross-well seismic
- Electrical conductivity
- Microseismic
- Passive seismic
- Soil gas sampling
- Detector arrays
- Eddy covariance
- Observation wells
- Time lapse microgravity
- Well temperature and pressure
- Well logs
- Tracers
- Ground water geochemistry
- Interferometry
- Satellite imaging
- Tilt meters

Extent of coverage vs ZEP project matrix

Archetype 1	• Lignite/co-firing with Biomass	• Pre-combustion, variant A	• Cross-border pipeline	• Offshore depleted oil & gas field
Archetype 2	• Gas	• Post-combustion, variant A	• Pipeline	• Onshore structural deep saline aquifer
Archetype 3	• Hard Coal	• Oxy-fuel, variant A	• Ship	• Offshore open deep saline aquifer
Archetype 4	• Hard Coal	• Post-combustion, variant A	• Pipeline	• Onshore depleted oil & gas field
Archetype 5	• Lignite	• Oxy-fuel, variant B	• Pipeline	• Onshore structural deep saline aquifer
Archetype 6	• Hard Coal	• Pre-combustion, variant B	• Pipeline	• Offshore depleted oil & gas field
Archetype 7	• Hard Coal	• Post-combustion, variant B	• Pipeline	• Onshore open deep saline aquifer

Demonstrated in operational large projects

Not demonstrated in operational large projects

Project matrix courtesy of EU Technology Platform for Zero Emission Fossil Fuel Power Plants - ZEP (2008)

Themes in Key Learning Points

- Effectiveness of monitoring techniques – what to drop and what to develop
- Injectivity – prediction, restoration and enhancement
- Dealing with hydrates
- Performance of materials in CO_2 environments
- Well designing, placing, monitoring

Preliminary Conclusions from Projects

- Elements of CCS are operating at large scale
- Integrated CCS is operating at large scale, just not from power plant
- **There is a lot that has been learnt from existing projects, but more can be done to share the learning**
- CCS industry can build on existing projects' experience
- Increasing IPR issues will affect sharing learning

IEA Greenhouse Gas R&D Programme

- General - www.ieagreen.org.uk
- CCS - www.co2captureandstorage.info