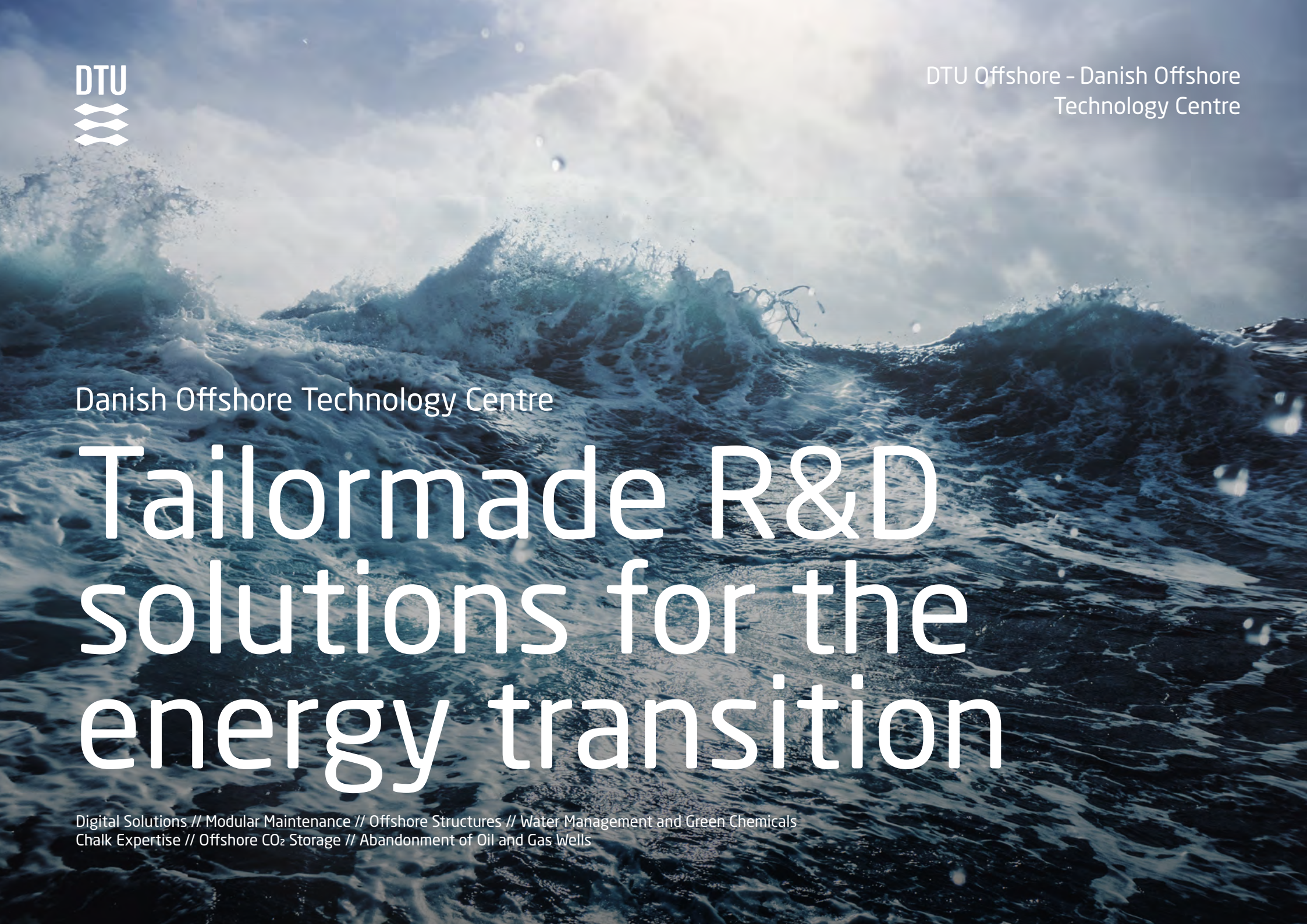

DTU

DTU Offshore – Danish Offshore Technology Centre

Danish Offshore Technology Centre

Tailormade R&D solutions for the energy transition

Digital Solutions // Modular Maintenance // Offshore Structures // Water Management and Green Chemicals
Chalk Expertise // Offshore CO_2 Storage // Abandonment of Oil and Gas Wells

A key player in the energy transition

DTU Offshore – Danish Offshore Technology Centre – is Denmark's national R&D centre for offshore technologies. We hold a central position in the energy transition by developing research-based technology solutions for the offshore industry in the North Sea.

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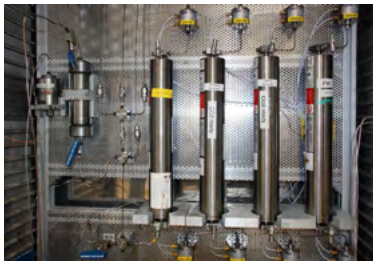
Digital solutions for the offshore industry



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Is your company ready for the energy transition?

