CCS and Hydrocarbon E&P – An Upstream Perspective

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Content

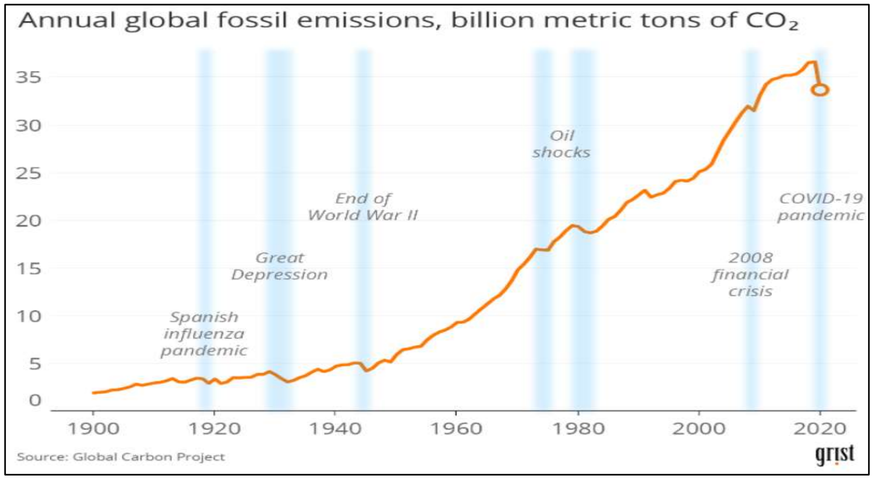
- CCS and why is it important
- Value chain: CCS vs HC
- Enablers for CCS
- Differences between CCS and Hydrocarbons E&P
- Performance requirements for geological storage
- Risk Management

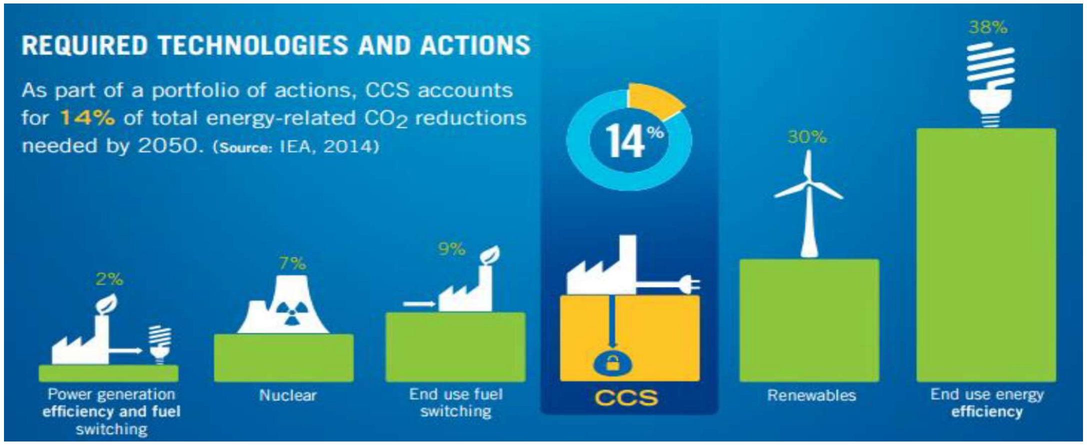
Key Drivers for CCS

- Global CO2 emission in 2019 ~37 Bt, projected to reach > 60 Bt by 2050 on current trend

- CCS is a part of the solutions for CO_2 emission reduction; CCS is estimated to contribute to 6-20% CO_2 reduction needed by 2050

Annual global fossil fuel CO2 emission (Bt)

