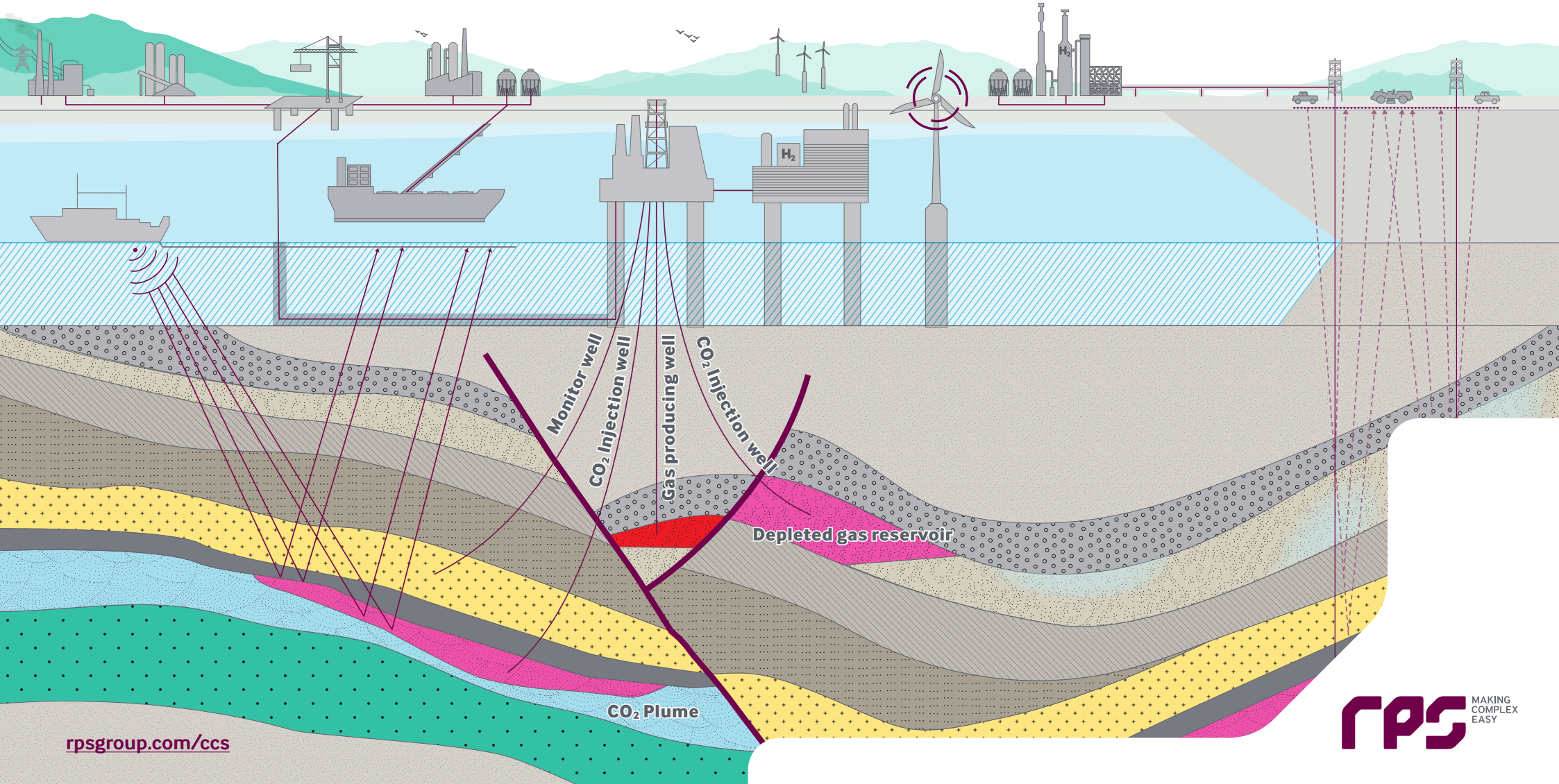
CARBON CAPTURE AND STORAGE

Supporting our clients to thrive in a low carbon economy



rpsgroup.com/ccs

rps MAKING COMPLEX EASY

MEETING THE GLOBAL DEMAND TO DECARBONISE

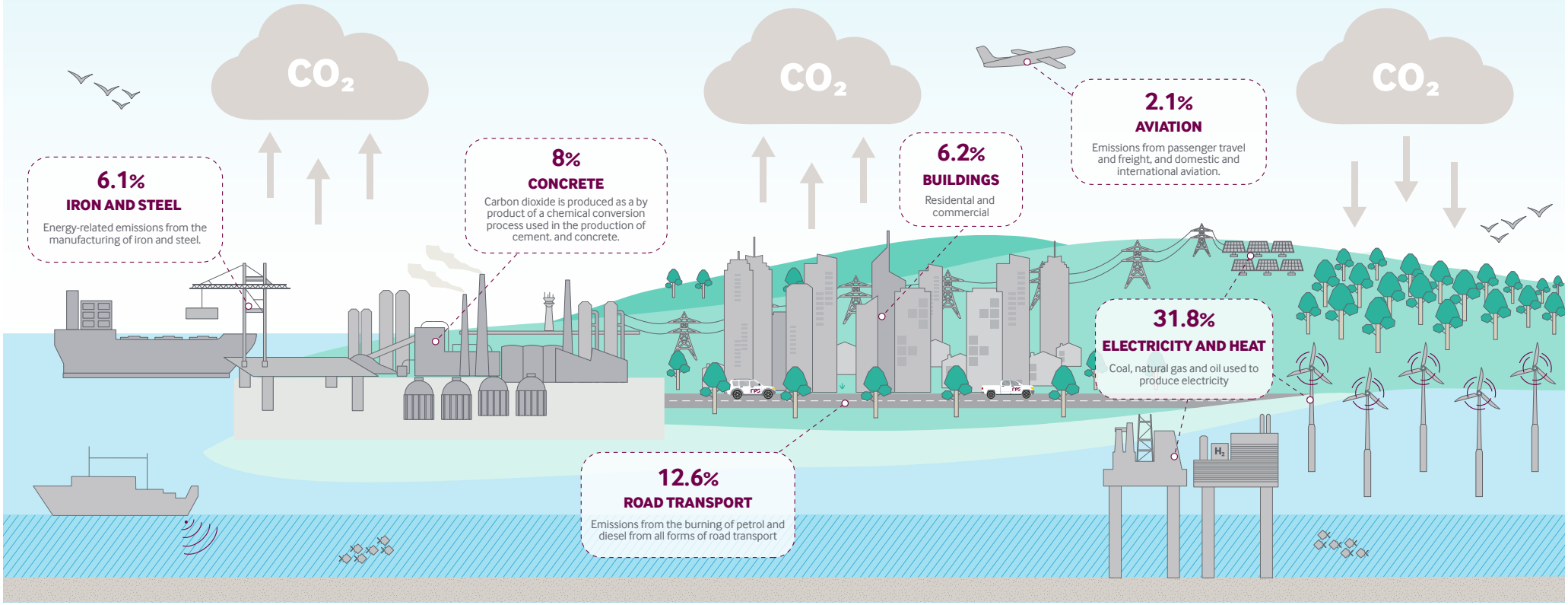
Carbon Capture and Storage (CCS) is recognised as being essential to meeting the global emission targets set out in the Paris Accord, removing up to 90% of carbon dioxide emissions produced from industry - playing its part in reducing emissions to the atmosphere by up to 19% by 2050.