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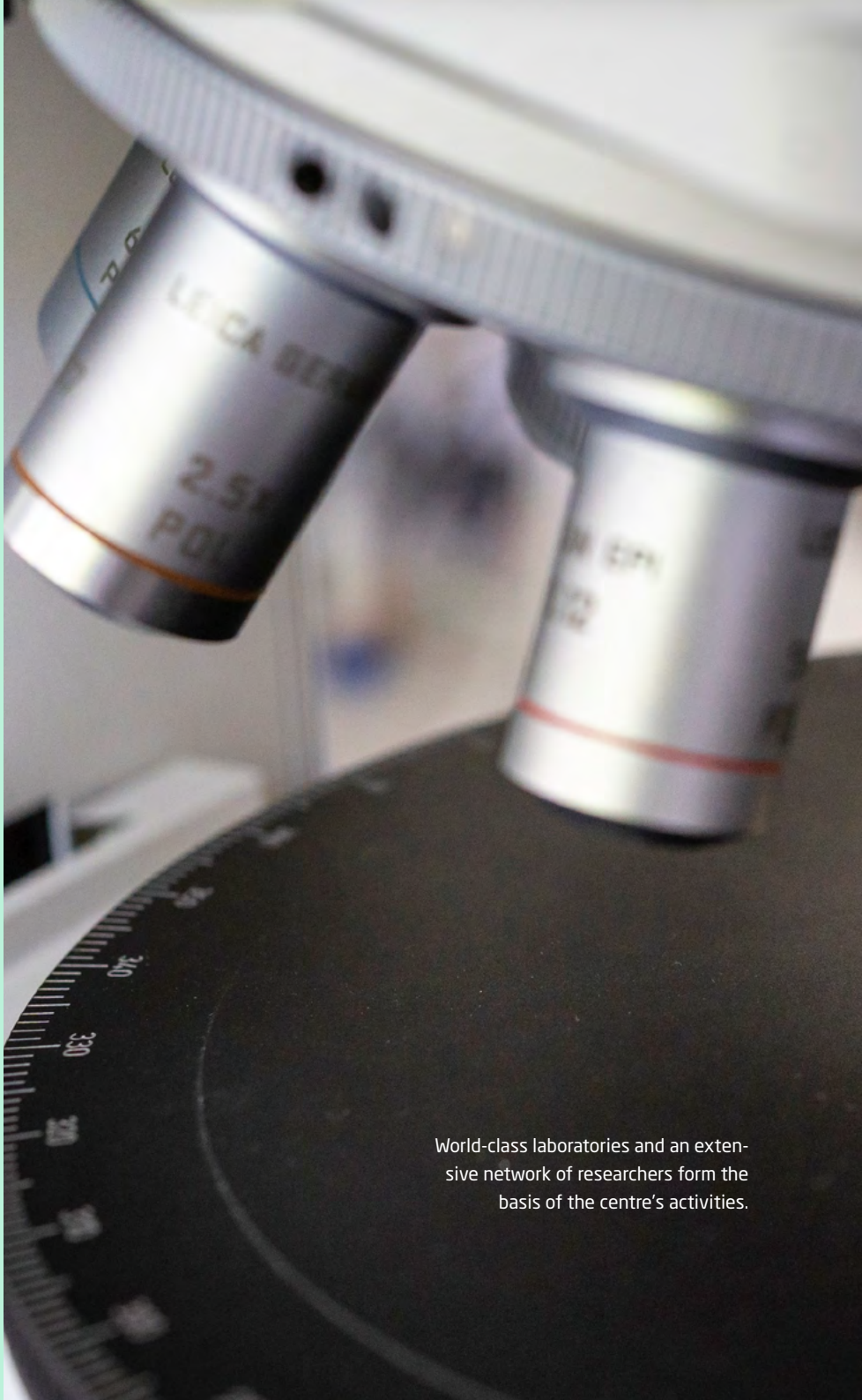
Unlocking the potential for CO_2 storage

The centre in brief

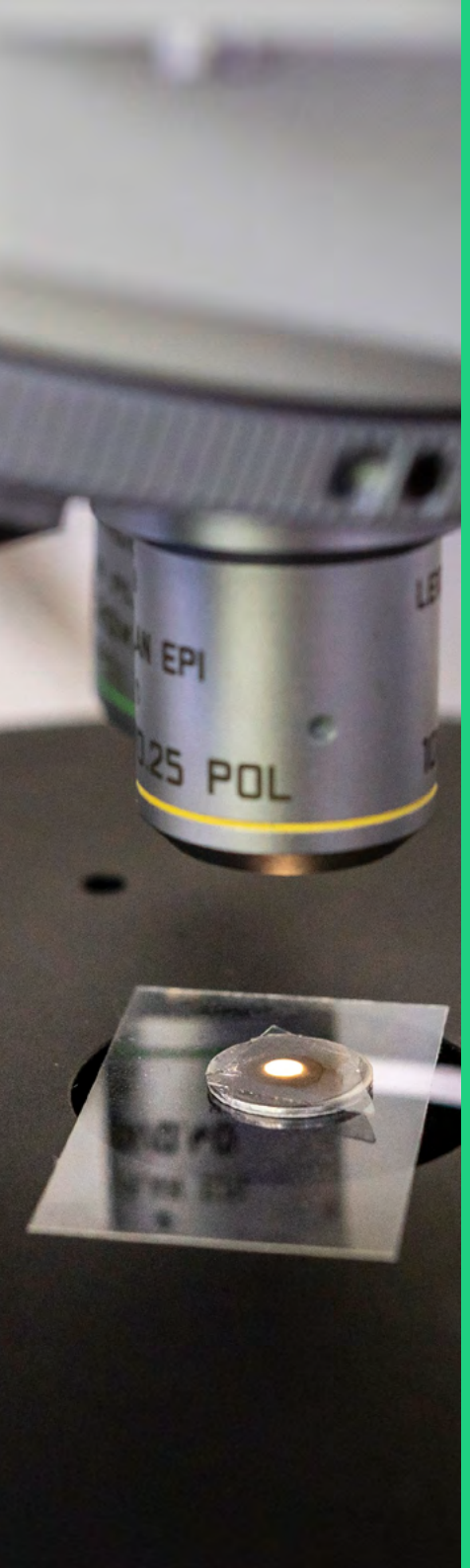
DTU Offshore – Danish Offshore Technology Centre – has since 2014 contributed with research-based, innovative solutions to the industry in the Danish North Sea. The centre is a network organisation with the key capabilities to expand collaborations across business and academia.