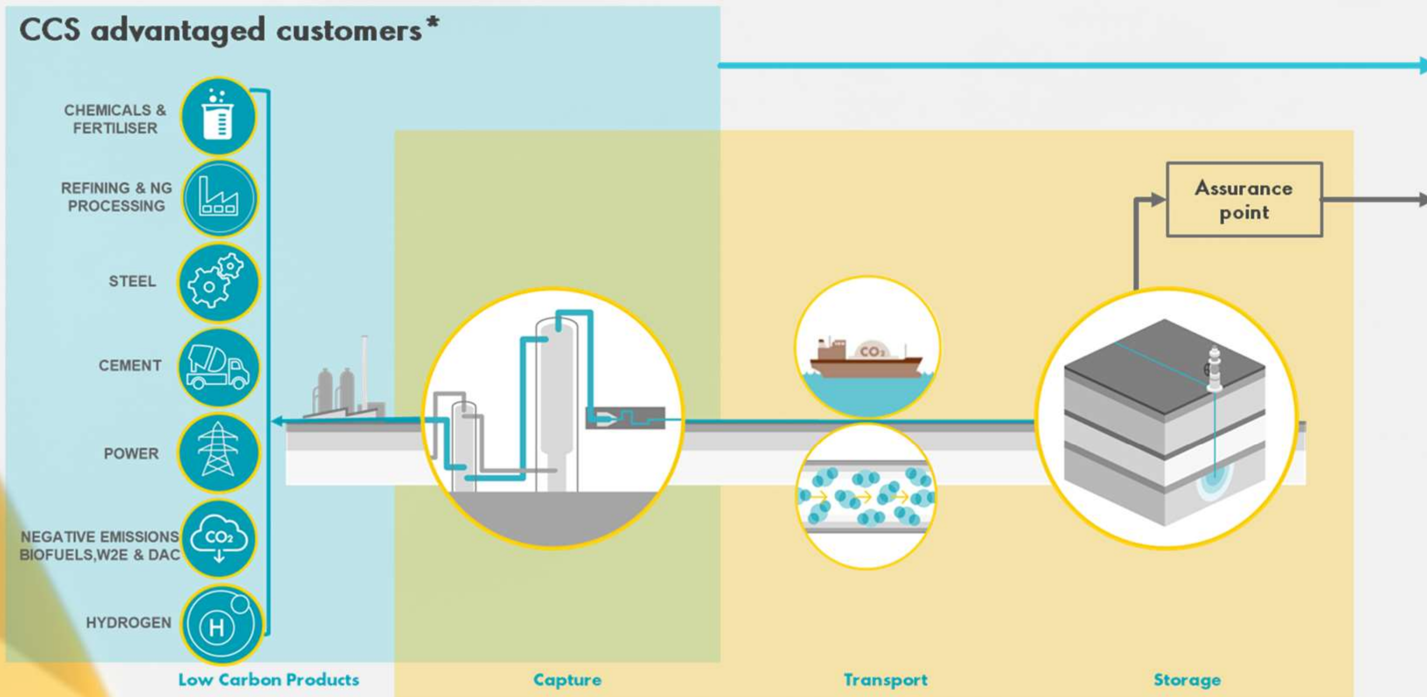


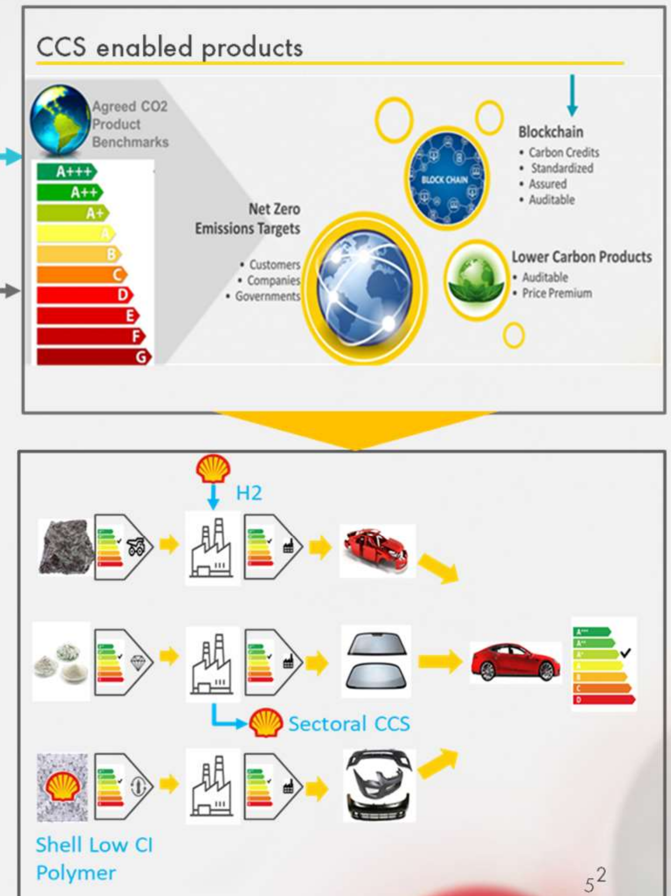


- CCS is a key technology for decarbonisation of:
  - Industrial CO_2 sources (e.g. "Quest" in Canada, CO_2 from Shell Scotford Complex, 6.5 Mt stored since 2015)
  - HC Production, either of contaminated fields (e.g. Gorgon LNG in Australia (14% CO_2), 5 Mt stored since 2019) or EOR (e.g. Synfuels-Weyburn in USA-Canada, > 30 Mt stored since 1984)

CCS VALUE CHAIN AND OFFERING

LIMITING WARMING TO 1.5 REQUIRES 3 – 11 GT/A OF CCS (IPCC, 2018)





Customers access value from CO2- and CCS enabled products pricing

Global CCUS Projects

Facility Category ● Commercial CCS ● Pilot/Demonstration

- A total of 237 facilities listed in the database
- 55 currently operational
- Many pilot and demonstration projects
- Economics driven by EOR, regulatory requirements and government incentives

Source: GCCSI CO2RE database - https://co2re.co/FacilityData OCT, 2021

Emission scope definition:
1: direct emission from own operations
2: indirect emission from use of company's products
3: all other indirect emission from company's value chain

OUR CLIMATE TARGET | **NET ZERO BY 2050** Net-zero emissions energy business by 2050 including all emissions (Scopes 1, 2 and 3) in step with society | **FROM 1.7 GTPA TO ZERO** We believe total carbon emissions from energy sold peaked in 2018 at around 1.7 Gtpa and will be brought down to 0 by 2050