Carbon dioxide (CO_2) is widely accepted to be a major contributor to global climate change. CCS refers to the process of capturing CO_2, transporting it to a storage site where it is captured to ensure it will not enter the atmosphere.

WHERE DOES CARBON COME FROM

Carbon dioxide can be emitted into the atmosphere in several ways. Most CO_2 comes from energy production and consumption. While transportation, including road, air and shipping, accounts for 14%, almost ⅓ of CO_2 emissions come from making electricity or heat. Cleaner fuels and electricity is are reducing and will continue to reduce emissions from these sectors.

Much harder to abate is the CO_2 which is a natural by-product of industrial processes such as cement and concrete manufacturing. These processes account for 6% of global CO_2 emissions.

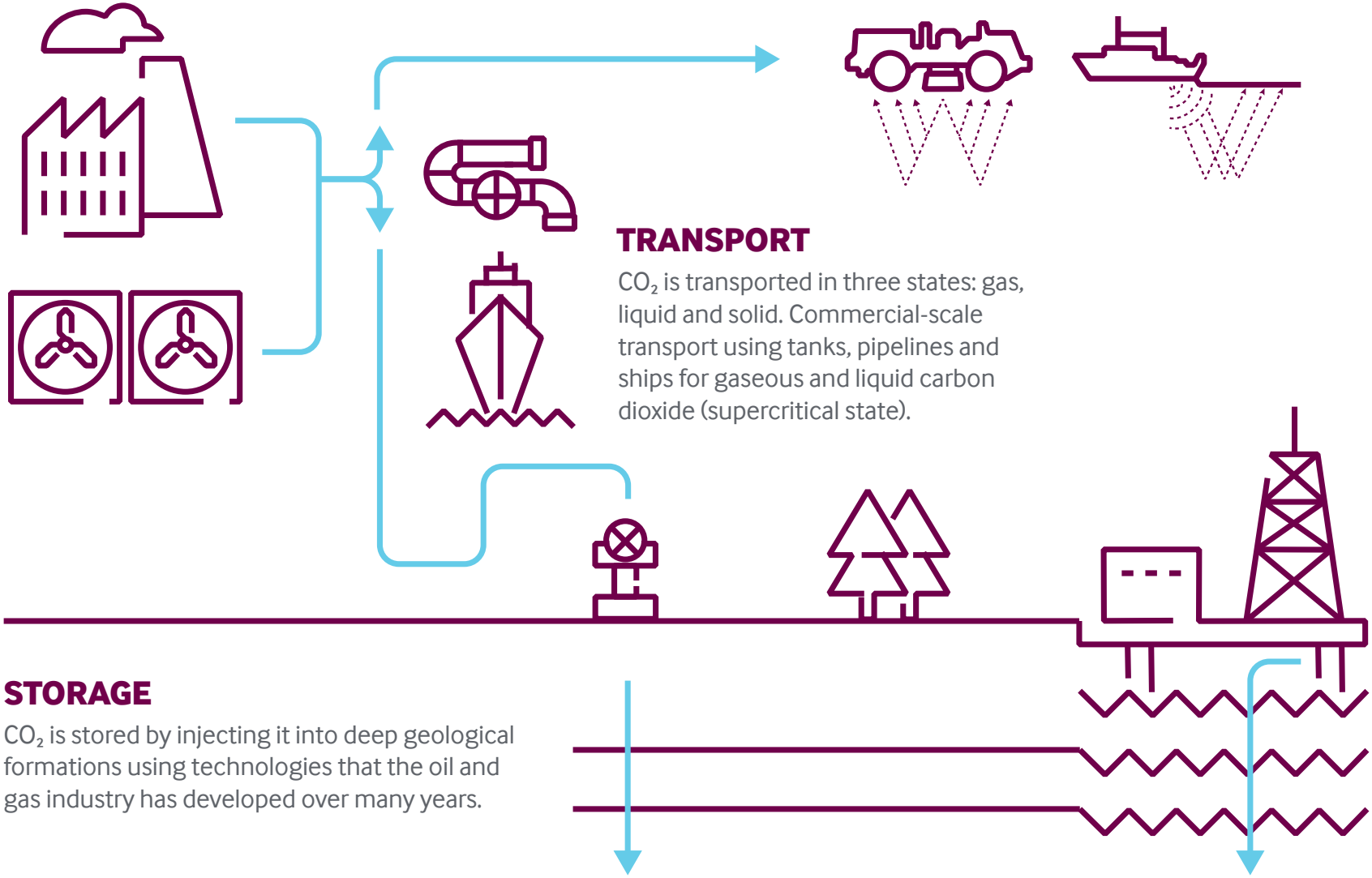


CAPTURE

CO_2 is captured from hydrocarbon or bio-mass power stations, industrial facilities such as cement and steel factories, or directly from the air.

