FIRST EDITION

State of CCUS

Danish research and innovation driving
CCUS solutions to combat climate change

INNO-CCUS
Carbon capture,
utilisation, and storage

About this publication:

This first edition of “Denmark: State of CCUS Research and Innovation” is developed and published by INNO-CCUS - one of four state-initiated mission-driven green research and innovation partnerships, supported by Innovation Fund Denmark.

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Foreword

Significant strides

To achieve the goals of the Paris Agreement, CCUS needs to play a crucial role. This is a fact that repeatedly has been emphasised by the International Panel on Climate Change. Therefore, it is my pleasure to introduce "Denmark: State of CCUS research and innovation" – a comprehensive publication bearing testament to Denmark's commitment to research and innovation within the field of CCUS to help combat global climate change.

CCUS is a core technology in the Danish green transition and onwards to climate neutrality. Denmark boasts a wealth of expertise across the entire CCUS value chain. From efficient power plants to innovative technology providers – we have it all. Our underground reservoirs, which have held oil and gas for millennia, are being repurposed for Carbon Capture and Storage (CCS). Denmark's abundance of renewable energy positions us perfectly to produce green hydrogen and utilise CO_2 (CCU), for example, to create eco-friendly fuels and plastics, tackling other pressing environmental issues.

Investments in green research and innovation are an important priority for the government. CCUS is one of four green missions identified in "Green solutions of the future – Strategy for investments in green research, technology, and innovation" from 2020. The missions address challenges where there is a need for accelerating the development of green technologies and solutions to reach the climate goals and help protect our environment and nature. From 2021 to 2024, a broad majority in the Danish parliament has prioritised 1.6 billion DDK to the four missions. The missions are to be solved mainly by four mission-driven partnerships, including the INNO-CCUS partnership.

The aim of the INNO-CCUS public-private partnership is clear: to be a catalyst for CCUS technologies, accelerating their implementation through partnerships spanning industry, academia, and public institutions. The collaborations focus on strategic research and innovation to surmount the barriers hindering the widespread adoption of CCUS worldwide. Combined, these research and innovations projects outlined in this publication, are a testament to Denmark's remarkable expertise within the field of CCUS. The compendium is beyond a mere collection of projects; it is a tool for researchers and experts to connect, collaborate, and secure the necessary resources to advance this mission.

All the elements are in place: technology, knowledge, dedicated individuals, and pioneering companies. Denmark's contribution to the global CO_2 emissions may be relatively modest, but our commitment to addressing the challenge is substantial. The collaboration between public and private sectors is instrumental in developing the technologies, policies, and partnerships required to propel the green transition. The challenge lies in making these technologies scalable and financially sustainable. This is where innovation and collaboration are essential.

This publication represents our commitment, featuring more than 100 projects across the CCUS value chain, involving various sectors and industries. Collaboration is the cornerstone of these efforts, and I am excited to see the diverse range of CCUS projects and the significant strides we are making.

In the spirit of innovation and cooperation, I invite you to explore the pages of this publication and discover what lies in the pipeline for scaling CCUS in the future.

Christina Egelund
Minister for Higher Education and Science

Reading Guide

The research projects presented in this publication are divided into five general categories: Capture, Nature-based solutions, Storage, Utilisation and Societal Coupling.

In each category, the projects are listed according to their expected Technology Readiness Level (TRL), starting from the most to the least mature projects. If a TRL estimate is not available, the projects will be listed alphabetically.

Each of the categories are described in brief on the following pages and in more detail in their respective sections of the publication. You can navigate to the different sections using the tabs on the right-hand edge of the publication.
In the back of the publication, you can find an index including registers listing all projects according to their titles, project tags and partners, respectively.

If you have any questions about this publication or INNO-CCUS, would like to provide feedback or have a project featured in the next edition, please feel free to reach out to us at:
info@inno-ccus.com

Content

At the global forefront

Dear reader,

Welcome to the first edition of our publication, Denmark: State of CCUS Research and Innovation.

Covering 100 research projects from more than 250 partners, this publication is a firm testament to the ingenuity, scientific curiosity and dedication characterising Danish knowledge institutions and the public and private sectors It showcases what can be achieved when these entities work together as well as the significance of the Danish foundations that are instrumental in keeping the field moving forward. Now more than ever, collaboration is needed if we are to deliver on the set assignment to develop and scale technologies that capture, store and use CO_2.

INNO-CCUS was created to help deliver on this exact purpose. As one of Denmark's four green mission-driven partnerships, we bring together close to 80 partners across research and companies in the CCUS field. The INNO-CCUS Partnership was established with the ambition to achieve a fundamental change in the way we view, value, and use carbon resources.