The centre is a private-public partnership between the DUC partners (TotalEnergies, Noreco, and Nordsøfonden) and academic partners DTU, University of Copenhagen, Aarhus University, Aalborg University, and GEUS. Our research and innovation happen in multidisciplinary teams across the network and utilize the cutting-edge expertise of each partner institution.

Frequently, we cooperate with other industry partners and researchers. We see this network approach as the best way to pioneering research with a clear line-of-sight to industry application.



World-class laboratories and an extensive network of researchers form the basis of the centre's activities.



DUC partners

TotalEnergies

nordsøfonden

NORECO

Danish Offshore Technology Centre - DTU Offshore

Academic partners

AALBORG UNIVERSITY

GEUS

UNIVERSITY OF COPENHAGEN

AARHUS UNIVERSITY

DTU

70+ corporate partners, including

RAMBØLL

LYNDAHL plastic extrusion technology

MUTAG

FLOATING POWER PLANT

Vysus Group

SINTEF

Ørsted

R&D creating value – our Equity Story

Based on a proven track-record of creating value for our industrial and academic partners, the centre continues to develop applicable technological solutions.

Independent evaluations show that our solutions will contribute 2 billion DKK to the Danish BNP and to our industry partners – that is twice the investment in the centre to date.

The centre attracts external funding from large public research and technology development programmes, such as EUDP and DFF. This supplements the funding from private companies (the DUC partners).

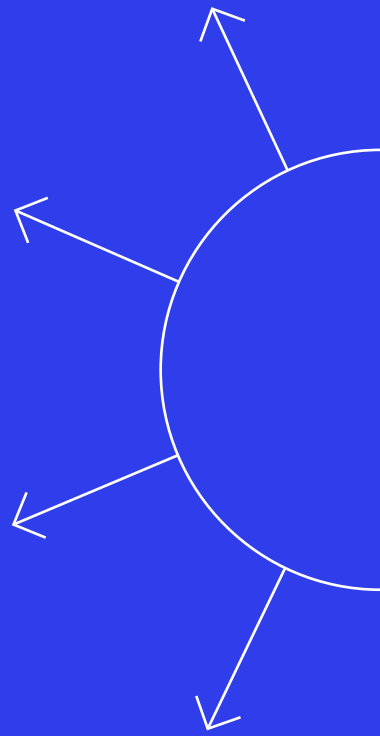
We see this as a strong starting point for future investment in the centre.

World-class laboratories

The research facilities at the centre include state-of-the-art chemical and rock labs, nano and micro CT-scanners, and advanced modelling software.

Clear strategy to be a key player in the energy transition

Since 2019, we have transformed the centre to become an important player in the R&D landscape when it comes to the energy transition. We will continue down this track while adapting to new challenges, for example is our research in CO_2 storage aiming at becoming an EU taxonomy eligible activity.



Talent development

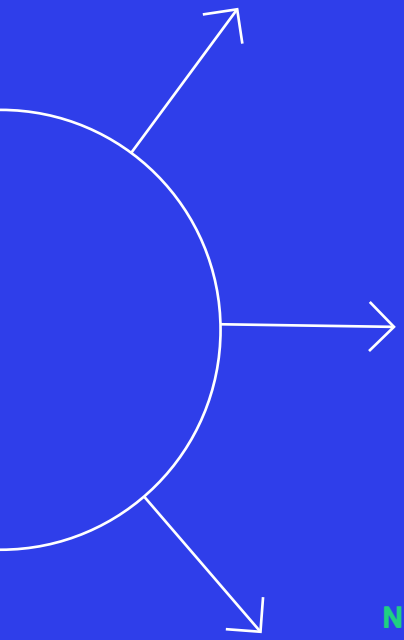
The centre has a proven track record in talent development with 50+ PhD's having graduated so far and many Master students affiliated to the centre. Our young talents learn first-hand about industry-academia cooperation, preparing them to work for companies in the energy and tech sectors.

Leading R&D centre creating value for industrial partners

We deliver tailor-made technology solutions to the leading North Sea companies.

Strong track record of high-quality applied research

The centre is an experienced R&D partner with a leading technical edge and well-documented innovation height in the projects. 600+ peer-reviewed publications have been published since the start of the centre.



Expertise in the most relevant technology areas

Our employees are leading experts in their fields, adapting to new challenges as the energy transition progresses. This flexible approach allows us to develop our project and programme portfolio according to the needs of society and industry.

Network organisation with strong project management and multidisciplinary workform

A unique structure with programme managers, a technology maturation team, and a business-oriented administration team forms the basis of the centre's work. It ensures that projects stay on track earning the benefits of a network-based, multidisciplinary workform and with a clear aim to provide tech solutions applicable for the industry.

Projects are expected to contribute

2 bn DKK to GDP

including external spill-over effects from research and innovation

Research has potential to reduce

85 pct. of oil discharges

to sea from oil production

The centre's researchers have published

600+

peer-reviewed scientific publications

Is your company ready for the energy transition?

DTU Offshore – Danish Offshore Technology Centre – has for almost ten years created solutions to concrete problems in the North Sea. And we have done it by combining academic research, industrial experience, and business understanding in a unique collaboration model. We are ready to welcome other innovative companies that are part of the offshore energy transition.

The North Sea plays a vital role for the energy transition in Denmark and Europe. After 50 years of oil and gas production, the North Sea is undergoing a transformation in the coming years with development of windfarms, energy islands, PtX, CO_2 storage, and more.

DTU Offshore – Danish Offshore Technology Centre – is a key player in this energy transition, which will require many new research-based technology solutions. In this publication, you can read about our competences in the research and development areas relevant to the energy transi-

> "We continue to aspire to contribute to the offshore energy system of the future with knowledge and technologies developed in a unique collaboration between academia and industry"
>
> **MORTEN JEPPESEN**, CENTRE DIRECTOR

tion – water management, carbon storage (CCS), digitalisation, offshore structures, and many more.