MONITOR

CO_2 storage must be monitored over long periods. Monitoring, using geophysical survey techniques including 4D seismic, establishes the effectiveness of the well and reservoir, maps any movement of the CO_2 plume, and helps detect leaks.



TRANSPORT

CO_2 is transported in three states: gas, liquid and solid. Commercial-scale transport using tanks, pipelines and ships for gaseous and liquid carbon dioxide (supercritical state).

STORAGE

CO_2 is stored by injecting it into deep geological formations using technologies that the oil and gas industry has developed over many years.

SUPPORT ACROSS THE ASSET LIFECYCLE

CAPTURE

Capture of CO_2 currently relies upon either a chemical solvent at the source, such as a flue from a power plant or via an energy-intensive, and therefore expensive, direct air capture. Most current CCS projects propose removing CO_2 directly from the processing source to keep costs low.

What we do	Making complex easy
Major infrastructure projects, including CCS developments, require a range of consents, **permits and licences**.	The need to secure the necessary permissions will apply across all stages and throughout the lifetime of the project. High levels of exposure to planning systems, public and stakeholder consultation, public inquiry, and regulatory compliance are handled by the RPS multi-disciplinary project teams delivering the best possible information to inform sound decision making.
Water resourcing and water/environmental management	Current capture technology requires large volumes of water. Our expertise covers all aspects of water resource investigation, development and management. From strategic planning and site investigation to detailed design, construction supervision and environmental monitoring, we provide solutions that reflect and respond to local environments, objectives and constraints.
Community and stakeholder **communication and engagement**	Communication with all stakeholders is key to successful project delivery. Web-based systems support the generation of rigorous assessment of potential Health, Safety, Environmental and Social impacts. This transparency helps differentiate between perceived and actual risk related to transportation of CO_2.

A PARTNER THAT DELIVERS RESULTS

CCS is necessary to meet national and international climate change targets as set in the 2015 Paris Accord.

RPS is uniquely positioned to support the successful delivery of CCS projects. We routinely support our clients internationally to deliver integrated infrastructure projects - with strategic guidance, feasibility planning and specialised technical, commercial and operational advisory services at each stage of the CCS lifecycle.

We can call on years of general and specific industry experience to support our clients with the visualisation, conceptualisation and implementation of CCS and CO_2 EOR (Enhanced Oil Recovery) projects.

CASE STUDY

Tata Chemicals Europe - CCU Demonstration Plant, UK

Featured in the UK government's '10 Point Plan for a Green Industrial Revolution' and backed by £1bn of funding, carbon capture and storage will be used to decarbonise our most challenging sectors and work is underway to establish the process in two industrial clusters by mid-2020. Our Environmental Permitting team have played a vital role in bringing the UK's largest carbon capture and usage project to life, helping to shape the future technology that will be key for industry in the pursuit of net zero carbon.

RPS provided permitting advice, supported pre-application and post-submission discussions with the Environmental Authority, and provided support for full permit variation application and post-application services, including air dispersion modelling and odour assessment. We also supported the application to vary the water abstraction licence to incorporate the additional volume of cooling water required for the carbon capture process.

Read the full case study **here**.

CASE STUDY

Pre-FEED study on Carbon Capture and Storage (CCS) in support of Ireland's Climate Action Plan

Ervia is the company responsible for the delivery of Ireland's national gas and water infrastructure and services. RPS delivered a Pre-Front End Engineering Design Study (Pre-FEED Study) to Ervia to support the business case development for this CCS project in Ireland.

The study has defined the key parameters, technical elements, and configuration of the infrastructure that will be required to collect, transport, store and export a total of 3 million tonnes per annum (Mtpa) of CO_2 from emitter clusters in Cork and Dublin. At approximately 5% of Ireland's national CO_2 emissions, the project could become a significant contributor to meeting targets for CO_2 reduction set out in Ireland's Climate Action Plan.

Initially, CO_2 would be exported (from Cork and Dublin) to the Equinor Northern Lights Project (the North Sea, off Norway) by ship. The feasibility of importing CO_2 to the Cork site for onward storage to the decommissioned Kinsale Head Gas Field was also examined. This included considering using sections of decommissioned gas transmission pipelines for CO_2 transport.