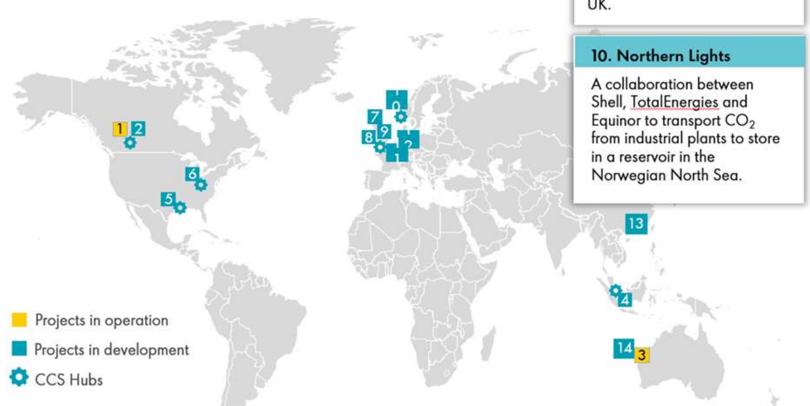
- Significant ramp up in CCUS project globally in 2021, especially in USA (45Q tax credit*) and Europe

*45Q offers a tax credit ($12-$50) per metric ton of carbon captured and stored, depending on project type (eg CCS vs EOR)

- Current and under development CO2 storage capacity at >100 Mtpa worldwide (by 2030 (Ringrose, 2020))

Compiled & summarized by C Lee, Dec-2021

Shell's CCS project portfolio



7. Acorn *
In Scotland, Shell UK, Storega and Harbour Energy are equal partners in the Acorn project, to provide critical CCS and hydrogen infrastructure for the UK.

8. South Wales Industrial Cluster *
Shell UK is part of the South Wales Industrial Cluster (SWIC), a group looking to decarbonise the region using, amongst other technologies, CCS.

9. Northern Endurance Partnership *
Shell UK is part of the Northern Endurance Partnership, working to develop the offshore CCS infrastructure to decarbonise two major UK industrial clusters.

10. Northern Lights
A collaboration between Shell, TotalEnergies and Equinor to transport CO_2 from industrial plants to store in a reservoir in the Norwegian North Sea.

11. Aramis *
Shell Netherlands, TotalEnergie, Energie Beheer Nederland and Gasunie formed a partnership to enable large-scale CO_2-reduction for industry in the Netherlands.

