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OIL & GAS

SAFELY RE-USING INFRASTRUCTURE FOR CO_2 TRANSPORT AND STORAGE

This paper sets out the six key checks that need to be made before pipelines and other infrastructure can be considered for re-use for CO_2 transport and storage. It also outlines the DNV GL guidance and recommended practices that should be followed, ensuring that re-use projects are successful.
Our conclusion is that a number of technical challenges exist, but with the application of appropriate risk assessments and well-engineered solutions, the risks can be managed effectively.

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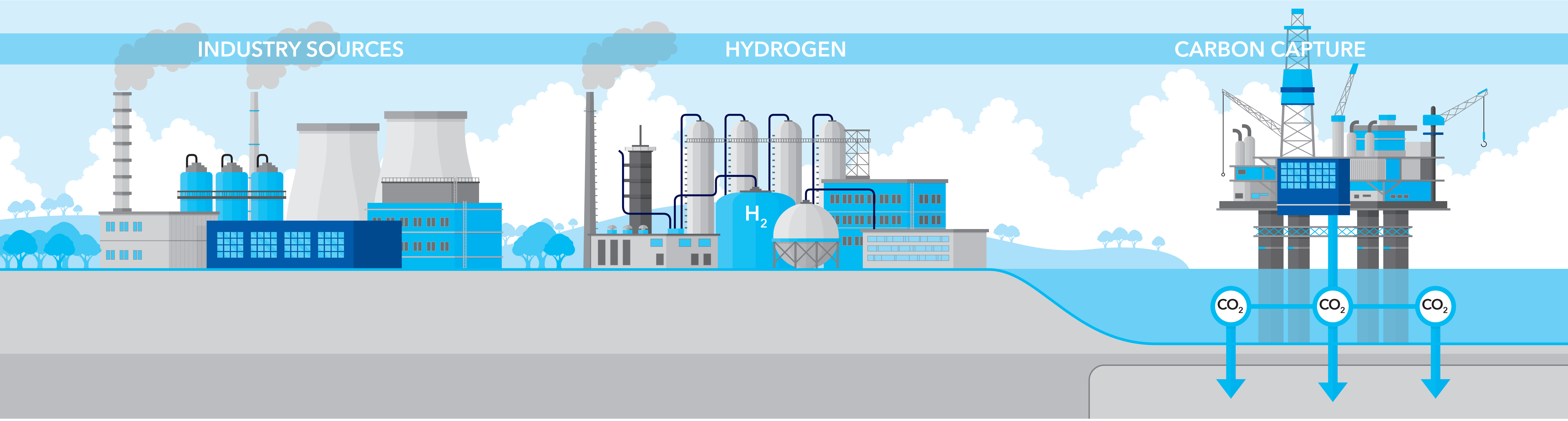


1. The importance of CCS

Carbon Capture and Storage (CCS) is a key technology for the mitigation of climate change. CCS involves capturing carbon dioxide (CO_2) from large industrial emitters, including coal and gas fired power stations and hydrogen production facilities, and re-using it or transporting it to permanent storage sites, such as depleted oil or gas reservoirs or saline aquifers.

CCS is justifiably seen as an essential enabler to the rapid decarbonisation progress demanded by reduction targets for CO_2 agreed at the Paris Climate Conference (COP21):

- The Intergovernmental Panel on Climate Change (IPCC) has concluded that without CCS, the cost of achieving the Paris Agreement objective of a rise in temperatures "well below 2 degrees" would be 138% higher on average – in most models, the target could not be achieved without CCS.[1]
- In the UK, the 2016 Oxburgh report[2] agreed that carbon capture and storage was an essential component in delivering lowest cost decarbonisation across the whole UK economy.
- The UK Committee on Climate Change has concluded that CCS is a "necessity not an option for reaching net-zero GHG emissions".[3] This is also partly because CCS is one of the only ways of delivering negative emissions.

As DNV GL's latest Energy Transition Outlook shows,[4] we believe that gas and renewables will be the only energy sources for which demand is higher in 2050 than today. However, they must work together alongside greater uptake of CCS to secure a rapid energy transition. We are therefore encouraged to see the UK Government consulting on business models for CCS across industry, power generation, hydrogen production, and on the re-use of oil and gas assets for CCS.