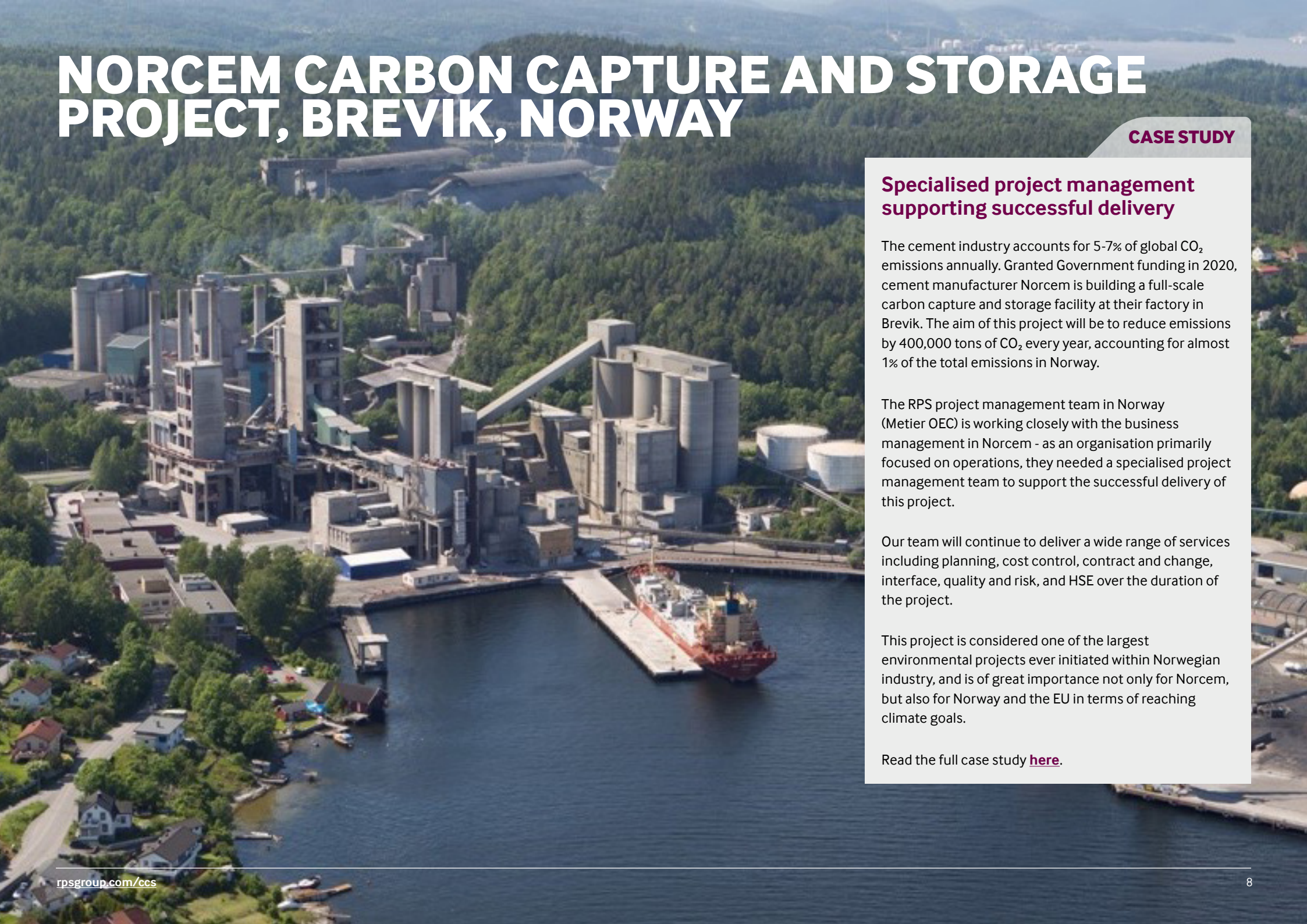
This pre-FEED study called in expertise from across RPS in the UK and Ireland in safety, energy, marine, environmental, planning, pipeline, electrical, civil and structural design. The project has been delivered to a very challenging timeline and provides an updated and robust cost estimate to allow the business case to be developed further. Our multi-disciplinary project team brought together a wide range of relevant expertise, and we have been able to fully address every aspect of this complex project within the tight project timescale. In preparing this study, RPS worked in partnership with Bechtel to provide additional engineering, procurement and construction expertise. Other partners on this project included HR Wallingford and ARC.

The study started in August 2021 with the Final Report being delivered in June, 2022. Findings will be widely shared, with the final report and presentations delivered to the Global CCS Institute and UK CCS Association in autumn, 2022.

"It is a significant win in the carbon capture and storage market, which is a key sustainability workstream in meeting Net Zero Carbon. There is great potential for the lessons learned on this project to be applied to other future CCS projects in Ireland, the UK or further afield, in particular within the cement and thermal waste treatment sectors."
Ciaran Butler Director - Gas & Utilities, RPS

Read the full case study **here**.

NORCEM CARBON CAPTURE AND STORAGE PROJECT, BREVIK, NORWAY



CASE STUDY

Specialised project management supporting successful delivery

The cement industry accounts for 5-7% of global CO_2 emissions annually. Granted Government funding in 2020, cement manufacturer Norcem is building a full-scale carbon capture and storage facility at their factory in Brevik. The aim of this project will be to reduce emissions by 400,000 tons of CO_2 every year, accounting for almost 1% of the total emissions in Norway.

The RPS project management team in Norway (Metier OEC) is working closely with the business management in Norcem - as an organisation primarily focused on operations, they needed a specialised project management team to support the successful delivery of this project.

Our team will continue to deliver a wide range of services including planning, cost control, contract and change, interface, quality and risk, and HSE over the duration of the project.

This project is considered one of the largest environmental projects ever initiated within Norwegian industry, and is of great importance not only for Norcem, but also for Norway and the EU in terms of reaching climate goals.