These R&D areas will help to combat climate change, protect the marine environment, and secure a reliable and affordable supply of energy, supported by the huge potential of digitalisation.

We work in close cooperation with our industrial partners TotalEnergies, Noreco and Nordsøfonden. The centre is focused on solving complex problems for the offshore industry, and is also open for other partnerships aiming at creating sustainable energy solutions.

Our unique way of working has proven valuable for the industry and for society in general.

Our collaborative R&D model will bring your company to the forefront of technology development and the energy transition.

On the following pages you can read about our expertise in some exciting and promising tech areas.

I hope you will enjoy reading about our work and invite you to contact me or our programme managers to learn more or investigate possibilities for collaboration.

Morten Willaing Jeppesen
Centre Director

Global challenges

Scarcity of energy resources and climate change are some of the monumental challenges that must be addressed now and in the coming years. This calls for a technology-driven energy transition to take place at a high pace.

DTU Offshore – Danish Offshore Technology Centre – views technological development as the key to solve the challenges and to support the massive push for a sustainable energy transition.

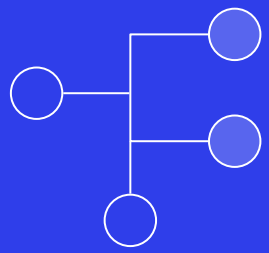
Everywhere, governments and businesses are looking for a steady supply of clean energy, but it is easier said than done.

Energy is a strategic resource, and scarcity combined with a need for emission reductions makes it very challenging to maintain a robust energy supply now and in the future. Digitalisation is one of the solutions.

During the energy transition, there is a need for a variety of different energy forms – some of which must be linked to CO_2 storage in the underground to reduce impact on climate change.

It is also about protecting the marine environment from pollution. Zero emission to the atmosphere and zero harmful discharge to the sea are ambitious goals that require development of new research-based technology solutions. Zero emission is an ambitious goal, but realistic if we manage to develop the proper technologies.

Therefore, we engage in research projects with top-level innovation height and collaborate with the industry. We also use the global trends as inspiration for our work, and we do so with a clear line-of-sight for application in the Danish North Sea.



A coherent energy system

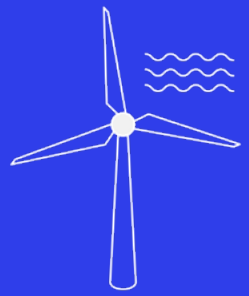
Modern societies are totally dependent on security of supply – and equally vulnerable when hit by a crisis that affects the energy supply. Hence, the energy transition must go forward in a balanced way that allows to build a coherent and robust energy system.

We have deep knowledge about several fields of research, originally developed for the oil and gas industry, which are applicable for other parts of the sector such as the wind industry and the energy islands. This could for example be the Modular Maintenance concept or our research on how waves can damage offshore structures.

Climate

The Danish subsurface can hold up to 22 billion tons of CO_2. This corresponds to a storage capacity that is 700 times greater than Denmark's current emissions – and the North Sea thus holds enormous potential when we are to achieve Denmark's goal of being CO_2 neutral by 2050.

We have been researching offshore constructions at the Danish Offshore Technology Centre for almost ten years and have deep insight into how the subsoil and the sea affect the structures. It is an insight that is essential for the decisions regarding both shutdown and potential reuse of the fields for CO_2 storage, just as it is valuable knowledge when new energy infrastructure is to be established offshore in the coming years.



Environment

Building infrastructure and operating energy production offshore requires a deep commitment to environmental sustainability.

The OSPAR Convention provides a legal framework for this; but we believe that the offshore industry must prepare for a future where a company's 'license to operate' goes beyond minimum standards.

This mindset is the basis for our R&D within offshore wastewater management, which aims to eliminate discharge of harmful chemicals to the sea.

