



ARB CCS QUANTIFICATION WORKSHOP

Shell presentation



Dr. Owain Tucker
Global Deployment Lead CCS

DEFINITIONS & CAUTIONARY NOTE

Reserves: Our use of the term “reserves” in this presentation means SEC proved oil and gas reserves.

Resources: Our use of the term “resources” in this presentation includes quantities of oil and gas not yet classified as SEC proved oil and gas reserves. Resources are consistent with the Society of Petroleum Engineers 2P and 2C definitions.

Organic: Our use of the term Organic includes SEC proved oil and gas reserves excluding changes resulting from acquisitions, divestments and year-average pricing impact.

Shales: Our use of the term ‘shales’ refers to tight, shale and coal bed methane oil and gas acreage.

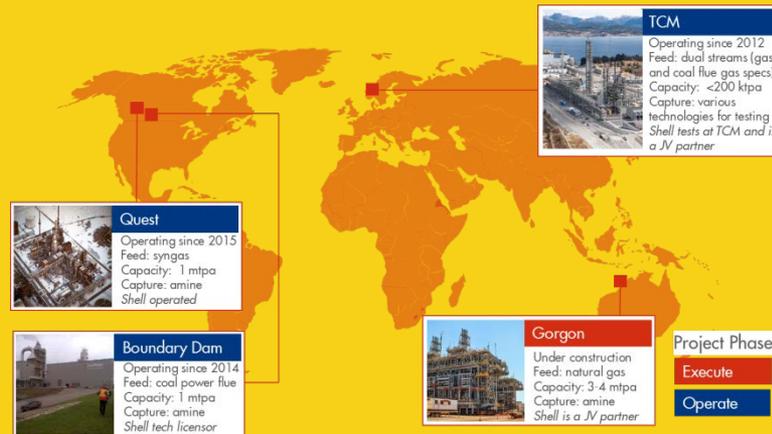
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1.0

SHELL'S GLOBAL EXPERIENCE IN CCS



WORKING ON CCS IN MULTIPLE COUNTRIES

OCAP



- Netherlands, CO₂ from refinery to greenhouses
- Operating since Summer 2005

Quest



- Alberta, Canada, Onshore saline
- CO₂ from hydrogen manufacturing unit
- Injecting since August 2015

Peterhead



- Scotland, UK, Offshore depleted field
- CO₂ from gas turbines
- Permits about to be finalized when support withdrawn

Barendrecht



ZeroGen



TCM



Longannet



Draugen



Gorgon



Observation: in all countries with mature regulation, the regulations have the same key components around characterization, MMV and closure

- Significant global experience
 - Europe, Australasia, North America

CCS ELEMENTS ARE MATURE AND PROVEN

CAPTURE

- Capture-related technology has been utilised in industry for decades for product decontamination.
- Most mature technology uses amine solvents.
- Emerging capture technologies build on industrial processes e.g. gas/ solid fluidised beds & membranes.

TRANSPORT

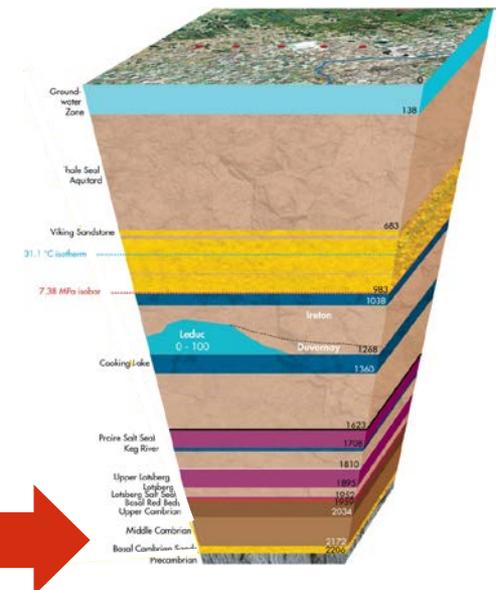
- Decades of CO₂- enhanced oil recovery (EOR) experience in the US.
- Established pipelines across the US and Europe

STORAGE

- Dedicated CO₂ storage has been in operation in Norway for nearly 20 years.
- CO₂ EOR with incidental storage started in the 1980s.
- Many accumulations of natural CO₂

SPOTLIGHT ON QUEST

- Delivering large scale emissions reductions, from upgrading at Scotford
- 1 million tonnes of CO₂/ year – already stored over 0.5 million tonnes since startup
- Equivalent to removing 250,000 cars (EU) from the road every year
- Deep secure saline storage
- Site specific risk assessment, monitoring plan and response plan
- DNV – Storage & monitoring plans certified
- Licensed by Albertan regulators



2.0

ACCOUNTING AND MONITORING

PRINCIPLES FOR CONSIDERATION

- 1) Simple, stimulate CCS deployment
- 2) Reasonable Equivalence for CCS in out-of-state jurisdictions (LCFS)
- 3) Difference between CO₂ avoided and CO₂ stored;
Avoid double counting in jurisdictions with comprehensive GHG regulation
 - Options: (a) Credit for double counted CO₂, (b) Credit for gross storage for first **X** years, then shift to CO₂ avoided
- 4) CO₂ avoided should include indirect emissions factor for absorbants
- 5) CO₂ avoided should not include system construction or materials used
- 6) Leakage defined as release to atmosphere
- 7) Start date = first injection; End date = 2-5 years after last injection (or date of liability transfer to state).
- 8) Review quantification protocol performance after **X** years

