

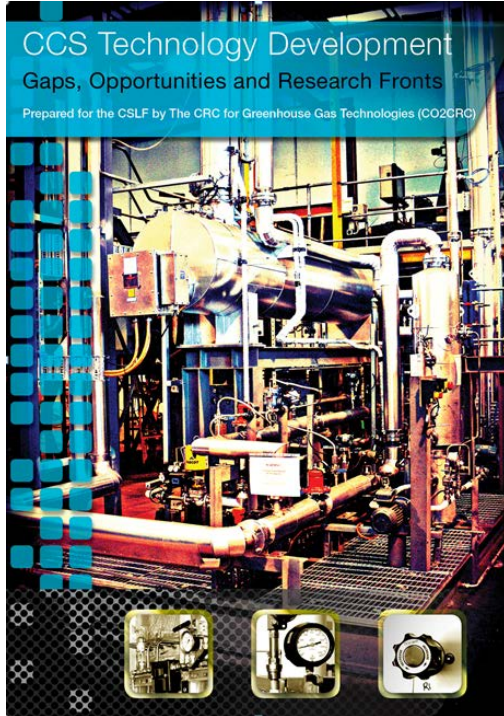


CCS Technology Developments Gaps, Opportunities and Research Fronts

Washington D.C. United States
CSLF Technical Group Meeting
November 5, 2013

Dr. Richard Aldous
CEO CO2CRC

Technology Opportunities & Gaps Task Force



– Members:

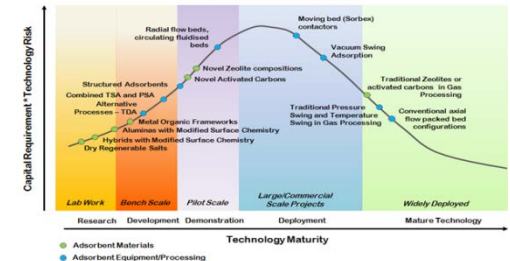
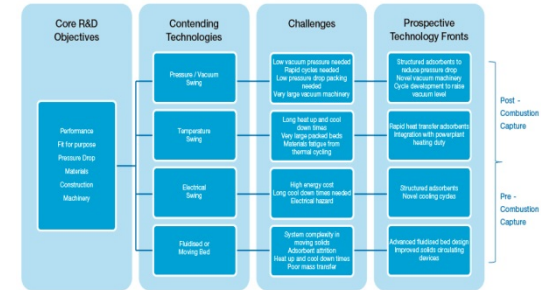
- Australia: Richard Aldous
 - Korea: Chang-Keun Yi
 - Norway: Lars Ingolf Eide
 - USA: Mark Ackiewicz
-
- Also valuable input from CO2CRC researchers and Valery Linton & Stanley Santos

Overview

- Identified key research fronts in CCS
- Opportunities, gaps & recommendations
- Considers the dynamics around CCS technology development
- Supports 2013 CSLF - TRM
- A CSLF listing of R&D pilot plants

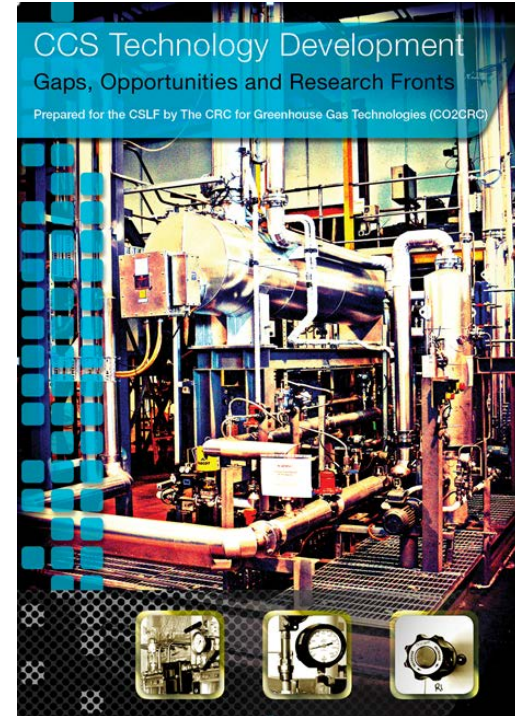


Gas Adsorption - Equipment



Sections of Report:

- **Capture and Integrated Combustion**
- **CO₂ Transport**
- **Storage**
- **MMV**
- **Knowledge & capability building**
- **Industry dynamics and technology development**
- **Listing of pilot projects**



Example

Solvent Absorption - Materials



Core R&D
Objectives

Contending
Technologies

Challenges

Prospective
Technology Fronts

Regeneration Energy

Prospective Technology Fronts : Solvents

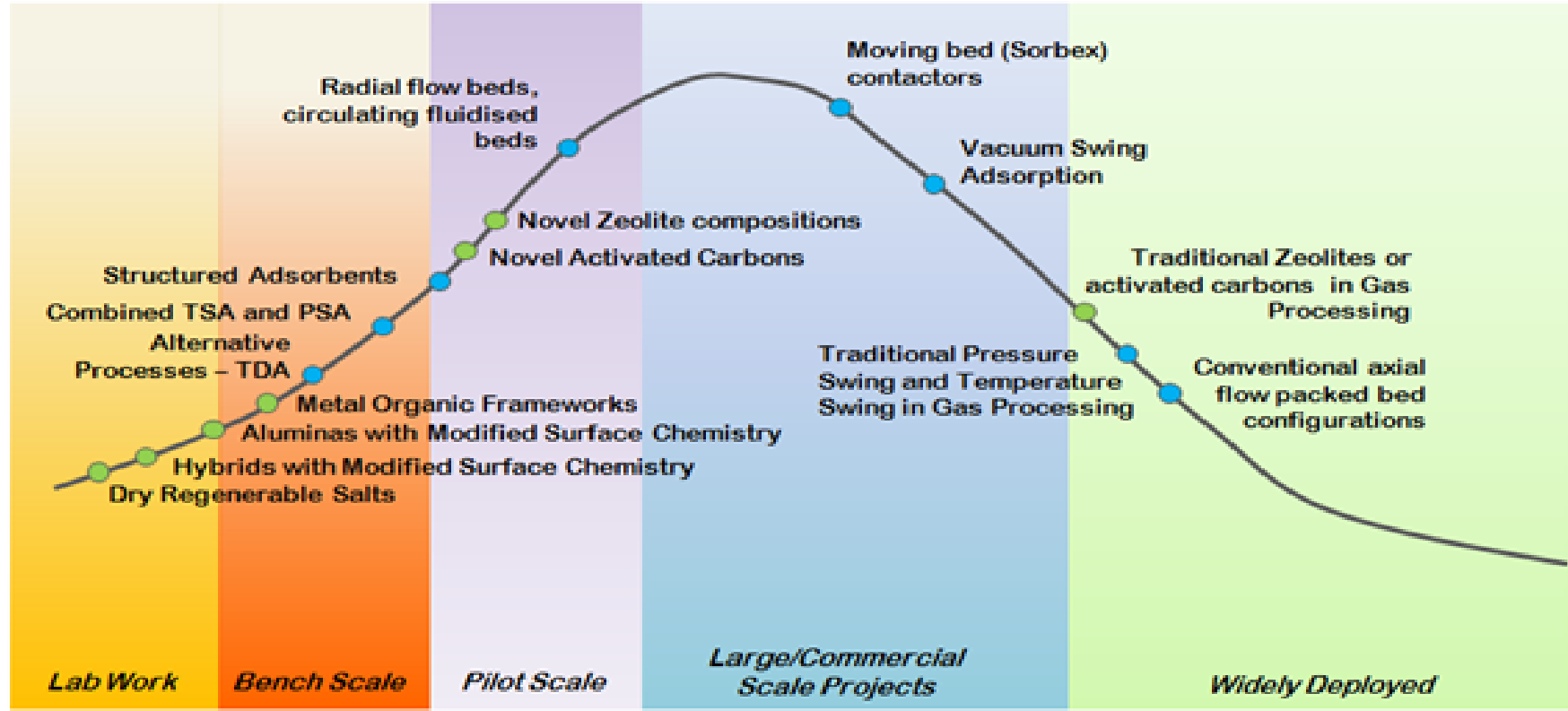
- | | |
|------------------------------------|---|
| - Amines | Precipitating amino acids
Oxidation inhibitors
Reducing vapour pressure |
| - Carbonates | Promoting reaction rates
Solids handling |
| - Blends | Combining best features of solvents |
| - Ionic liquids & Immiscible liqs. | Separation techniques
material manufacturing |
| -Physical Solvents | Blends to improve absorption rates
High temperature thermal stability |