We support the development of technologies that capture, store, and use CO_2 so that we can secure a significant contribution to achieving the Danish government's climate goals on CO_2 reduction through CCUS solutions – efficiently, scalable and financially sustainable. In the long term, we can help turn CO_2 into a resource instead of a problem.

As this publication demonstrates, all the necessary pieces are there. Both in the form of technology, knowledge, people, and forward-looking companies that can pave the way for reaching the government's target of a CO_2-neutral Denmark in 2045. What will also become evident as you read through this publication is that there is much left to explore – indeed, many unknowns yet to be uncovered, which has always propelled scientific exploration.

With this publication, we want to give the first-ever comprehensive overview of the breadth and depth of Danish research and innovation within CCUS, situated firmly in the global forefront of the field. We aim for the publication to serve as a resource for researchers, knowledge institutions, decision-makers, and partners to find inspiration and new collaboration opportunities.

We would like to extend our warmest thanks to all researchers and partners who have contributed information about their projects and provided valuable feedback in the making of this publication.

If you have questions or would like a project represented in the next edition of this publication, please feel free to reach out to us.

We also extend our thanks to Innovation Fund Denmark for their support in developing this publication.

Happy reading,

Morten Stage, Chairman of the Board

Karina Marie Søgaard, Partnership Director

Scan the QR code to learn more about INNO-CCUS:

The INNO-CCUS partnership

The INNO-CCUS Partnership comprises close to 80 partners across knowledge institutions, GTS institutions, private companies, public companies, and organisations.

Ammongas

AquaGreen

BlueNord

CBS

clean
DANMARKS MILJØKLYNGE

CO2 Techn .com

COWI

Danfoss

DGC
Dansk Gasteknisk Center

DHI

DTU

EBI European Biochar Industry

energy CLUSTER DENMARK

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EXPLICIT
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The INNO-CCUS Partnership is funded by:

Looking ahead, Denmark is well positioned to play a key role in meeting the growing demand for CO_2 storage capacity in Northern Europe.

CCUS in Denmark 2023

Denmark has come a long way in a short period of time when it comes to establishing a strong set of framework conditions and creating an enabling environment for the development and implementation of a full CCUS value chain.

The Danish Climate Agreement for Energy and Industry, established on June 22, 2020, reflects Denmark's commitment to its climate policy goals by prioritising the capture, utilisation, and storage of CO_2. This commitment is further exemplified by the establishment of a market-based and technology-neutral pool dedicated to advancing CCUS. Since 2020, a series of political agreements have been forged to ensure the market-based deployment of Carbon Capture and Storage (CCS), including the comprehensive CCS strategy. These agreements are anticipated to yield a reduction of 3.2 million tons of CO_2 by 2030.

The Climate Agreement outlines the central framework conditions supporting the development of the entire value chain of CO_2 capture, transport, utilisation, and storage within Denmark. These conditions aim to provide a stable framework for the emergence of a new industry in Denmark while ensuring that society benefits from potential gains when shared resources are utilised. The agreement additionally defines the importance of a national CCUS strategy, with two sub-agreements from June and December 2021 paving the way for permits to store CO_2. A Power-to-X strategy, established in March 2022, explores the use of CO_2 in developing green hydrogen-based solutions. In addition, several legislative proposals have been passed in the Danish Parliament, establishing the legal framework for market development.

The year 2023 marks a historic year in Denmark for CCS, with the first CO_2 storage in the North Sea in March and Ørsted winning the tender for the first phase of the CCUS fund in May to establish the first full-scale CCS project in Denmark from 2026. A new comprehensive agreement from September this year paves the way for the capture of at least 34 million tons of CO_2. The agreement provides greater certainty for the full realisation of the potential for CO_2 capture and storage as early as 2029 while simultaneously removing obstacles and providing clarity regarding the establishment of CO_2 pipelines, transport, and the development of CO_2 storage facilities.

Looking ahead, Denmark is well positioned to play a key role in meeting the growing demand for CO_2 storage capacity in Northern Europe. The Danish underground is recognised for its substantial potential to contribute to both Danish and European climate goals. To ensure equitable distribution of future gains from CO_2 storage, the state will become a co-owner of permits for Danish CO_2 storage. Agreements with Belgium and the Netherlands that will enable future cross-border CO2 transport and geological storage beneath the seabed has already been made.

This publication is a testament to the number of projects and activities that have been established in the CCUS research and innovation field in Denmark within the last few years. Many of these projects are also a testament to how we seek to overcome our common challenges through international collaboration.