[1] Intergovernmental Panel on Climate Change, Climate Change 2014 Synthesis Report, referenced in the CCS Cost Challenge Task Force report

[2] Oxburgh (2016): 'LOWEST COST DECARBONISATION FOR THE UK: THE CRITICAL ROLE OF CCS.' Report to the Secretary of State for Business, Energy and Industrial Strategy from the Parliamentary Advisory Group on Carbon Capture and Storage (CCS)

[3] Committee on Climate Change, Net Zero: The UK's contribution to stopping global warming, May 2019, p.23, p.71 and p.178 https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

[4] DNV GL, Energy Transition Outlook 2019 eto.dnvgl.com/2019

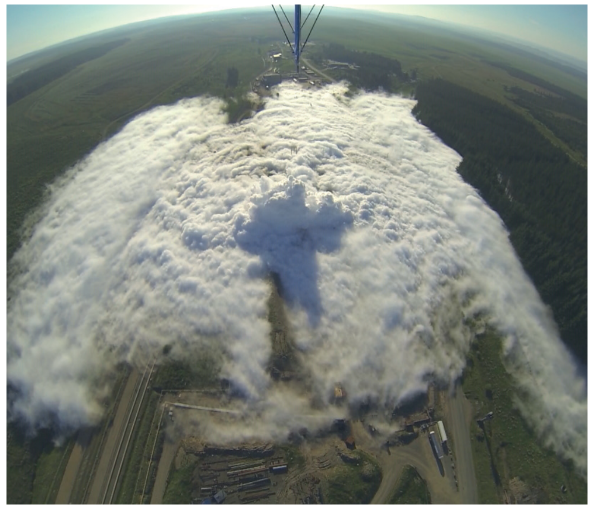
2. The critical need to avoid leaks

For large scale CCS to be developed successfully, it is critical not only that appropriate business models are put in place, but also that major incidents are avoided through careful design, assessment and through-life integrity assurance of new and adapted CCS infrastructure.

Many CCS pilot and demonstration facilities have been successfully implemented[5]. Although much CCS infrastructure is offshore, a number of proposed onshore CCS projects to repurpose existing pipelines or facilities have failed to progress or encountered strong local opposition. We cannot assume that this will not happen in the UK.

As we set out below, there are real issues and challenges associated with the capture, handling and storage of extremely large quantities of impure CO_2. Effective management of its hazard potential is vital to ensure that a fledgling CCS industry is not impacted by the consequences of a preventable major incident.

We therefore recommend that special care is taken when considering the re-use of existing pipeline infrastructure or oil and gas assets for CCS, given that they were not specifically designed to handle CO_2, which has a unique set of properties.



[5] See the Global Status Report produced annually by the Global CCS Institute https://www.globalccsinstitute.com/resources/global-status-report/

3. Six key checks before re-use of infrastructure for CCS can be considered

Whilst re-purposing pipelines is superficially attractive, there are several key criteria that need to be considered carefully – and checks that need to be made – before approving a piece of onshore or offshore infrastructure for CCS re-use.

3.1 The design pressure of the re-used pipeline

Onshore natural gas transmission systems and many of the offshore pipelines feeding in to them are largely designed to operate at the local ground or ambient temperatures, for example between -10 and 40 °C, and at pressures between 40 and 85 bar. The density of natural gas at these conditions varies from 25 to 100 kg/m³. The operating domain for a typical natural gas transmission system is shown by the red box – in this region, natural gas is well away from its two-phase region and the system is operating in the gas region of the phase diagram.