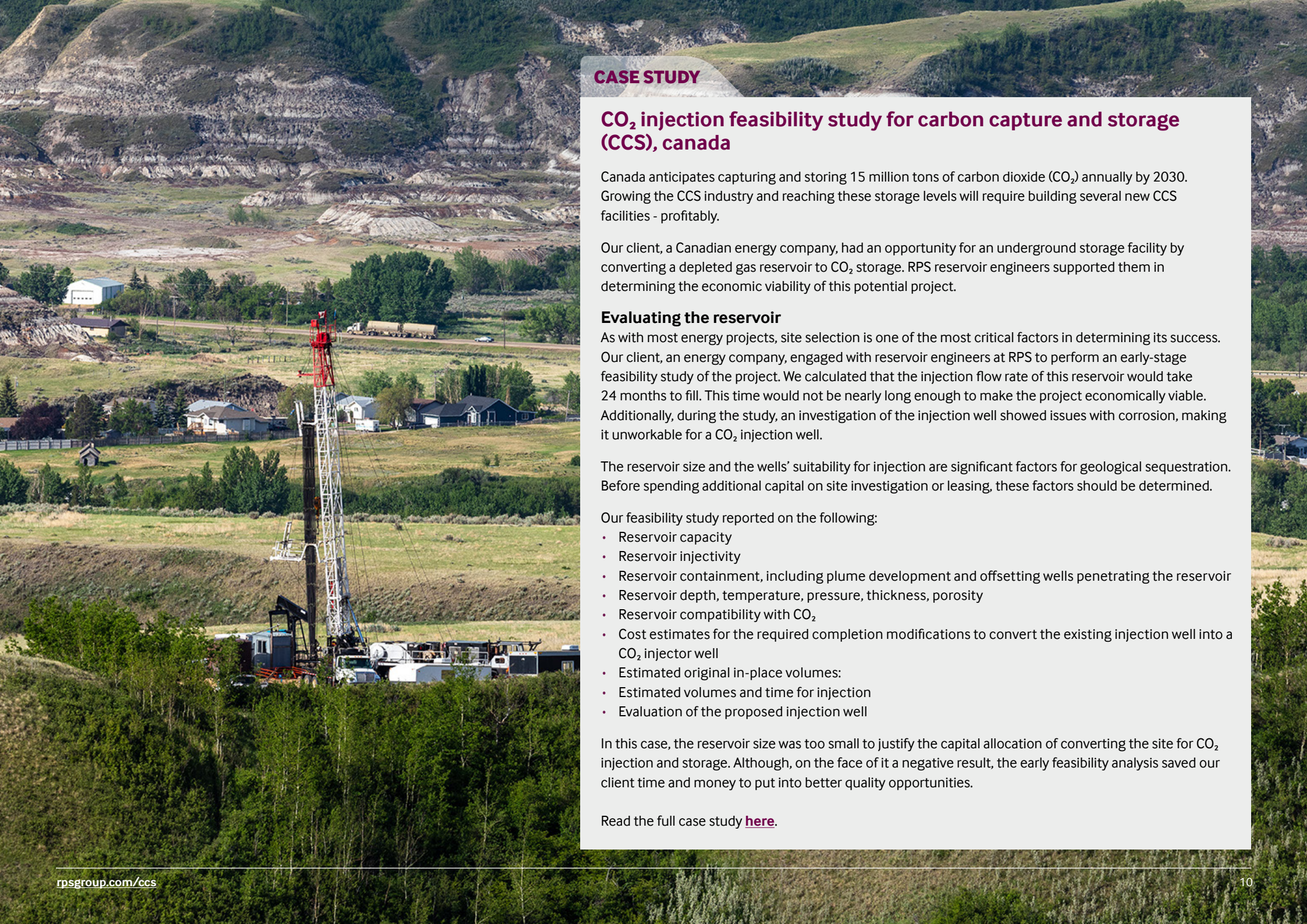
Read the full case study **here**.

TRANSPORT

CO_2 is transported in three states: gas, liquid and solid. Commercial-scale transport uses tanks, pipelines and ships for gaseous and liquid carbon dioxide (supercritical state). Supercritical carbon dioxide is a **fluid state of carbon dioxide** where it is held at or above its critical temperature and critical pressure.

After capture, CO_2 is then either dried for transportation, which limits the formation of carbonic acid that could detrimentally affect the pipeline system. Or, it's compressed to liquid state, such as in Norcem's Longship Project.

What we do	Making complex easy
Safe transport of captured CO_2	Safe transport is critical and involves careful planning, specialised engineering and risk management. CO_2 is already transported via high-pressure pipelines, however, as the scale of infrastructure increases, more populated areas may be impacted. Experienced engineers provide field-based assessments of pipeline routes, interfacing with key engineering contractors. Geological Information Systems allow visual recognition of complex spatial situations for route selection.
Pipeline monitoring and leak detection	RPS has deep expertise and a long track record of pipeline monitoring and leak detection across several industry sectors including water and oil and gas.
Risk assessment for CO_2 transportation	Renewables and clean energy sources are not without risk. Understanding the potential consequences of activities or accidents that may result from carbon dioxide transportation is essential. While CO_2 is relatively nontoxic and is not flammable, it can create an asphyxiation hazard (by replacing oxygen) if concentrations exceed 4%. CO_2 is denser than air and can settle in low areas where it may disperse more slowly. RPS have supported the energy industry and regulators with risk assessment tools and services for various potential releases, including dispersion modelling over land surfaces, in water bodies, and in the atmosphere. Adapting these modelling tools that have been vetted, validated, and presented in regulatory formats allows project approvals to be streamlined, and the potential for public comment/concern is minimized.
Ports	To accommodate the amount of shipping of CO_2 by tanker to offshore storage locations will necessitate upgrading port facilities. RPS offer solutions in engineering, marine science, master planning, environmental monitoring, safety, procurement, project management and more. We draw on decades of experience working on some of the world's most successful marine infrastructure projects.



CASE STUDY

CO_2 injection feasibility study for carbon capture and storage (CCS), canada

Canada anticipates capturing and storing 15 million tons of carbon dioxide (CO_2) annually by 2030. Growing the CCS industry and reaching these storage levels will require building several new CCS facilities - profitably.

Our client, a Canadian energy company, had an opportunity for an underground storage facility by converting a depleted gas reservoir to CO_2 storage. RPS reservoir engineers supported them in determining the economic viability of this potential project.

Evaluating the reservoir

As with most energy projects, site selection is one of the most critical factors in determining its success. Our client, an energy company, engaged with reservoir engineers at RPS to perform an early-stage feasibility study of the project. We calculated that the injection flow rate of this reservoir would take 24 months to fill. This time would not be nearly long enough to make the project economically viable. Additionally, during the study, an investigation of the injection well showed issues with corrosion, making it unworkable for a CO_2 injection well.

The reservoir size and the wells' suitability for injection are significant factors for geological sequestration. Before spending additional capital on site investigation or leasing, these factors should be determined.

