Learning from Doing: CCUS Reference Cases

John Gale

Programme Director

IEA Greenhouse Gas R&D Programme

Resources for the Future Seminar

Carbon Capture, Utilization, and Storage (CCUS): Status, Issues, Needs

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Current status of CCUS

- CCS technology is proven and in use around the world.
- 22 large-scale CCS projects in operation or under construction globally - CO_2 capture capacity of 40 Mtpa.
- 6 projects in construction as of March 2017
  - 3 projects to be operational in 2017 & 3 in 2018
- 5 more large-scale CCS projects at an advanced stage of development planning,
  - CO_2 capture capacity of ~ 8 Mtpa.
- 11 more large-scale CCS projects are in earlier stages of planning
  - CO_2 capture capacity of ~21 Mtpa.

Source: Global CCS institute

Worldwide distribution

Source: Global CCS Institute, 2016, "The Global Status of CCS 2016 – Summary Report"

Power Sector CCS

- Boundary Dam 3, Canada
  - o 110MWe, coal fired
    - » Solvent based technology
    - » >1.3Mt CO_2 captured
    - » CO2 used for CO2-EOR
- NRG Parish
  - o 250 MW slip stream
    - » amine based PCC technology
    - » 90% capture
    - » CO2 sold for EOR
- Kemper County
  - o IGCC technology/Lignite
  - o Start up awaited
- Osaki CoolGen
  - o IGCC Technology/Lignite
    - » Co2 capture slip stream 2018/19

What have we learnt?

Power sector

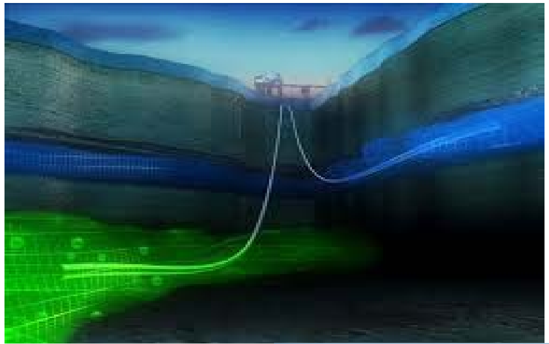
- BD3 and NRG are PC boiler retrofits with Amine Scrubbing technology
  - Both capture units built on schedule and to cost
    - Cost over runs at BD3 due to existing boiler retrofit
- Both had existing electricity supply contracts
  - BD3 more efficient turbine offset parasitic load
  - NRG added a new steam boiler for capture unit
- BD3 could be built again at lower cost
  - 30%CAPEX, 20% OPEX

Business Models

- **BD3, NRG & Kemper**
  - Long term stable fuel price for coal
  - Government subsidy for CAPEX
  - OPEX offset by sale of products
    - CO_2, Sulphur and ash
    - Plus electricity – long term supply contracts
- **Osaki CoolGen**
  - Government subsidy for CAPEX
  - Electricity sales offset OPEX

Industry CCS

- **Natural Gas Processing**
  - Sleipner, North Sea
    - 20 years operation
    - 16Mt CO_2 stored
  - Snohvit, Barents Sea
    - Operating since April 2008
    - 0.7Mt/y CO2
  - Lula, Brazil
    - Floating Platform offshore
  - Gorgon, Australia
    - 3.5Mt/y CO2
    - Starts operation late 2017



Business Models

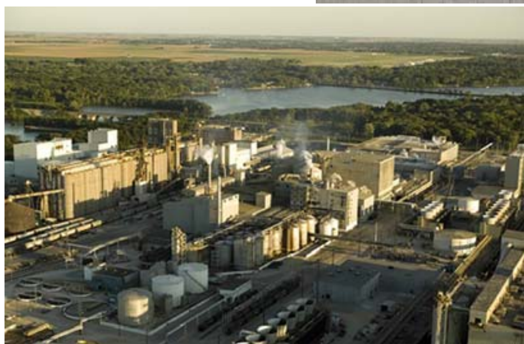
- **Sleipner/Snohvit**
  - Capture plant cost included
    - Needed to meet pipeline standards for NG
  - Compression and pipeline capital costs
  - Offshore emissions tax of €35/T
    - Pays for OPEX and capital investment
- **Lula**
  - Cost recovery through increased oil production
- **Gorgon**
  - Cost recovery through LNG sales