Post -
Combustion
Capture

Pre -
Combustion
Capture

Current Status of Adsorbent Technology

Capital Requirement * Technology Risk



Research Development Demonstration Deployment Mature Technology

Technology Maturity

- Adsorbent Materials
- Adsorbent Equipment/Processing

Overall High Level Observations



- At a high level there are no major technology gaps
 - CCS technologies are ready and available and being deployed today.
- There are many contending capture technologies – in both current technologies & 2nd and 3rd generation technologies
- Next generation technologies vital for substantial cost reduction
- No strong market pull for technologies at the moment
- The lack of exploration is a significant barrier to rapid deployment and thus learning by doing

Observations on Capture & Integrated Combustion



- Capture technologies are available (mostly solvent-based) and deployed
 - cost of these technologies will continue to fall substantially by 2025-2030.
- Need to support 2nd and 3rd generation technologies,
 - Lead times can run to decades.
 - Adsorbents and membranes may well play a big role.
- Pre-combustion capture also progressing
- Chemical looping – cement industry developments
- Oxy fuel technologies progressing well – low cost ASU the key
- Capture of CO₂ from gas combustion needs to be progressed

Technology and Engineering Fronts for Oxyfuel Combustion

Core R&D Objectives

Improving the performance and efficiency of Oxyfuel combustion for Coal Based Power Plants with CO₂ Capture

Contending Technologies

Fuel Preparation

Boiler Design, materials & operation

Oxygen production

Flue gas processing and Heat integration

CO₂ Processing Unit (CPU) after oxyfuel combustion

Challenges

Optimising the specific fuel for the process

Optimising the boiler design for efficient and flexible operation, limiting corrosion and downtime and also progressively moving to Ultra Super Critical - USC (Mostly vendor specific)

Commercial demonstration of mega-scale ASU (i.e. single train oxygen production > 5000 tpd)
Develop novel oxygen production

Develop technologies for multi-pollutants removal
Improve technologies for low grade heat recovery
Optimise waste water management

Improving CO₂ separation process from flue gas and removal of specific impurities (noting the link to transport and storage specs)

Prospective Technology Fronts

Demonstrating lignite drying technologies in large scale

Control and location of the flue gas and oxygen injection
Warm flue gas injection
Test materials for advance USC application suitable for high concentration of acidic gas and water

Reliability of large scale units with greater turn down range
Membranes and ceramics for high temp oxygen production

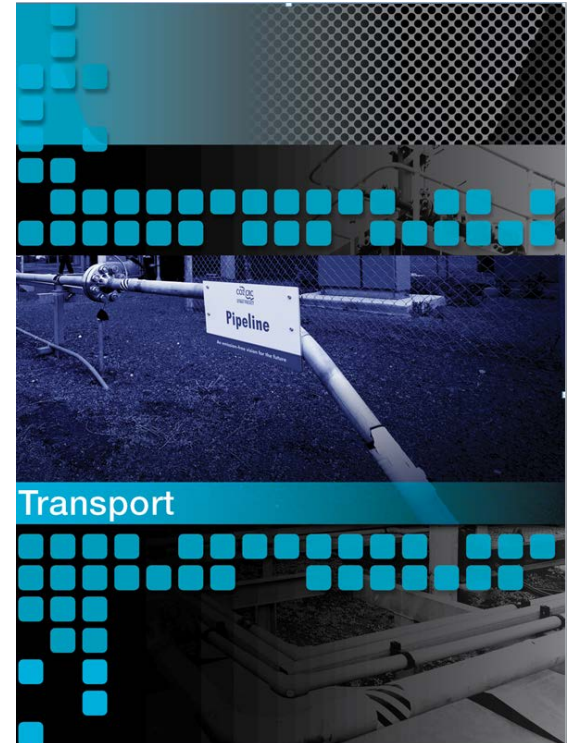
Improve flue gas processing equipment to address high temperature corrosion issues in the recycle path and boilers
A variety of removal technologies being developed and improved by different vendors