12. Porthos *
A JV between EBN, Gasunie and the Port of Rotterdam to transport CO_2 from industrial plants in the Port of Rotterdam, including Shell's Pernis refinery, to store in empty gas fields beneath the North Sea.

13. Daya Bay *
A joint venture with CNOOC and ExxonMobil to explore offshore storage of CO2 to be captured from petrochemical plants and others in the Guangdong region.

14. Angel *
A joint venture with Woodside, Shell, BP, Chevron, Mitsui and Mitsubishi to develop a CCS hub offshore North-West Australia

1. Quest
In Alberta, Shell Canada operates Quest, a CCS facility that captures, transports and stores more than a million tonnes of CO_2 every year from the Scotford Upgrader.

2. Polaris/Atlas *
A CCS project planned for Scotford in Canada to capture CO_2 from Shell's Scotford refinery and chemicals plant and storage from other emitters.

3. Gorgon
Shell Australia holds a 25% stake in the Gorgon liquified natural gas project that uses CCS to capture CO_2 produced.

4. Southeast Asia Hub *
Shell is exploring the creation of a CCS hub in Singapore to help customers reduce CO_2 emissions, including emissions from the Shell Energy and Chemicals Park Singapore.

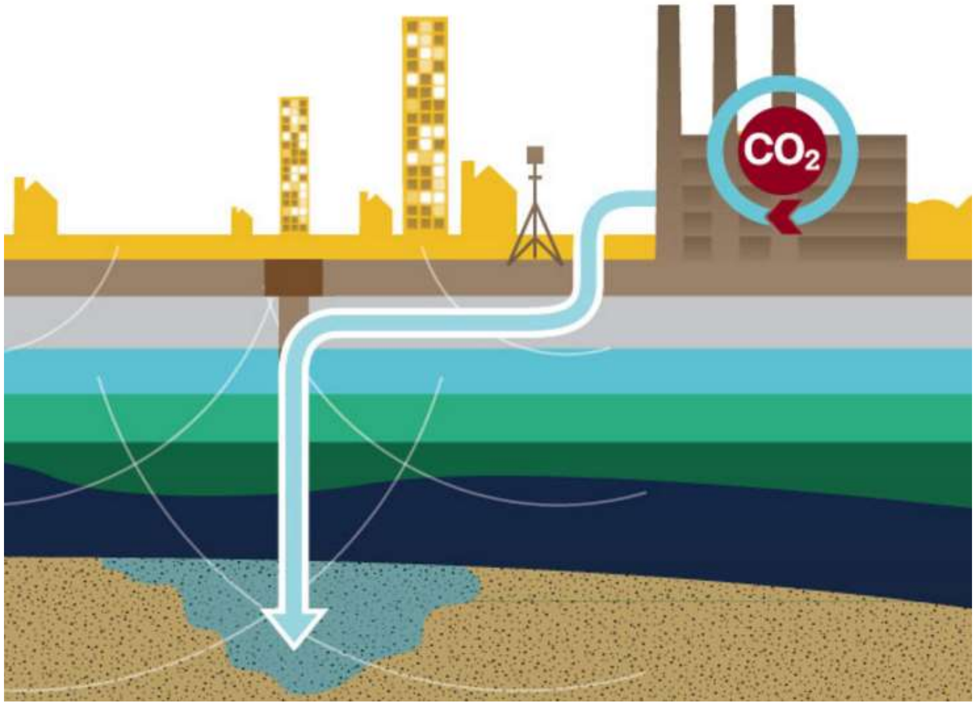
5. Louisiana Hub *
Development of a CCS project in Louisiana focused on Shell's CO_2 footprint at the Norco, Convent, and Geismar facilities. It will also act as a CCS hub for other emitters in the region.

6. Ohio River Valley *
In the tri-state area of Pennsylvania, Ohio and West Virginia, Shell is developing a hub linked to our CCS project at the Shell Polymers plant in Monaca, Pennsylvania.