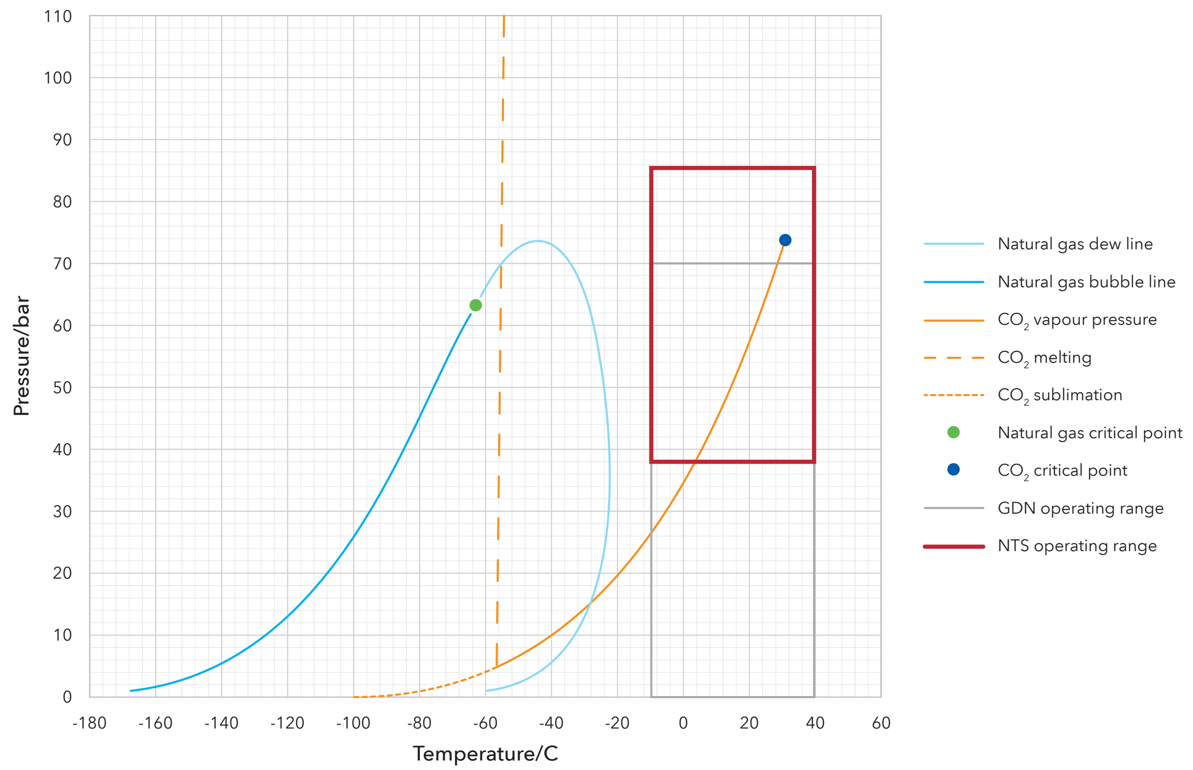


Figure 1: Comparison of the phase envelopes of natural gas and CO_2

Unfortunately, for CO_2 this operating domain would be unsuitable because the vapour pressure curve, which is the transition between the gas and liquid phases, passes right through the middle of the red box. Additionally, close to the Critical Point the density of CO_2 varies considerably, whereas the maximum density of transmission natural gas is about 100 kg/m³, the corresponding densities of CO_2 range from 100 to 1,000 kg/m³. When impurities such as nitrogen remain in the CO_2, the two-phase region goes from a line to a loop as shown in the following figure; this makes the transport of CO_2 at conditions familiar to the onshore natural gas industry even more challenging. For pipelines with pressure ratings above about 100 bar, CO_2 can be transported well above the two-phase region in the dense liquid phase. For onshore and other pipelines only rated to 70 or 80 bar, CO_2 needs to be transported in the gas phase and the maximum pressure for single phase flow is likely to be about 35 bar.