Auto refrigeration using impure CO₂ as refrigerant
Pre-treatment of CO₂ ex boiler
Variety of vendor specific technologies

Transport



- Transport pipeline technology is mature and available; however, some technology improvements are needed to get costs down and further increase safety.
- Large scale transport of CO₂ by ship offers promise and needs to be demonstrated at scale.
- Experience is needed in planning, designing and implementation of large-scale CO₂ transport networks.



Fundamental Storage R&D

Storage Geology

Eg Seals, faults saline aquifers

Sub surface CO2 behaviour

Eg fluid flow, trapping
mechanisms.

MMV technologies

Eg seismic EM etc

Storage

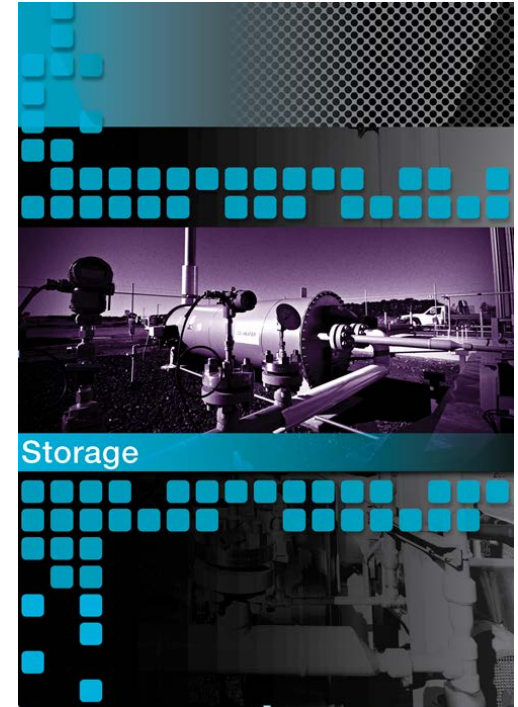
- CO₂ storage technology builds on years of research & experience in oil & gas
- There are fundamental and applied aspects of CCS that are unique



Recommendations on Storage



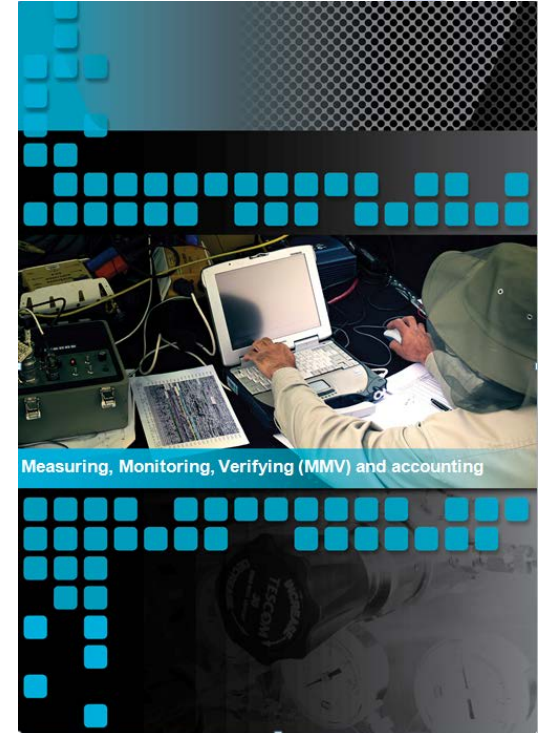
- Need to continue both fundamental and applied R&D
 - Modelling and understanding CO₂ behavior in the subsurface must be continued to improve operational efficiency and effectiveness of storage
- Internationally consistent standards required (based on oil and gas industry practice) for:
 - Storage site characterisation methodologies;
 - Storage efficiency factors; and
 - Capacity estimation and reporting standards.
- Technology and risk management strategies to mitigate or manage unintended CO₂ migration.