CCS IS "PUTTING FOSSIL CARBON BACK INTO THE FOSSIL RECORD"

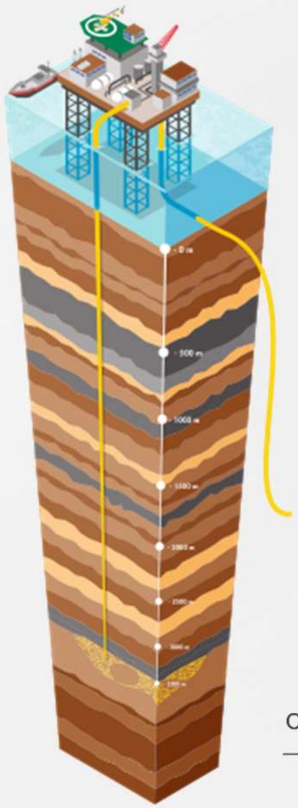
- Geological storage, sometimes termed Sequestration, is the injection of CO_2 into geological strata with the aim of permanently isolating the CO_2 from the atmosphere
- Climate mechanisms pay – and that means governments or government backed instruments
- Income is normally derived from the sale of clean products or the absence of emissions

- Very high level of scrutiny on storage security
- Significant characterisation providing evidence that the store is not expected to leak
- High level of monitoring and assurance during and after injection



Source: ZEP

SKILLS ARE THE SAME, BUT THE FOCUS IS SUBTLY DIFFERENT



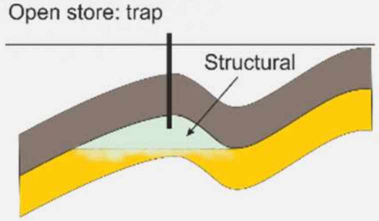
Hydrocarbon production

- How much oil/gas is in the accumulation, what is my Reserves to Production (R/P) ratio?
- Will production, or water / gas injection, cause unwanted effects – out of zone flow, induced seismicity, impact other users?
- How long do we maintain plateau production rate, before decline and ultimately COP?
- Can we develop an effective well, reservoir, and facilities management plan (WRFM)?
- Energy goes down in the system – we are extracting the fluids.
- Connected volume of highly compressible hydrocarbon, focus is on the field.

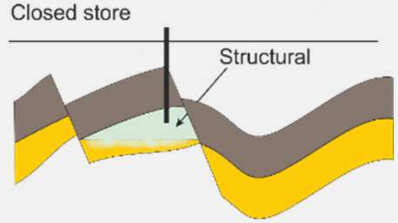
CO_2 storage

- How much CO_2 can I safely store, what is my Capacity to Injection (C/I) ratio?
- Will the CO_2 be contained **for millennia** and will injection cause unwanted effects?
- How long can I guarantee the injection rate, most contracts require us to **guarantee a fixed injection** rate for decades?
- Can we develop an effective well, reservoir, and facilities management plan (WRFM)?
  In addition we must demonstrate that we are able to monitor the store to show that we are containing the CO_2.
- Energy goes up in the system. In a structural store we are creating a gas field. In an aquifer store we create a plume.
- Every cubic meter of CO_2 injected has to push away a cubic meter of water – focus is on connectivity at a distance