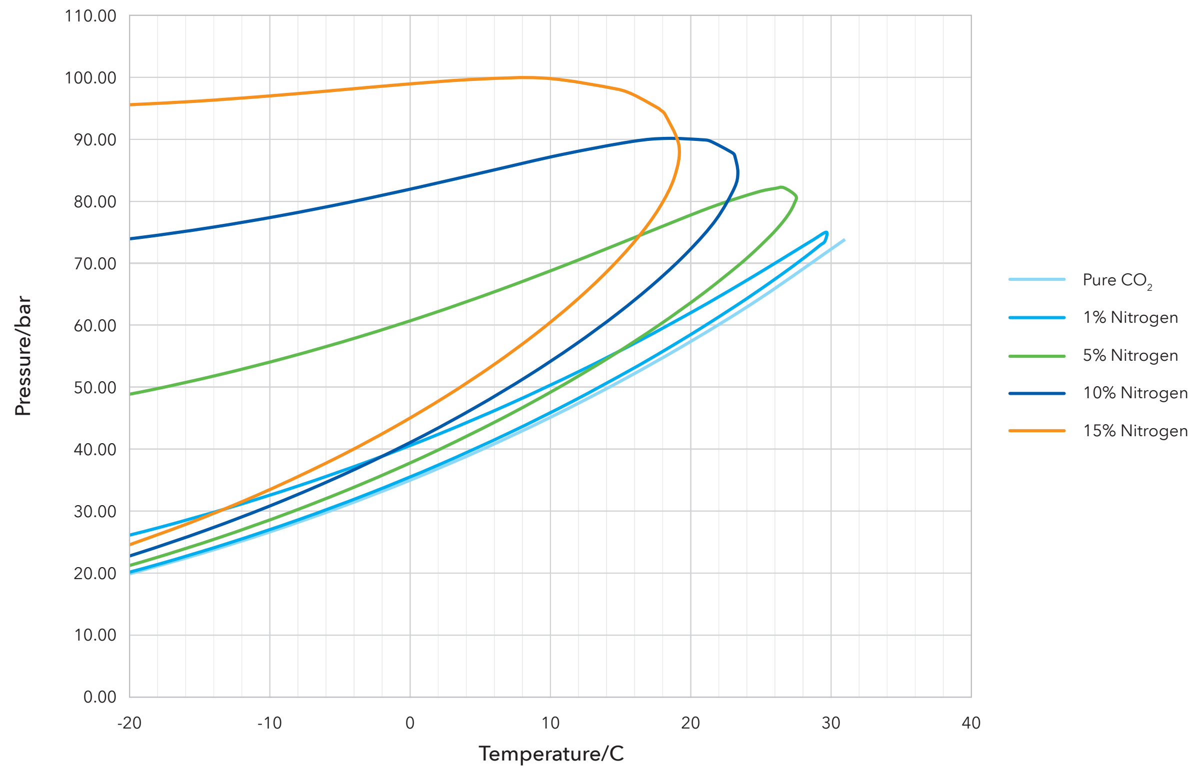


Figure 2: Phase behaviour of CO_2 + N_2 mixtures

3.2 Material requirements concerning fracture initiation

Pipelines transporting two phase fluids, supercritical dense phase fluids, or liquids with a high vapour pressure are susceptible to long running pipeline fractures. When a pipeline fails, there is a temperature drop due to the pressure reduction resulting in evaporation of the liquid phase, creating a plateau in the decompression curve and maintaining the driving pressure at the crack tip for much longer than with gaseous fluids. The pipeline must therefore have sufficient toughness to arrest such a running ductile fracture. The higher the saturation pressure, the more energy the pipeline inventory contains, and the higher the probability of long ductile fractures. An assessment must be made on whether the design toughness requirement for a re-used natural gas pipeline would be suitable for transporting dense phase CO_2.

There are difficulties in predicting the toughness to prevent a running ductile fracture in dense phase CO_2 pipelines.[6] Whilst recent work by DNV GL for the Norwegian Research Council and Australian Energy Pipelines Cooperative Research Centre (EPCRC)[7] goes some way to addressing this problem, a design philosophy is still being defined. Applying any new design criteria to old pipelines may bring challenges, as they will probably have relatively low toughness and may not meet the requirements to prevent ductile fracture, without restrictions in the operating conditions, which in turn may affect the economic viability of a project.

3.3 Other materials issues

The water dew point of a CO_2 pipeline is much more critical than that of natural gas since any liquid water present will form strongly corrosive carbonic acid (H_2CO_3). Therefore, CO_2 pipelines require more stringent drying precautions than natural gas pipelines and there would be the requirement to thoroughly dry all pipeline infrastructure prior to re-use. This would be a major undertaking for former multi-phase lines and complex undersea systems.

In addition, dense phase liquid CO_2 is an excellent solvent for organic material. Hence, special attention must be paid to the suitability of components like seals, valves, gaskets and lubricants that could come into contact with CO_2.

[6] IPC2014-33080 'Analysis of Two Dense Phase Carbon Dioxide Full–Scale Fracture Propagation Tests' Proc. of the 2014 10th International Pipeline Conference, Calgary, Alberta, ASME, 2014

[7] CO2SafeArrest project, nearing completion

3.4 Zoning issues

As the chemical and physical properties and hazard potential of CO_2 differ significantly from those of natural gas the risks related to the transmission of CO_2 will differ. Although CO_2 is not flammable it is a heavier-than-air substance that can create a hazard at a significant distance from a leak location.
The zoning around a re-purposed pipeline will thus need to be redefined to reflect zoning requirements for CO_2 pipelines.

3.5 Documentation, general condition and age

When an existing pipeline is considered for CO_2 transport, it needs to be assessed in order to estimate the required modifications, such as cleaning, valve replacements and safety measures. In this case, it is of vital importance that the documentation of the pipeline is available. Material certificates, maintenance history and inspection results should all be there to ensure that the reused pipeline can be operated safely and reliably. An additional hurdle to repurposing a pipeline could be missing documentation.

3.6 Other life-extension checks

By definition, repurposed pipelines and assets will already have been in service and in many cases would require large scale life-extension efforts to be viable for transporting or storing CO_2. For example, due to changes in regulations, CO_2 injection wells may not meet the current integrity standards for the new service and need recompletion. Well packers may not to be compatible with CO_2, and would need to be replaced and the well locations, originally optimised to maximise production, could be poorly sited for CO_2 injection.

Pipelines would also need assessment to see if they can withstand the increased pressures, taking into account any corrosion defects present. It is worth noting that a repurposed pipeline is unlikely to have been sized, located or routed optimally for CO_2 injection purposes. This may lead to compromises in terms of operating pressures, velocities in the pipeline and compression requirements. The compressibility of CO_2 is non-linear in the range of pressures common for pipeline transport and (as shown in the earlier figure) is highly sensitive to impurities. One of the consequences of this behaviour is that CO_2 needs very specific compressors.