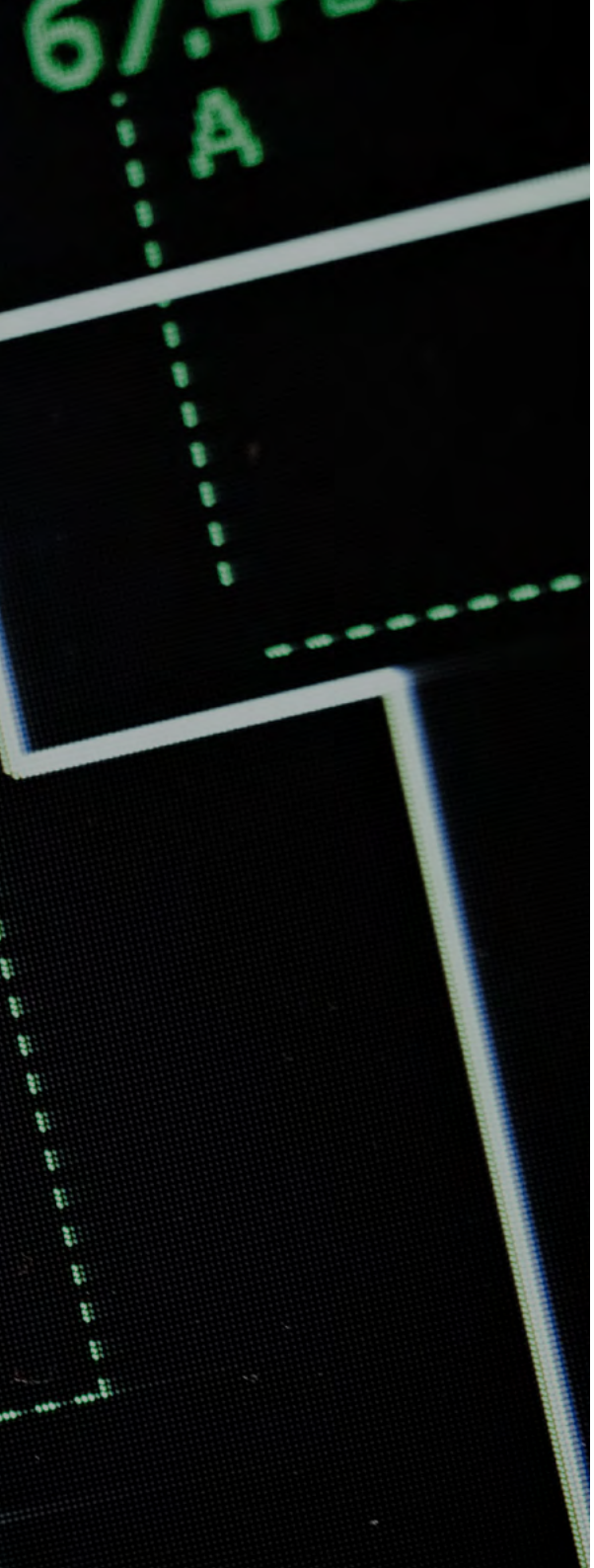
Digitalisation

The green and digital transitions are two sides of the same coin. In the European Green Deal, the EU's strategy for achieving the climate goals for 2050, it is called "The Twin Transition" because the two areas are mutually dependent. Neither can succeed without the other.

DTU Offshore – Danish Offshore Technology Centre considers digitalisation an enabler for the energy transition. Data analytics, AI, machine learning and other advanced digitalisation technologies are indispensable elements in our work to create solutions to concrete problems.

Digital solutions for the offshore industry

DTU Offshore develops advanced digital solutions for the entire value chain in the offshore industry.



Digitalisation is one of the most important trends in society in general, and this is clearly reflected in the offshore industry. Hence, it is a high priority for the centre to develop solutions that can be used by our industrial partners; over the years the centre has built a strong capacity in doing just this.

Our digital portfolio is extensive with modelling and simulation being a top priority.

We develop and work with advanced digital modelling tools, making it possible to map the underground under the North Sea in three and four dimensions (with time as the fourth dimension) in what can be described as 'Google Maps for the subsurface'.

Our ability to understand and digitally model the underground comes from many years of cooperation with the oil and gas industry. The same competencies can be used for Carbon Storage in depleted reservoirs or saline acquifers, and this may in the future lead us to explore even further possibilities, such as supplying geothermal energy to consumers.

Another example is the so-called Control Room Assistant, which has been developed together with Kairos Technologies and implemented in the North Sea energy sector. It is an advanced digital tool aiming at helping the staff monitoring production facilities. With this tool it becomes easier and less stressful for the staff to prioritise and act, when a sensor somewhere sends signals about a current or potential problem.

New digital technology solutions are being developed and matured by the centre in close collaboration with the industry to contribute to the Danish energy industry.

Many of the digital solutions developed by the centre in collaboration with our industrial partners are applicable in other industry sectors as well. We expect this aspect of our work to increase in the years to come – with sector coupling (increased integration of energy end-use and supply sectors with one another) being one of the key words.

Tech area

Modular maintenance

Emerging modular maintenance technologies offer ways to significantly improve productivity, quality, and enable huge cost savings for the energy industry.

Comprehensive and time-consuming maintenance remains a major challenge for the energy industry. The centre has therefore through extensive research developed an intelligent digital modular maintenance architecture for streamlining maintenance management.

The research has focused on optimising the scheduling of maintenance activities in highly maintenance intensive offshore platforms.

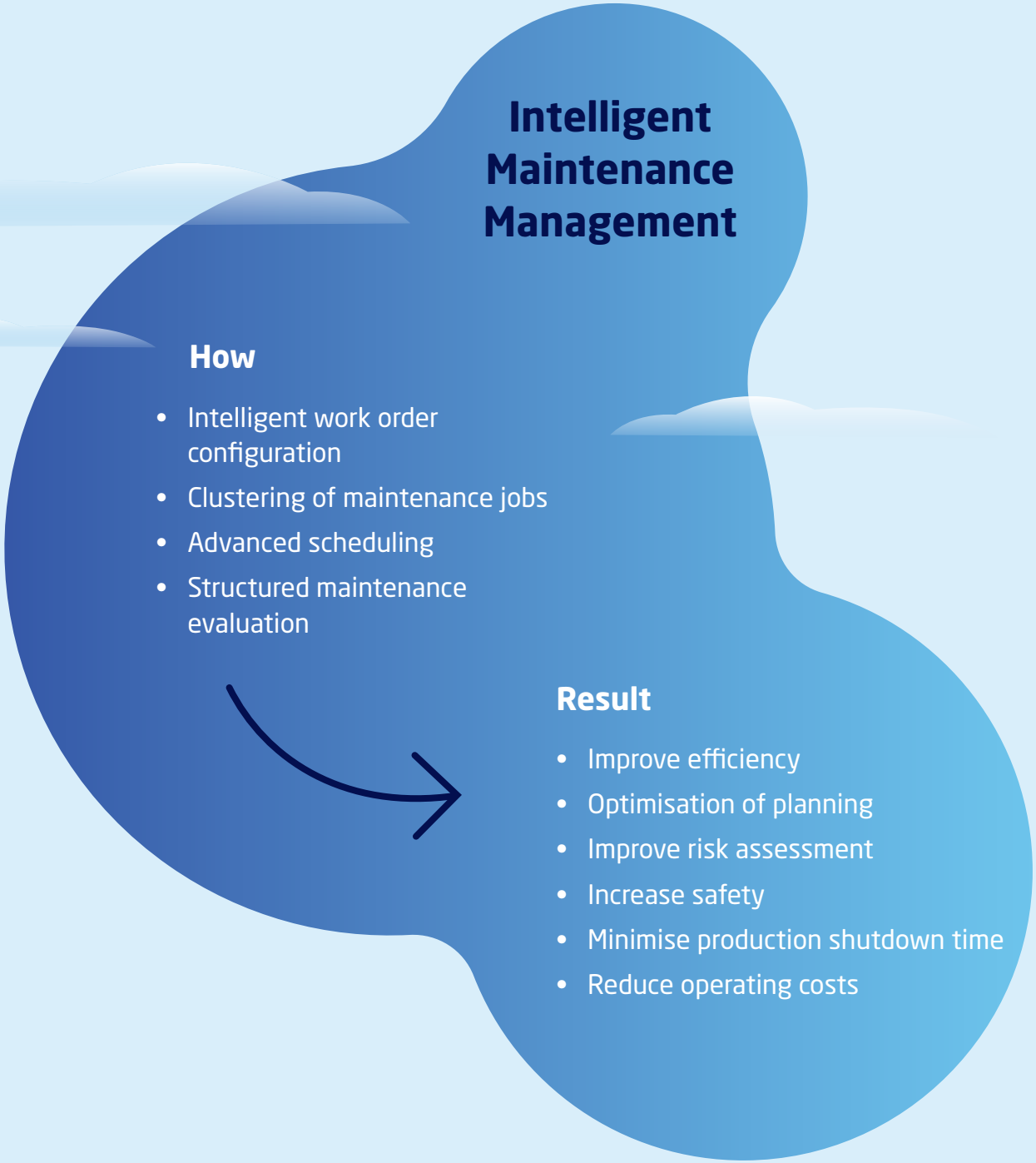
The architecture is based on computer algorithms, smart configuration systems, and systematic use of historical data. The modular maintenance architecture helps to manage the complexity; it makes it possible to systematically manage the full maintenance process: Identify, plan, schedule, and execute maintenance activities.