Industry CCS (2)

- CCS now deployed in:
  - Hydrogen refining/upgrading
    - o Quest – solvent based technology
      - » 1Mt injected into deep saline aquifer
    - o Air Products, PSA technology
      - » Over 3 Mt – used for CO2-EOR

  - Steel sector
    - o Emirates Steel – Amine based capture
      - » Now operational
      - » 800,000 tonnes CO_2 for CO2-EOR

  - Bioethanol production
    - o ICCS Project, Illinois USA
    - o Start up Q2 2017
    - o 1Mt/y - deep saline aquifer



Business Models?

- **IISD**
  - Government loans for 1st phase project development – Decatur (300,000t/yr CO_2)
    - Compression, dehydration and storage components
  - Capital investment for phase 2 components
    - Up to 1Mt/y CO_2
  - $20/t credits (Q45) for storage in deep saline aquifer
    - Offsets operating costs.

Business Models?

- **Quest and AirProducts**
  - Government support for CAPEX
  - AirProducts – OPEX offset by CO_2 sales
  - Quest – OPEX offset by CO_2 storage credits
- **Emirates Steel**
  - Pre-existing capture facility on DRI plant
  - Capital investment only for compression and pipeline
  - OPEX covered by additional oil and natural gas revenues

Jubial City CCU Project

- SABIC CCUS project uses the captured CO_2 to produce methanol and urea.
  - First commercial application of Linde post combustion capture technology
  - First capture unit on an ethylene glycol plant.
  - At 500, 000Mt CO_2 pa it was the biggest commercial capture unit.
  - Business model CAPEX/OPEX recovered through sale of Products

Learnings from UK CCS Competition

- Key messages
  - No technical barriers
  - Barriers were; financial, commercial and policy related
  - Peterhead could have been delivered
  - With White Rose issues included:
    - Risks re pipeline leakage
    - Financing of storage component

file://fscluster2/data/IEAGHG/Homes/John.Gale/Documents/CCSA_Lessons_Learned_report_digital_FINAL_June_2016.pdf

UK Competition Conclusions

- The full chain business model does not work
  - UK Government should fund the pipeline and storage component – new national storage company formed
- Building in larger pipeline networks increased the costs for first mover projects
- Depleted gas fields are a good starting point
- Rules on financing in the EU CCS Directive may be too onerous
- EU state Aid rules may prevent UK investment in such projects

Norwegian Model

- Industrial CCS Programme under development
  - 3 industry FEED studies underway
  - Decision by Spring 2018 to proceed with one (or more projects)
  - Commercial operation by 2021
- Capture facility separated from storage component
  - New storage and transport company to be set up
    - Ship transport and offshore storage
    - Funded by storage credits

Transport infrastructure

- EU example
  - Funded by EU infrastructure fund with multi party access rights
- UK example
  - Industrial hubs under development funded by CO_2 storage credits?
- USA example
  - Finance increase of existing CO_2 pipeline network
    - Section 45Q Tax Credit for Carbon Dioxide Sequestration
    - U.S. Department of Energy's (DOE) Loan Programs Office

Summary

- Significant progress has been made on CCUS demonstration project deployment
- 22 CCUS projects now operating worldwide storing 40MtCO_2/yr
  - Most required Government support
  - Some industry projects are commercial without
- Early projects have identified cost reductions for next build plants
  - Learning by doing helps drive down costs
- Government support will be still needed to help drive down costs and/or make business model attractive to industry
- Ultimately we need to create business models that allow projects to be self financing
  - No "one fits all solution"
- Need to build out from existing transport and storage infrastructure
  - Options to finance additional infrastructure through government loans, taxes or storage credits are being considered.
  - Government investment needed to prove storage resource globally

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