Recommendations on MMV



- Continue towards continuous, high resolution, low cost, low impact subsurface monitoring;
- Develop new seismic interpretation and inversion techniques for enhanced CO₂ detection.
- Establish technologies and methodologies for offshore (sub marine) MMV
- Continue work on controlled release calibration and natural analogues; important for CO₂ detection and accounting;
- Develop an agreed methodology and language for dealing with most monitoring – a null result;



Recommendations on other aspects



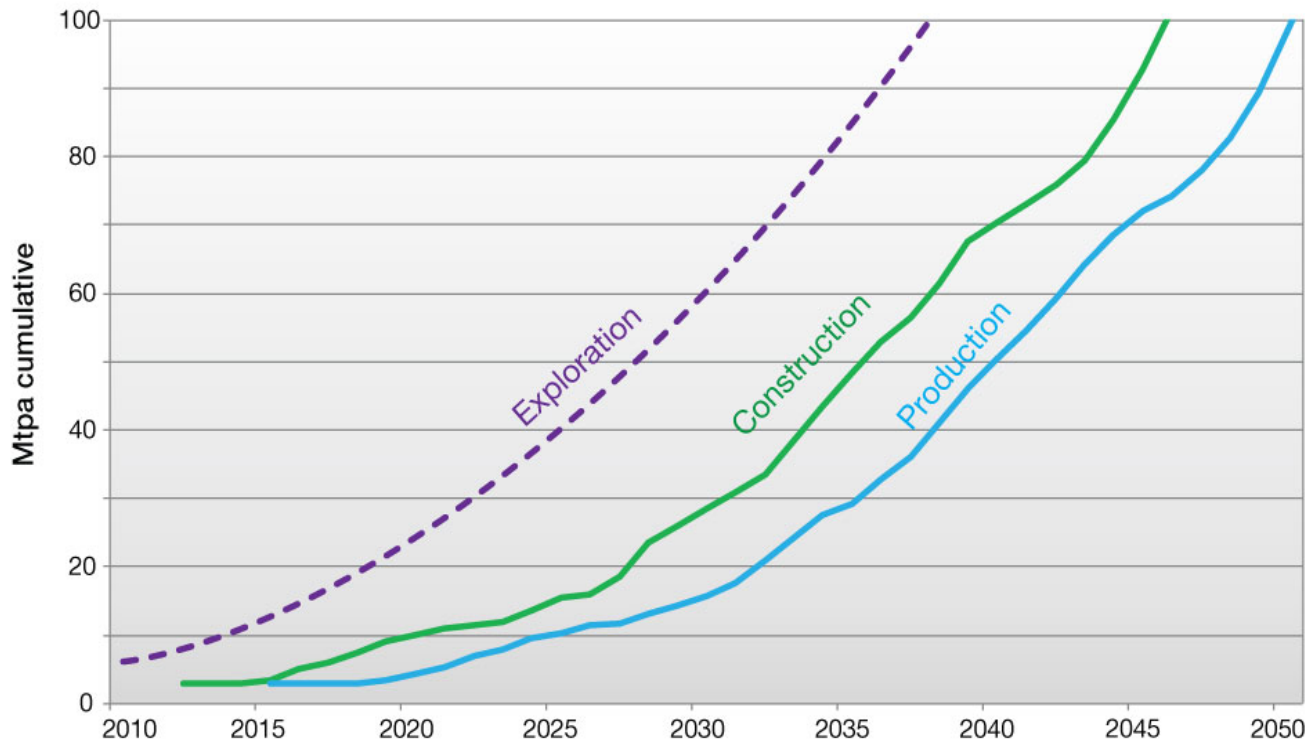
Building technical knowledge capability and people

- Continue R&D and technology development to both develop the knowledge base and to train engineers and scientists in CCS technologies.
- Stimulate international collaboration.