The configuration system can handle dependencies between equipment, failures, procedures, and resources. As a result, companies will experience minimised time spent on maintenance and shutdowns, and optimised utilisation of resources.

The modular maintenance solution has been tested and implemented on production platforms by one of our industrial partners – and with great success.

The modular maintenance architecture was originally developed for the oil and gas sector, but now the solution is ready to benefit other industries. It can be adapted into industries and sectors that deal with a high level of complexity.

This architecture is a frontrunner in optimising the utilisation of resources of complex and maintenance intensive structures as it enables informed decision making and improved strategies for maintenance. In other words, a tool for making the right decisions at the right time.



Tech area

Offshore structures

The North Sea is a rough environment calling for extreme measures to run energy production in a safe and responsible way. Our experience with developing solutions for the oil and gas industry may now benefit other sectors, such as the wind industry and the energy islands.

High winds, extreme waves, salt everywhere. The North Sea can be described as 'the perfect storm' when it comes to the need for protecting and maintaining infrastructures.

Developing new technological solutions for this purpose is one of the core capabilities of the centre, where we together with our extensive network in academia and the offshore industry build and test advanced innovations.

By combining real-life data and digital tools, it is possible to gain new insights that can be applied in today's offshore industry (oil, gas, and wind) as well as the planned energy islands.

We use advanced methods to analyse the structures' response to wave impact, to verify and update structural models, and to assess the state of the structure. In combination with a risk assessment tool, we are developing a monitoring system that allows for the identification of extreme load events and the corresponding damage to the structure. This will support the operator in making risk-based decisions on structural health and evaluate the need for repair and inspections.

The Wave Mapper

'The Wave Mapper' is a project scanning waves in the North Sea in 3D using advanced LIDAR technology. The purpose is to identify the extreme 'breaking waves' that can be hazardous to offshore installations but are difficult to calculate. Based on data from Wave Mapper and other sources, we may build a wave database that can be useful to the oil and gas industry, the wind sector, and the energy islands.

Corrosion Fatigue

'Corrosion Fatigue' is also focused on the issues that come from the constant movements of offshore structures because of wind and waves. These movements make tiny cracks which over time will result in metal fatigue. This is obviously a serious danger to the stability of the offshore structures and it calls for a rigid inspection and maintenance regime. The project addresses this issue through developing new design codes, taking modern materials into consideration, and optimising inspections.

Near Shore Test Centre

Still on the drawing board, the Near Shore Test Centre is an exciting possibility for the future. The concept is to set up an offshore structure west of the island of Anholt and use this as a testbed for wave analysis. The test facility will allow wave tank data to be correlated with real-life conditions, and the Near Shore Test Centre will at a 1:8 scale reflect the conditions of the North Sea.

Stevns Klint is not only a popular tourist destination but also frequently visited by our researchers on study trips.

Chalk expertise

After almost a decade of research, technology maturation, and application of tech solutions in the industry, DTU Offshore has become one of the leading R&D centres on the chalk structures underneath the North Sea.

Different times call for different measures. But chalk expertise continues to be a core competence at the centre as carbon storage replaces the need for oil recovery.

EOR – enhanced oil recovery – used to be a cornerstone of our offshore research and technology development. Now we use the technical competencies gained from EOR programmes to develop technologies for storing CO_2 in the offshore underground and for a controlled abandonment of depleted oil reservoirs.

Understanding the chalk structures underneath the North Sea is of vital importance for these projects. The centre's expertise is based on a deep knowledge of several fields of research combined in a multi-disciplinary approach, such as modelling of fractures and reservoir characterisation.