The projects in this publication are divided into five categories demonstrating the span across the entire value chain: Capture, Nature-based solutions, Storage, Utilisation and Societal Coupling

Category	Number of Projects	Accumulated Budget
Capture	13	DKK 314,386,000
Nature-based solutions	18	DKK 649,897,000
Storage	29	DKK 742,477,000
Utilisation	30	DKK 832,437,000
Societal Coupling	10	DKK 78,193,000

Categories in this publication

Capture

CCUS starts with the capture of CO_2. CO_2 can for instance be captured from the flue gas of large point sources such as power generation or industrial facilities that are using either fossil fuels or biomass as fuel. It can also be captured directly from the air. Currently, CO_2 capture technology in Denmark is developed for small-sized CO_2 reduction applications. In the coming years, the technology needs to be scaled up to end-users. The Danish Energy Agency has estimated a potential for carbon capture at point sources in Denmark of 5,4-10,8 million tons/ year by 2040..

Nature-based solutions

Nature-based solutions for climate change involve conserving, restoring, and managing ecosystems to remove CO2 from the atmosphere. Natural biological processes, such as photosynthesis, already play a significant role in capturing and storing carbon in ecosystems. However, land management practices, crop selection, and biomass use significantly influence the effectiveness of this storage. Danish research offers a unique foundation for improving and expanding carbon storage in biobased systems and materials through specific and targeted management practices.

Storage

Permanent storage of CO_2 in geological structures is necessary required to reach net-zero and negative emissions. The Danish underground has the potential to store up to 22 billion tonnes (GT) of CO_2, which is equivalent to 500 to 1,000 years of Denmark's current total emissions. This makes it relevant not only to store Danish emissions, but also to act as a storage hub for Northern Europe. Pilot CO_2 injections have already been accomplished in Denmark but the successful implementation of large-scale CO_2 storage in Denmark calls for up-scaling through research on the expected behaviour of the CO_2 once injected into the subsurface.