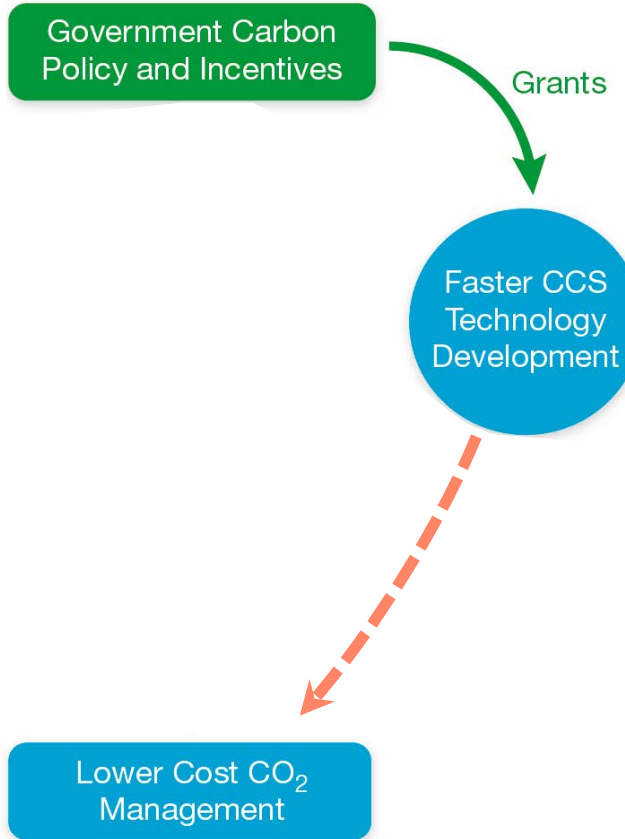
Industry dynamics associated with exploration and technology development

- Start the identification and pre-competitive data generation of prospective storage basins, making assessments of the likely realistic storage capacity.
- Either start exploration or incentivise the private sector to start exploration.

Exploration Lead Times



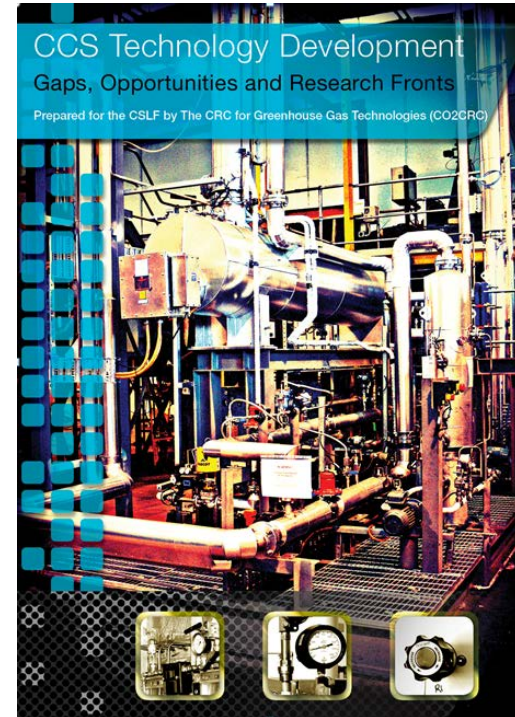
Incentives Dynamics Exploration & Technology



- Governments provide grants or incentives
- Market dynamics will drive exploration and technology progress

Concluding Thoughts

- Governments now have a technology that can be deployed to manage carbon emissions.
- Consider the role of government in USA SO_2 scrubbing and the nuclear industry , and gas pipelines in many countries
- The rate of take-up and associated improvements in technology needs to be incentivized.
 - important for getting new projects up
 - vital to pull next generation technologies through development



Carbon Sequestration leadership forum

www.cslforum.org



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