The centre's expertise is based on a deep knowledge of several fields of research combined in a multi-disciplinary approach – and with exciting future perspectives:

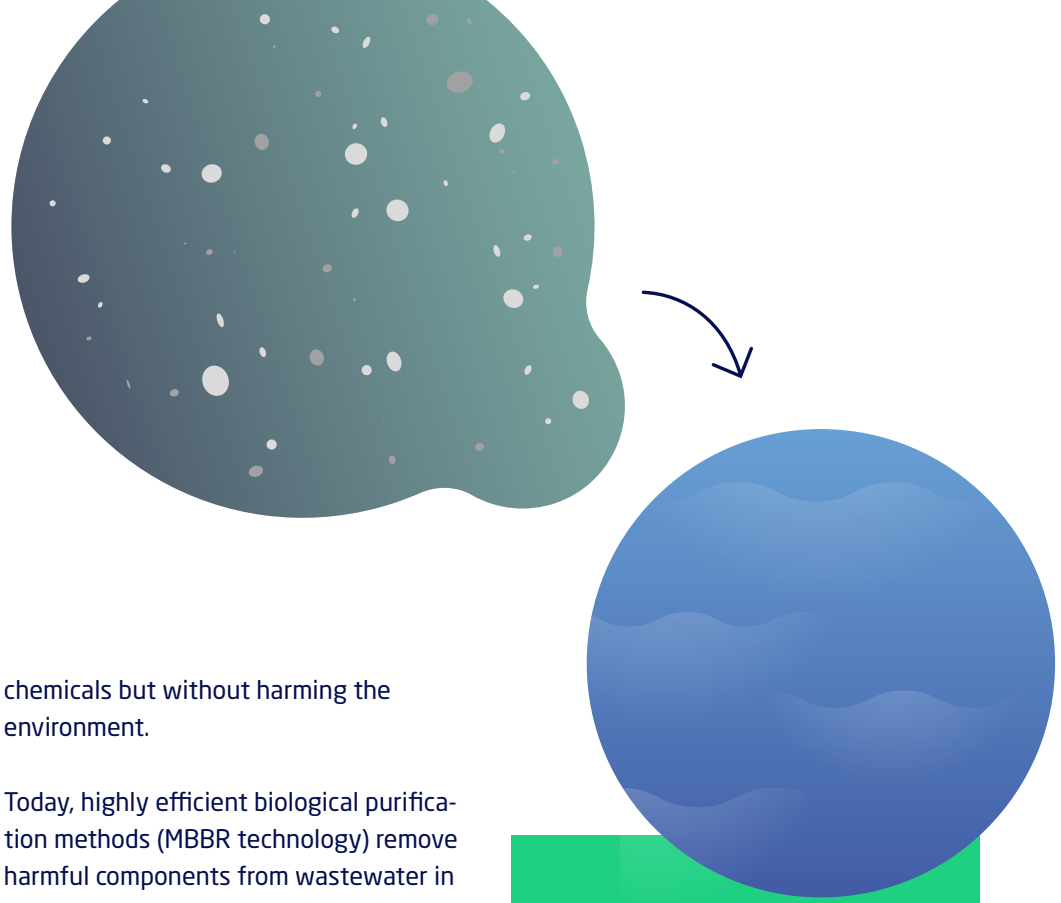
- **Modelling of fractures**
- **Multiphysics modelling / coupled modelling**
- **Reservoir characterisation**
- **Injectivity**
- **CO_2 storage**
- **Abandonment of reservoirs**

The centre's water management activities aim for zero discharges of harmful components into the sea.

Tech area

Water management

Our innovative water management solutions will help safeguard the marine environment in the North Sea and hold great potential for other industrial sectors.



Protecting the marine environment is the cornerstone of the centre's water management activities. We work on advanced research and technology development projects aiming at reducing discharges into the ocean with a long-term goal of zero harmful discharge.

Our Produced Water Management programme focuses on how the harmful components in water produced in connection with oil and gas extraction can be handled in the most environmentally responsible way. One focus area for the programme is to explore the possibilities of re-injecting produced water to a much greater extent instead of discharging it to the sea. This will significantly reduce the environmental impact on the North Sea.

Quantification of the environmental impact of energy production is another cornerstone in our activities. We develop new principles and analysis methodologies for this, and couple those with intelligent eco-toxicity testing strategies, including bio-degradability in the ocean environment.

We are also investigating whether environmentally friendly chemicals (so-called 'green chemicals') can replace the more harmful chemicals used today to optimise the offshore process: This will help preventing microbial activities, corrosion and scale mitigation as well as supporting H2S removal. 'Green chemicals' are plant-based substances, which will have some of the same functionality as traditional chemicals but without harming the environment.

Today, highly efficient biological purification methods (MBBR technology) remove harmful components from wastewater in municipal facilities located on land. In a research project funded by EUDP, we test how such biological purification units can operate offshore and underwater.

The perspectives in our program thus extend beyond the current challenges with wastewater from oil and gas production and far into the future energy solutions Denmark and the world urgently need.

Scaling and corrosion

We have developed high level expertise on understanding complex processes in reservoirs, wells, and pipes. This allows us to contribute to the on-going battle against scaling and corrosion. Mitigating this directly affects the use of chemicals and reduces discharge of inhibitor additives into the North Sea.