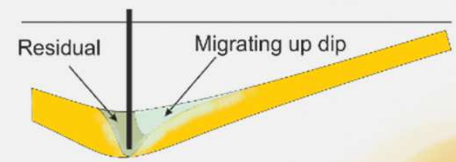
Open store: trap



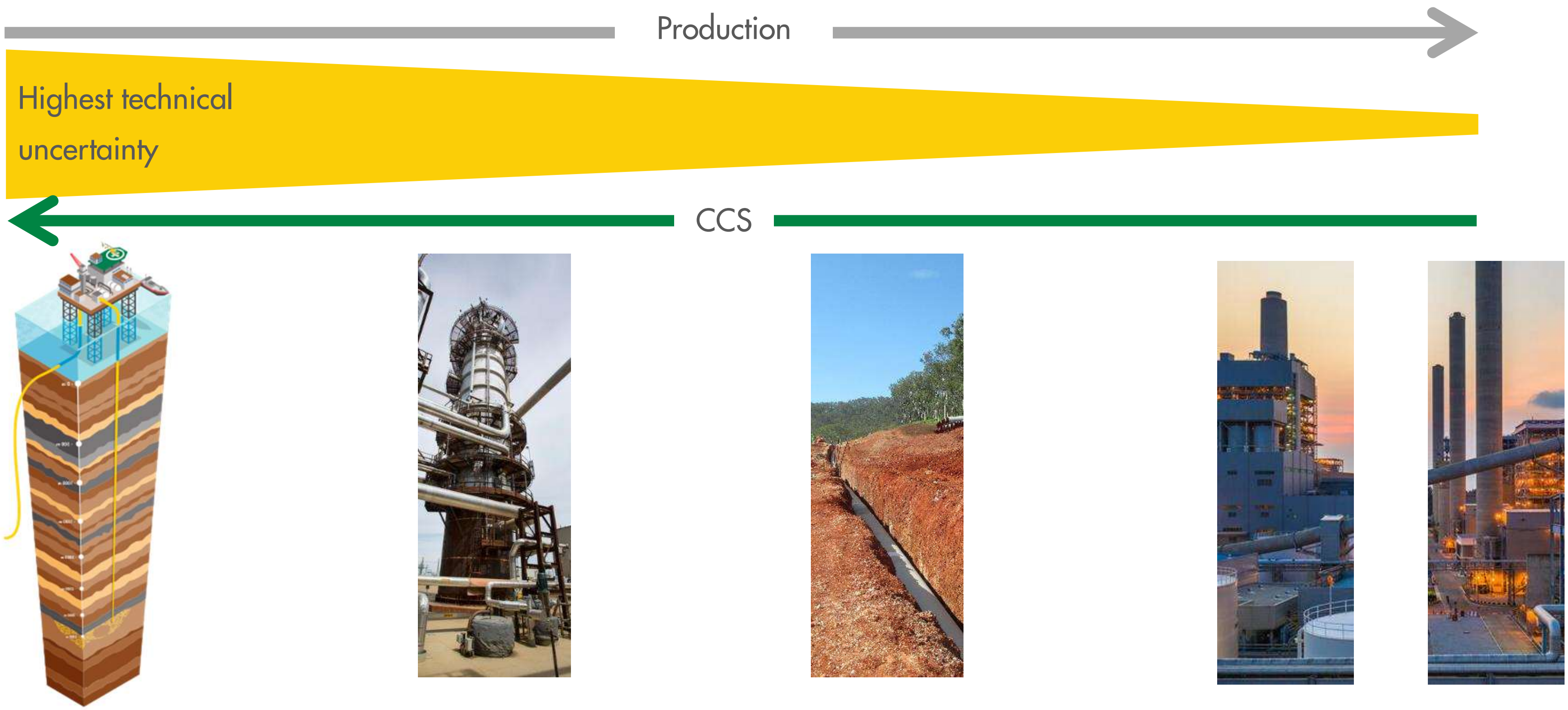
Closed store



Open store: migration



Reversing the flow



- Subsurface
- Gas processing
- Transport
- Emitters/Customers

Five performance requirements for geological CO_2 storage

- How Shell ensures safe, long-term CO_2 storage

STORAGE SITE FEASIBILITY

Capacity & Injectivity

Does the storage site have the required capacity and sustained injectivity at rates that are economical?

Containment

Can the storage site contain the CO_2 indefinitely?

Transport

Can CO_2 be transported to the site safely and economically?