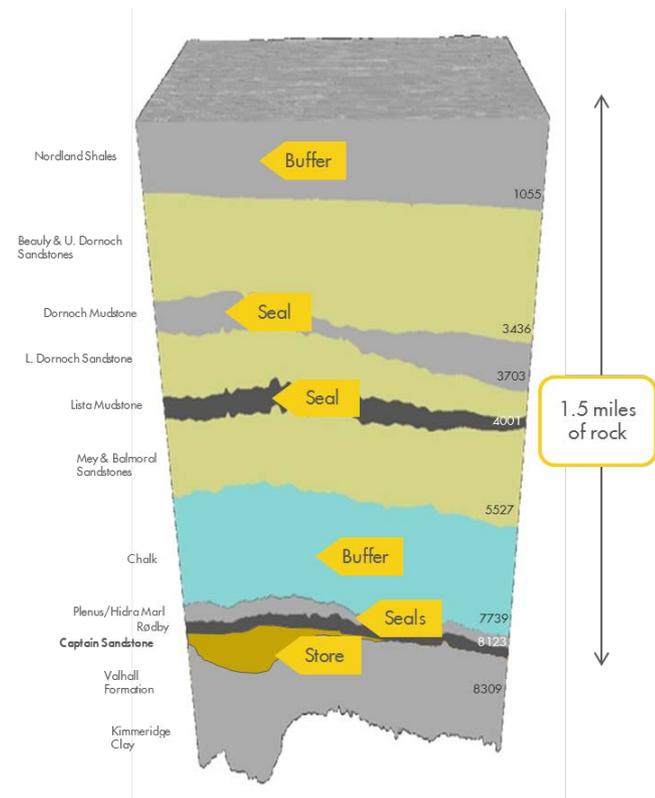
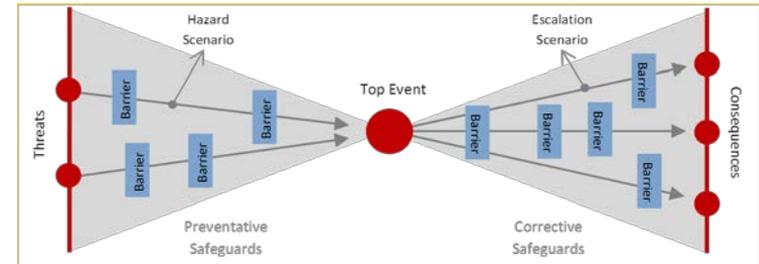


PRINCIPLES FOR CONSIDERATION

- 1) Presumption is zero leakage to atmosphere post-injection
 - Good site selection is key
 - Risk-based MRV (third party review for early projects?)
 - Revisit operational plans if migration is detected outside of primary store
 - Best engineering estimate to quantify leakage to atmosphere
 - Surface CO₂ flux can be highly variable (many factors influence) – assurance monitoring
- 2) Fugitives in dense phase system would be readily visible. Dense phase systems do not suffer from persistent undetected fugitives.



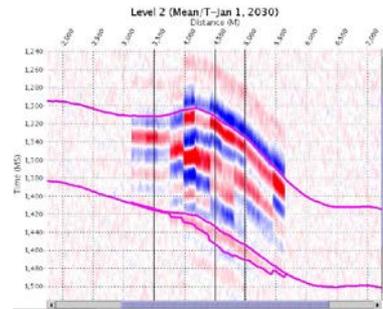
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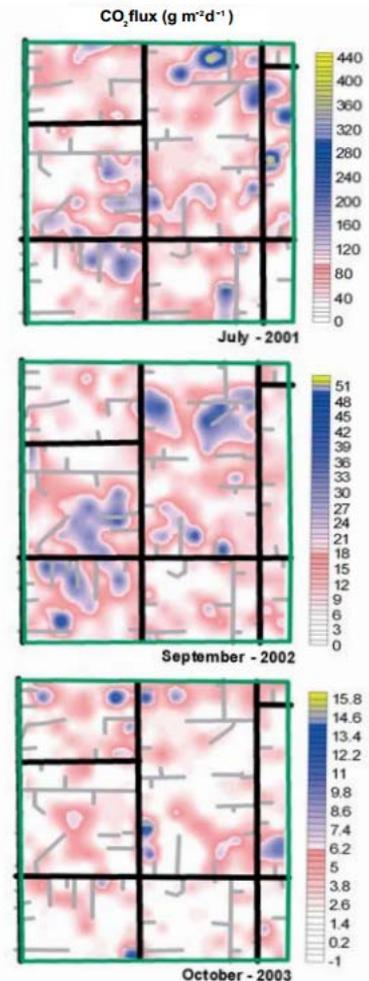
MONITORING: SURFACE VS. DEEP, NOISE VS. SIGNAL

- Above ground and soil monitoring is best suited to assurance
 - Natural variability in CO₂ flux measurements means that surface measurements are not diagnostic of subsurface migration.
- Deep geophysical monitoring is best suited for detection of migration
 - Conformance
 - Containment

Simulated seismic signal from CO₂ migration above the store (Peterhead, UK)



Measurements of Natural CO₂ flux at Weyburn showing seasonal variations.



METERING COMMENTS

Treat in a similar manner to natural gas metering

- 1) Meter CO₂ post compression (quality)
- 2) Meter CO₂ at distribution manifold in field (fiscal quality)
- 3) Meter CO₂ at individual injection wellheads
- 4) Calibrate meters to manufacturer specifications on frequency defined by common standards body
- 5) Expect meters for purchased energy inputs (electricity, natural gas)