Tech area

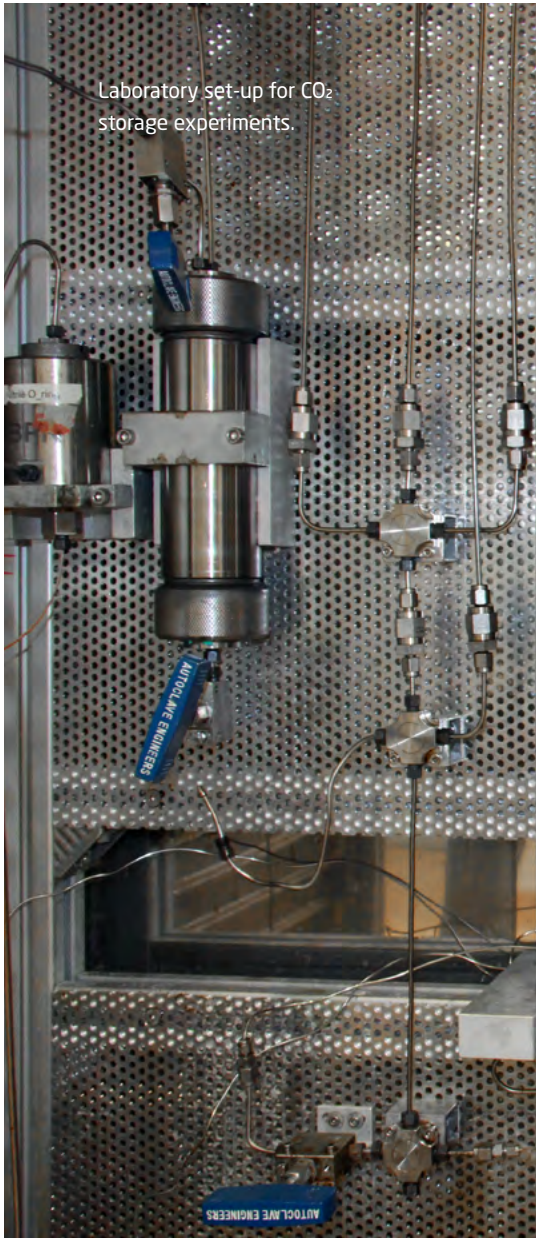
Unlocking the potential for CO_2 storage

In collaboration with our industrial partners and based on extensive offshore experience, the centre currently takes part in several activities on CO_2 storage. We are investigating how the existing oil and gas fields in the North Sea can be re-utilised by injecting CO_2 into depleted oil and gas fields.

CO_2 storage is one of the most promising technologies to address climate change. By reusing the existing infrastructure in the offshore oil and gas fields that are gradually being depleted, we can create a long-term sustainable storage solution. This holds great potential, as CO_2 storage is considered a vital technology to reach climate reduction goals set out by governments and international organisations.

Our research programme is based on a comprehensive state-of-the-art study, where we identified what is required to make CO_2 storage in the Danish offshore chalk fields a reality. Chalk expertise thereby remains a cornerstone in our work. Our ongoing research into the properties and behaviour of chalk under conditions such as CO_2 injection is fundamental for repurposing the Danish chalk fields to support the energy transition in Denmark through CO_2 capture and geological storage.

While our activities are focused on subsurface storage, wells, and monitoring for future leaks, we have cooperation partners along the whole value chain, including capture and transportation. We are continuing to develop our activities on CO_2 storage and are looking to expand the activities even further.



Laboratory set-up for CO_2 storage experiments.

Project Bifrost – a big leap towards large-scale CO_2 storage in the North Sea

Project Bifrost is an interdisciplinary collaboration between DTU, Ørsted, and the DUC partners (TotalEnergies, Noreco and Nordsøfonden). The project is financed with DKK 75 million from EUDP and combines decades of accumulated knowledge about the behaviour of the underground with new and current technological solutions to ensure the permanent storage of CO_2.

Project Bifrost aims at providing a long-term solution for CO_2 transportation and permanent geological storage by the reuse of existing offshore infrastructure. The plan is to initially store 3 million tons of CO_2 annually by the progressive conversion of two depleted gas fields in the Danish North Sea.

At DTU Offshore, we contribute with our chalk expertise, combined with decades of accumulated knowledge on the behaviour of the underground, to demonstrate the potential for permanent CO_2 storage in the Harald East chalk reservoir. This is ground-breaking research in the sense that it will be a world-first demonstration of CO_2 storage in chalk. The project therefore holds a significant potential to unlock large additional storage capacity both in Denmark and globally. And in parallel, our researchers are working on new and current technological monitoring solutions optimised for the offshore storage environment.

Tech area

Safe abandonment of retired platforms

The oil and gas fields in the Danish North Sea will in the coming decades become depleted, and with the Danish Parliament's decision to close oil and gas production no later than 2050, an immense abandonment task is ahead of us.

With our research programme on abandonment, we will first and foremost ensure effective abandonment for short- and long-term environmental protection. Advanced monitoring technologies are key for verifying long-term integrity of the abandoned wells, and we develop sensors that can monitor for and detect potential future leaks.

However, natural hydrocarbon seepage in the North Sea can mask the monitoring results. Therefore, our work to map the natural hydrocarbon seepage around the existing fields will give us a baseline that enables differentiation between natural seepage and potential leaks from an abandoned well.

Another long-term environmental impact of the abandonment operations is the removal of the offshore structures. How will this removal affect the marine environment? Several platforms have existed in the North Sea since the 1970s. We will investigate if they have become part of the ecosystem as a kind of artificial reef with the steel structures now a home for plants and fish. The role of the platforms for the surrounding marine environment is being examined in a three-year research project looking specifically at the cods.

For future leak prevention, the durability of the barrier material used for abandonment is key. Our research is looking into how the cement is behaving over time and whether the naturally occurring shale layers can form long-lasting barriers for the abandoned wells.

Our activities on abandonment are intertwined with our efforts within CO_2 storage in the existing oil and gas reservoirs. Hence, the development of monitoring technologies and the understanding of the durability of the abandonment barrier materials are important in the CO_2 storage scenario. Being able to use the existing oil and gas reservoirs for CO_2 storage can open for a second life for existing infrastructure.

The old Tyra platform has been removed and recycled. In the coming years, much of the infrastructure in the Danish North Sea must be abandoned in a responsible way.

Contact us

Do you want to know more about
our R&D solutions?

Do not hesitate to contact us:

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You may also meet us at one of the events, we organise on a regular basis. Read more on our web site - and don't miss out on the annual Technology Conference in November.

Published by
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