4. Safety of CO_2 subsurface storage

Industrial experience with injection of CO_2 and other gases into geological subsurface formations is vast and growing exponentially.

Approximately 70 million tonnes per year of CO_2 are currently injected below ground using over 10,000 wellbores at over 130 sites worldwide. CO_2 was first used as injection fluid to increase oil recovery from mature reservoirs starting in 1972.

In addition, injection of natural gas below ground for seasonal storage began as a commercial activity over 100 years ago and is now used at over 400 sites.

In its 2018 Status Report[8] the Global CCS Institute reported that there were 18 large scale CCS facilities in commercial operation, 5 under construction and 20 in development.

CO_2 has been stored in deep saline aquifers 900-2,000 metres below surface at field scale since 1996, with no incidents. Monitoring solutions have been comprehensively tested at several separate storage sites and provide insight into the movement and long-term fate of CO_2 below ground.

It is generally recognized that every geological storage site is unique, and as such, must be chosen, designed and operated according to its particular site characteristics. The storage sites must be clearly suitable for storing the quantities required with acceptable impacts and risks to the local environment.

Independent review, verification and auditing needs to play a key role to maintain confidence that CO_2 is stored safely.

[8] See https://www.globalccsinstitute.com/resources/global-status-report/

5. DNV GL guidance for the safe management of infrastructure re-use

The industry guidance documents that DNV GL has made available for each link of the CCS chain (see www.dnvgl.com/CCS) clearly detail the specific issues that need to be addressed for CCS projects. These documents include recommended practices, service specification documents, and guidance documents and data from Joint Industry Projects (JIPs) such as CO2RISKMAN and CO2PIPETRANS.

In particular the CO2RISKMAN Guidance Level 4 presents the issues and challenges and potential risk management measures for each link of the CCS chain including on and offshore pipelines, offshore platforms and wells. For each link of the CCS chain, the relevant issues are systematically detailed along with risk management measures for inherent safety, prevention, detection, control, mitigation and emergency response.

Therefore, anyone wishing to look at re-using existing offshore infrastructure could use the information in the CO2RISKMAN Guidance (and supporting guidance such as CO2PIPETRANS) to assess the infrastructure against the issues detailed.

We suggest that a robust assessment and scoring tool be developed. This could be based on DNV GL CCS technical and risk management knowledge and experience and backed up by reference to industry guidance documents. Such a tool could then be applied in the assessment of existing infrastructure. This would provide industry, regulators and investors a means to better understand, measure and compare CCS development options be they re-use, new-build or a combination.

DNV GL RECOMMENDED PRACTICES AND GUIDANCES ACROSS THE CCS CHAIN

- DNVGL-RP-J201 Qualification procedures for CO_2 capture technology
- DNVGL-RP-F104 Design and operation of carbon dioxide pipelines
- DNVGL-RP-J203 Geological storage of carbon dioxide
- DNV-DSS-402 Qualification Management for Geological Storage of CO_2
- DNVGL-SE-0473 Certification of sites and projects for geological storage of carbon dioxide
- CO2RISKMAN Guidance on CCS CO2 Safety and Environment Major Accident Hazard Risk Management

Our CCS experience

We have undertaken 150 carbon capture and storage (CCS) projects around the world over the last 20 years, to help lay the foundations for the sector. These include:

- **Best practice:** We have led joint industry projects with national authorities, international institutions and public enterprises to develop three key DNV GL recommended practices for the full CCS chain, including a qualification procedure for CO_2 capture technology, the design and operation of CO_2 pipelines, and the geological storage of CO_2.
- **Testing:** We have carried out large-scale testing and materials research programmes in our three major facilities at Spadeadam, Groningen and Columbus, Ohio, to improve the safety of CO_2 handling, including understanding how and when CO_2 pipelines fail.
- **Verifying:** We have verified the design of a pipeline for the world's longest-running CO_2 storage site.

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About DNV GL
DNV GL is the technical advisor to the oil and gas industry. From project initiation to decommissioning, we enhance safety, increase reliability and manage risks in projects and operations.

Our oil and gas experts offer local access to global best practice in every hydrocarbon-producing country. Driven by a curiosity for technical progress, we provide a neutral ground for collaboration; creating competence, sharing knowledge and setting industry standards.

Our independent advice enables companies to make the right choices. Together with our customers, we drive the industry forward towards a safe and sustainable future.