Our feasibility study reported on the following:

- Reservoir capacity
- Reservoir injectivity
- Reservoir containment, including plume development and offsetting wells penetrating the reservoir
- Reservoir depth, temperature, pressure, thickness, porosity
- Reservoir compatibility with CO_2
- Cost estimates for the required completion modifications to convert the existing injection well into a CO_2 injector well
- Estimated original in-place volumes:
- Estimated volumes and time for injection
- Evaluation of the proposed injection well

In this case, the reservoir size was too small to justify the capital allocation of converting the site for CO_2 injection and storage. Although, on the face of it a negative result, the early feasibility analysis saved our client time and money to put into better quality opportunities.

Read the full case study **here**.

STORE

Injection of CO_2 into deep geological formations utilises technologies that have been developed by the oil and gas industry over many years. Well drilling and completion technologies have been developed for optimal performance under extreme operating conditions such as high pressure, temperature and complex chemical environments.

What we do	Making complex easy
Drilling and well studies	Our team has years of experience in the provision of well planning, well engineering and design, execution, management and post well project close-out worldwide. It is applicable to drilling and well studies for evaluating CO_2 injection into depleted gas reservoirs or dedicated saline aquifers.
Storage facilities designed and engineered to accommodate CCS	To meet the global demand for CO_2 storage it is estimated that 5-6 billion tonnes of CO_2 will be required to be injected annually by 2050. RPS' subsurface expertise and experience includes reservoir characterisation, static and dynamic modelling and environmental monitoring gained over decades working on both oil and gas and CCUS projects. This deep understanding and experience of potential carbon stores ensures we can support the successful delivery of future storage requirements.
Site selection is critical - not all subsurface formations are suitable for carbon storage, nor are they located in all regions.	Locating and assessing appropriate sites is a critical step in planning any CCS project and involves multiple technical disciplines. A deep technical understanding of the world's geology comes from our extensive oil and gas sector experience, gained over the last 30 years. This includes 20 years of experience working on CCUS projects.

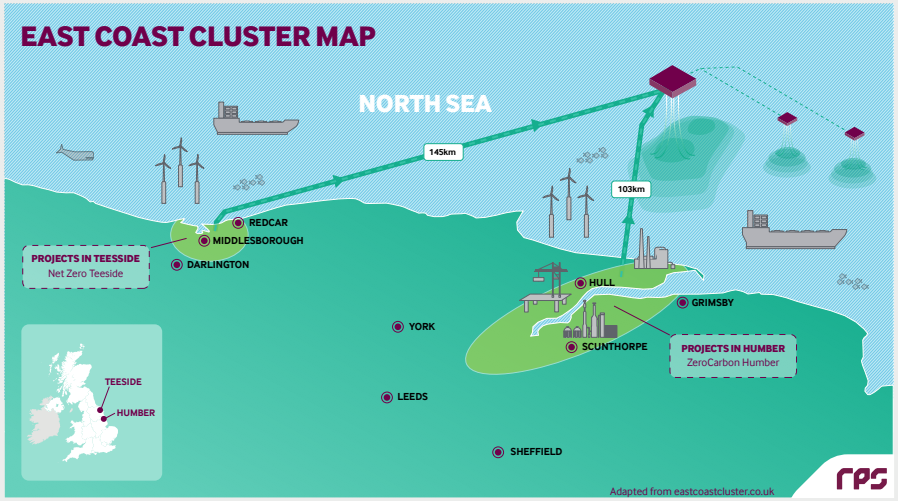
Baseline 3D seismic survey for the Northern Endurance Partnership's CCS project

The Northern Endurance Partnership (NEP) is the CO_2 transportation and storage company designed to provide the East Coast Cluster projects the infrastructure needed to store CO_2 underground. The NEP is a partnership between bp, Equinor, National Grid, Shell and Total, with bp leading as operator. The project is named after Endurance, the dedicated saline CO_2 storage reservoir located approximately 145km offshore from Teesside in the UK North Sea. This reservoir has the capacity to store up to 450 million tonnes of CO_2. The 2022 seismic survey also covered potential expansion stores.

Site selection and continuous monitoring are critical factors in the safe storage of CO_2. On this project, RPS has provided bp 3D seismic survey optimisation and simultaneous operations (SIMOPS) management for the baseline survey, which started April 15th, 2022 and concluded in mid-June. The survey will be used in determining the CO_2 storage capacity of the structures, optimising well locations and act as a baseline for subsequent surveys. Future surveys will monitor any changes within the geological formations as CO_2 is injected into the reservoir, approximately 1.6km below the seabed.

During mobilisation, the RPS optimisation specialist, using our proprietary Osprey technology, modelled different acquisition options to devise the most efficient method to acquire the survey concerning the sea currents in the region. The specialist also managed the SIMOPS during the project. Osprey supports our SIMOPS planning by generating a visual overview of the project location. As infield conditions change, coordinators and QC specialists use Osprey's unique visualisation tools to adjust plans and improve the efficiency of the seismic survey.

Read the full case study here.



CASE STUDY

Northern Lights CO_2 transport and storage - baseline seismic survey planning and optimisation

Northern Lights JV is a Joint Venture owned by TotalEnergies, Equinor and Shell and is the transportation and storage component of the full carbon capture and storage (CCS) value chain initiative by the Norwegian state called "Longship". The project's first phase will be completed in mid-2024, with an initial capacity of up to 1.5 million tonnes of CO_2 per year.