Monitoring & Remediation

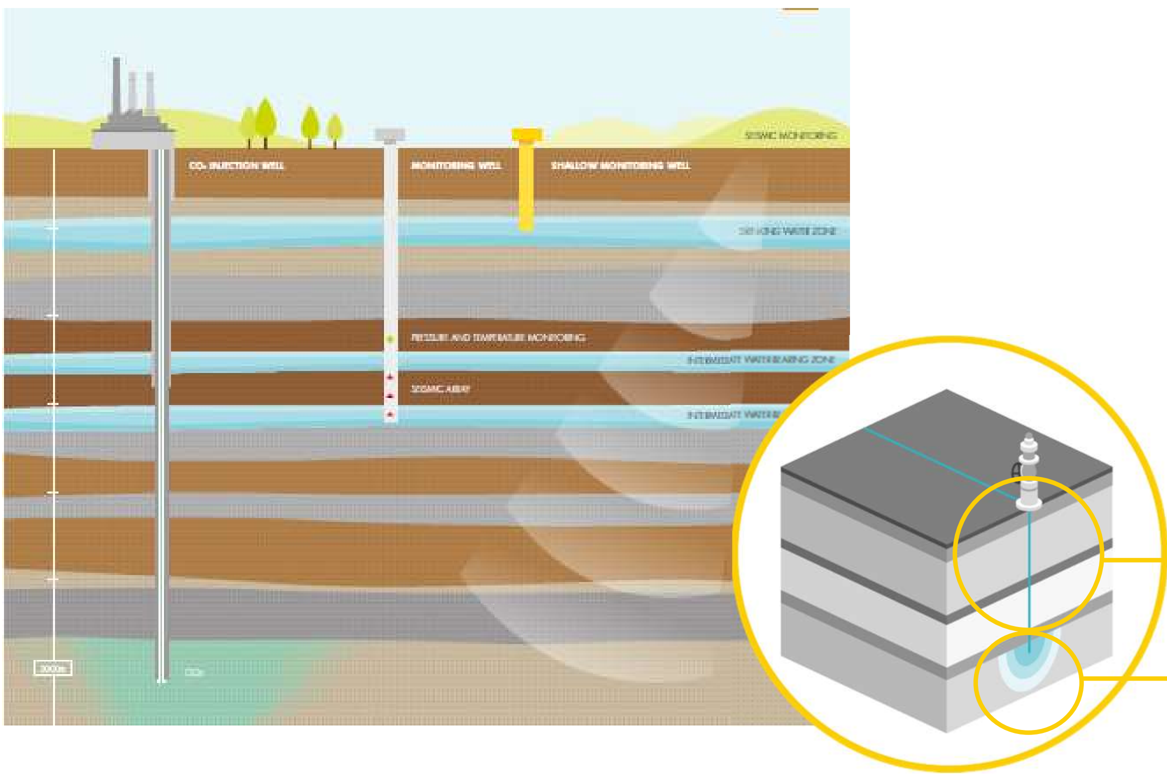
Can the injected CO_2 be monitored, and remedial activities deployed within economic limits?

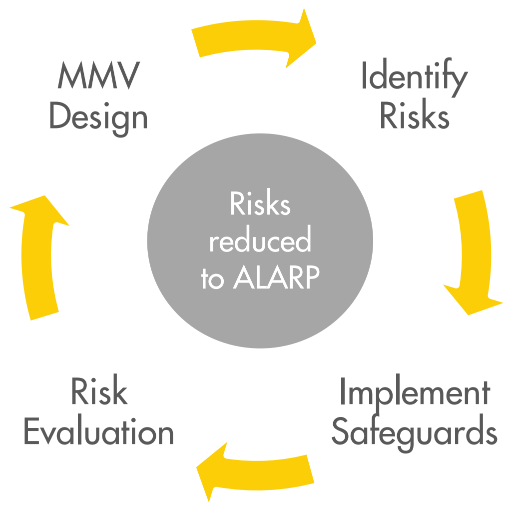
Stakeholders

Are all stakeholders in agreement?

Risk-based Measurement, Monitoring and Verification (MMV)

Purpose: Containment, Conformance, and Confidence





- Verify containment
- Establish conformance

Risk-based Measurement, Monitoring and Verification (MMV)

Purpose: Storage Permit

- Building trust based on evidence:
- For example, the Goldeneye storage permit documentation was over 800 pages long

Outline financial security based on site selection, characterisation, the design decisions and risk assessment results	10 pages
Present closure and post closure plans that draw evidence from conformance results from monitoring	25 pages
Outline corrective measures that complement monitoring to create additional safeguards for containment	90 pages
Design MMV plan based on containment risk assessment	90 pages
Bring evidence together in containment risk assessment	200 pages
Detail all evidence from site characterisation and design	400 pages

Summary

- CCS is a needed solution for meeting national and global climate goals
- CCS projects are driven by different value than hydrocarbons
- Current knowledge and skills in the Energy industry especially upstream is very relevant and transferrable to CCS – we need to think and utilise the knowledge in a different way - start asking different questions
- The highest technical uncertainty is in the subsurface where detailed site characterisation is important for the storage permit
- By fulfilling the five performance requirements for geological CO_2 storage: capacity, containment, transport & injectivity, monitoring & remediation, stakeholders – we can ensure safe and efficient CO2 storage.
- **Risk-based approach:** Following the "identify, assess, mitigate, monitor" risk framework to containment, adapting MMV through time as risk-profile changes with project maturity