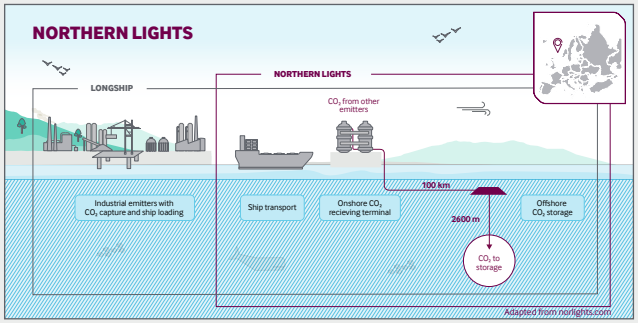
Once CO_2 is injected into a subsea reservoir, it must be closely monitored to understand how the injected CO_2 is causing geological changes in the reservoir or the well. For example, in the presence of water, CO_2 forms carbonic acid that can cause severe corrosion to the infrastructure. Migration paths in the upper layers of geology that trap the CO_2, can be formed by poor well construction or geological faulting.

The first step in instituting a CCS monitoring plan is to establish a baseline survey of the reservoir by acquiring 3D seismic data. Then subsequent surveys are taken so any changes in the reservoir or trapping layers can be detected and interpreted, and the CO_2 plume development can be modelled.

Before the survey, RPS optimisation specialists used Osprey, proprietary software, to model different acquisition options. The model considers the multiple infield simultaneous operations (SIMOPS) while the survey occurs.

Once in the field, the specialists use the optimised plan and Osprey software to assist with the daily management of the operation, making adjustments as required.

The optimisation specialist communicates with other vessels so that everyone is up-to-date and working safely.



Read the full case study here.

COMPARATIVE BENEFITS OF STORAGE
DEPLETED AND DEEP SALINE RESERVOIRS

DEPLETED RESERVOIRS

1

Geoscience and engineering

Data Proven 'trap' of known dimensions.

Historically 'contained' a pressurized fluid.

Known porosity and permeability.

Known flow-rates and drainage boundary conditions.

2

Existing Infrastructure

Transport pipelines, platforms, & processing facilities and in some cases, well-bores (that could reduce initial storage project costs and in delaying otherwise necessary decommissioning).

3

Lower Pressure

A common belief is that a depleted field's low pressure will make injection easier.

Ability to "re-pressurize" back to initial conditions with a high degree of confidence that the 'seal' will hold to at least those initial pressures.

However...
...because of the volatile phase behaviour of CO_2, this apparent benefit has its limits and can quickly become a major disadvantage in certain circumstances.

VS

DEEP SALINE RESERVOIRS

1

More storage potential

Tend to be present at more of a 'basin wide' scale;

Widely distributed when compared to the generally smaller scale 'accumulations' that define oil and gas fields.

2

Location and Depth

Generally found in tectonically 'passive' areas.

Negligible subjection to significant stress or strain and, consequently, are often in areas of very low faulting density.

Generally deep and far below any fresh-water aquifers.

3

Hydrostatic Gradient

Generally pressured based on the hydrostatic gradient and are thus highly suitable for injection of super-critical CO_2 (high density, low viscosity).

4

Monitoring Suitability

Saline aquifers are also better suited to 4D seismic monitoring and tracking the movement of the CO_2 plumes. Whereas, the presence of residual hydrocarbons can have a significant adverse effect on the ability to identify and monitor the CO_2.

So what is the ideal scenario for geological storage of CO_2?

Time
Depleted reservoirs provide a relatively rapid path to storage with significantly less uncertainty on containment and injectivity efficiency from day 1. Drawback - the very penetrations that reduce the performance uncertainty also increase the risk of potential leakage points.

Pressure
Realistically, only depleted reservoirs that have a residual pressure in excess of 1071 psi are likely to be commercially attractive.

Infrastructure repurposing
The "re-use" of existing infrastructure may not be as cost-effective in terms of its suitability for CO_2 transport and injection as first sight might suggest. Upside - the ability to delay decommissioning may be a significant financial incentive/benefit.

Storage potential
Deep saline reservoirs will take longer to bring to project maturity. Upside - They have an order of magnitude more storage potential if injection rights can be secured over large areas.

Project design – management and monitoring
Deep saline reservoirs will almost certainly support super-critical injection and transportation in dense phase making the project design much simpler to manage and monitor.

MONITOR

To ensure safe CO_2 storage and containment over long periods of time it is imperative that the storage design and monitoring reflects this and provides assurance to all stakeholders including site regulatory and licencing authorities as well as developers, investors and the general public.

What we do	Making complex easy
Monitoring, Mitigation and Verification	MM&V capability gives surety to regulators and local government who must approve large CCS projects by providing confidence in the volumes of CO_2 stored, to ensure safety, environmental and commercial viability. Our teams support all phases of an installation from concept design through to decommissioning, providing services to deliver an installation's Safety Case and ongoing safe operation. Ongoing MM&V draws on several RPS disciplines such as geophysical survey design, support and analysis, stack monitoring, geohazards, meteorological, oceanographic and environmental sampling consultancy services. There are various techniques to monitor plume development and possible unplanned migration. These include gas detection, monitoring wells, microseismic, 4D seismic, and seabed monitoring by remote-operated vehicles.
Health, safety and risk mitigation	We combine sector specific regulatory and operational knowledge with experience of sector-specific best practice. RPS has established an excellent reputation for HSE and risk management services to the oil and gas, chemical, power, manufacturing, nuclear and defence sectors.

SLEIPNER WEST, NORWEGIAN NORTH SEA

CASE STUDY

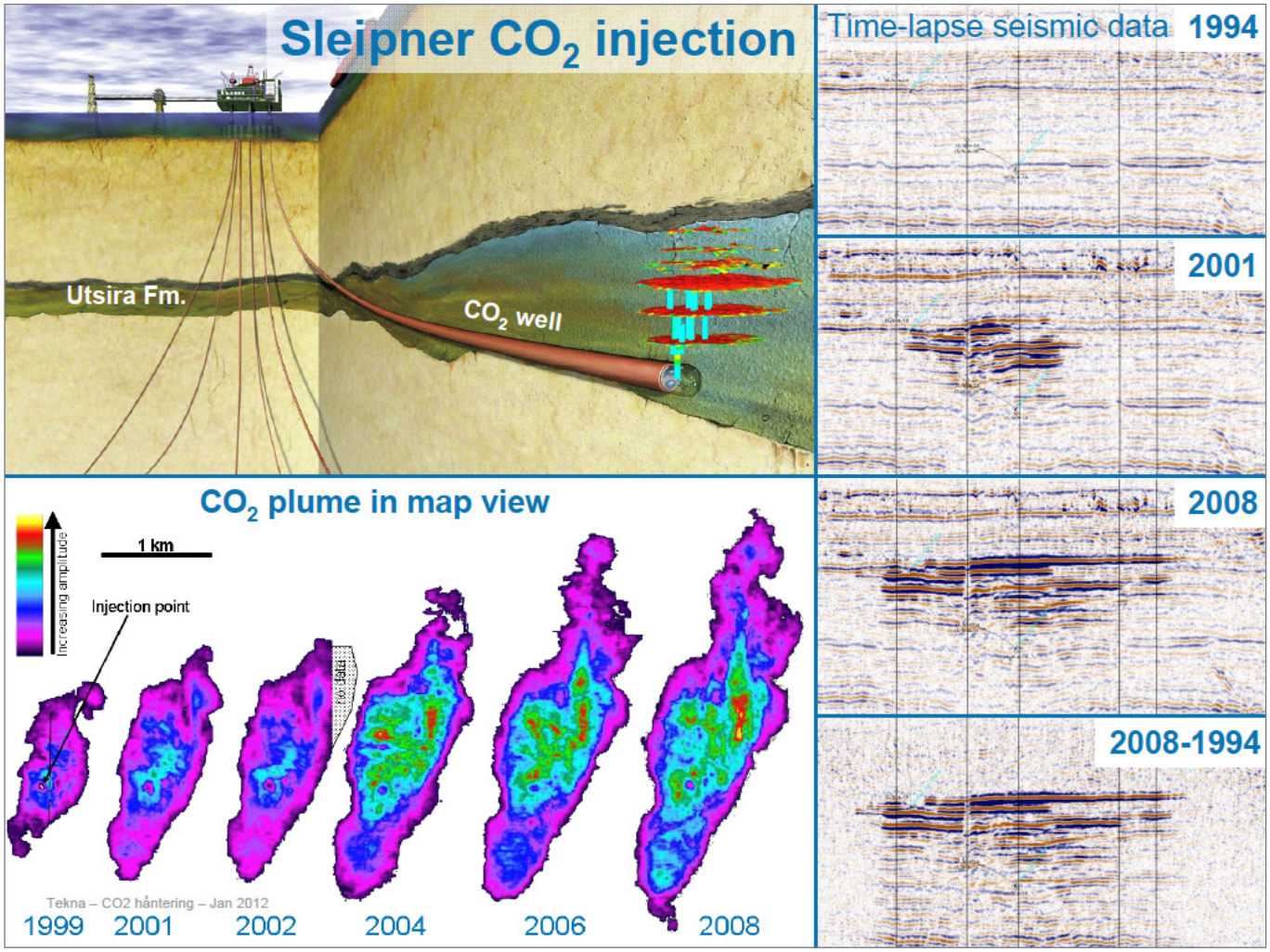


Image courtesy of Equinor

Carbon Capture and Storage 4D Seismic Monitoring

The objective of this carbon capture and storage (CCS) repeat seismic survey is to regularly monitor the distribution of Carbon Dioxide (CO_2), which has been injected into the 800 - 1100 m deep Utsira Formation. sandstone since 1996. Until now, about 18 million tons of CO_2 have been injected into the formation, and through time-lapse seismic studies the migration of the CO_2 will be studied.

The RPS solution involves making optimal line planning decisions to ensure that the survey data is acquired efficiently, minimising the number of lines required for completion. Achieving the 4D repeatability specifications ensures that the data acquired is of sufficient quality to meet the geophysical objectives to image the CO_2 plume.

The acquisition of the 2020 Sleipner CO_2 4D survey yielded good coverage and repeatable results ensuring the survey met its geophysical objectives. SIMOPS played a part during the survey, which was coordinated and managed by RPS with no lost time or rejected data.

Read the full case study **here**.

CAPABILITY DEVELOPMENT FOR CCS

Major national and international energy companies have heavily invested in CCS as they diversify their portfolios and strive to meet Net Zero goals. Governments and regulators around the globe are working on updating existing permitting and consenting regimes for CCS. The financial sector is looking at carbon markets for new opportunities.

These changes present new technical challenges for the companies and the individuals within them, requiring the development of new skills. However, many of the same skills used in oil and gas can be used in CCS but require additional specific expertise and context.

More information and a complete schedule can be found **here**.

Our self-paced e-learning courses provide participants with an awareness and understanding of subsurface CO_2 storage, CO_2 flow in the subsurface, and the critical issues of reservoir depth, well design, reservoir lithology and quality in relation to CCS. Skills transition courses focus on applying conceptual and technical approaches used in hydrocarbon exploration and production to the storage and utilisation of carbon dioxide. This focus enables geoscientists and engineers to apply their knowledge and skillset to the burgeoning CCS industry.

Instructor-led training is delivered in the classroom, virtually or in the field and can be blended with self-paced learning. Courses are also available for in-house training.

OUR STORY

RPS is a leading global professional services firm providing technical consultancy and operational support to the delivery of low carbon solutions throughout the asset lifecycle. We have deep expertise in the delivery of both offshore and onshore projects.

With 5,000 employees across 125 countries, we are a global organisation with a connected outlook and approach. We have a strong focus on Environmental, Social and Corporate Governance (ESG), with sustainability at the heart of our strategies.

The stand-out for our clients is that we use our deep expertise to solve problems that matter, making them easy to understand and we're easy to work with – Making complex easy.

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MAKING COMPLEX EASY