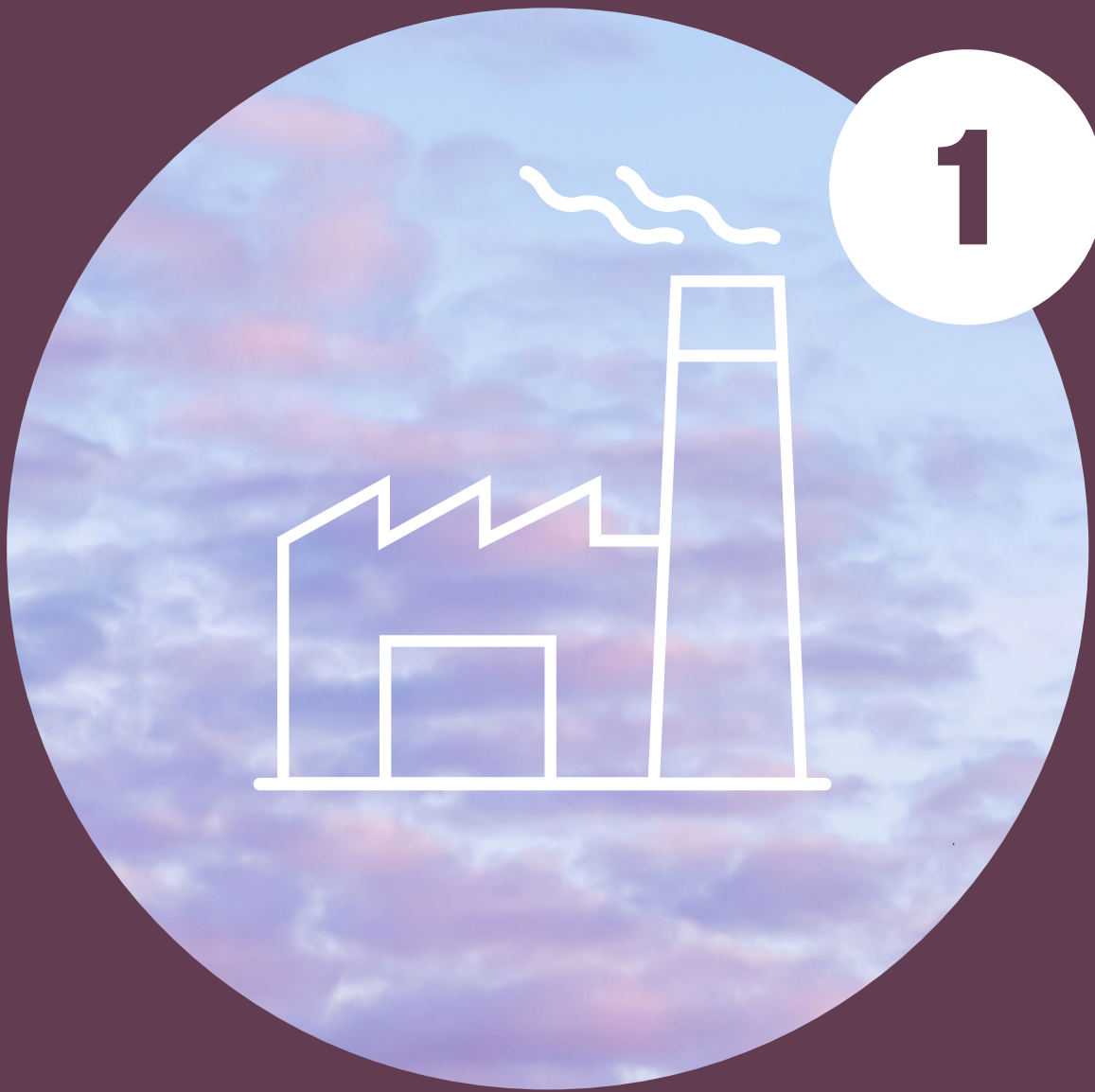
Utilisation

Carbon Capture and Utilisation will play a role in mitigating climate change by reducing CO_2 emissions and, at the same time, using CO_2 as a raw material for producing valuable products. CO_2 utilisation for chemicals and carbon-rich materials is a key enabler for deep decarbonisation in the hard-to-abate sectors. Even as recycling processes for materials are expected to improve significantly, there will still be a continuous demand for carbon-based materials. CO_2 utilisation industry is poised for growth, however, there is still a significant need for more research and innovation. Denmark has the potential to emerge as a global leader in this field, sharing its expertise with Europe and beyond.

Societal Coupling

Societal Coupling are focused efforts to reduce uncertainty and de-risk the CCUS sector. To succeed, the CCUS sector will not only require technological solutions and innovation but also public acceptance and the development of appropriate economic, regulatory, business models, and policy frameworks. The new sector will be an integral part of the larger energy system and decarbonisation efforts. To gain political and public acceptance and support it will require more coordinated development on both the supply and demand side.

Capture



Capturing CO_2

Carbon Capture, Utilisation, and Storage (CCUS) is a means to remove excess carbon dioxide (CO_2) emissions in our atmosphere. Carbon can be captured from various point sources, including industrial emissions, heat and power plants, waste-to-energy facilities, and biogas plants or it can be captured directly from the air.

One common method of capturing CO_2 from flue gases is to channel it through extended pipelines into a liquid medium, which contains specific additives facilitating the absorption of CO_2. Once the CO_2 is absorbed in the liquid, it can be separated and either utilised for alternative purposes or stored underground, either onshore or offshore.

Currently, CO_2 capture technology in Denmark is developed for small-sized CO_2 reduction applications. In the coming years, CO_2 capture in Denmark will be scaled up significantly when the first large-scale project set to capture 430.000 tons/year from two waste-to energy facilities begins in 2026.

The technical potential for carbon capture at point sources in Denmark is estimated by the Danish Energy Agency to be 5,4-10,8 million tons/year in 2030. The need for Direct Air Capture (DAC) has been estimated in different scenarios and could potentially contribute to reduce carbon from the atmosphere by approximately 5 million tons/year in 2050.

Achieving this goal necessitates innovation aimed at enhancing energy efficiency, reducing material costs, implementing large-scale process equipment, and exploring opportunities for industrial integration to enable the reuse of heat and the cyclic application of resources. These are all aspects that Danish projects and scientists are diligently working to optimise.

CAPTURE

CCCH2

Combined carbon capture and hydrogen production

Objective and hypothesis

The project will develop a new carbon capture technology based on electrochemical regeneration of the solvent combined with hydrogen production. Key objectives include scaling up the technology from pilot scale to a demonstration scale of several hundred kg CO_2/h removal from flue gas. The project will demonstrate the reliability and robustness of the technology, making it ready for commercialisation. Upon successful demonstration, the technology will be matured for full-scale plant implementation.

Approach

The project partners will collaborate to develop and demonstrate the technology. The process, devised by Estech, involves capturing carbon from flue gas using a solvent that is regenerated using (green) electricity in an electrochemical process and generates hydrogen that can be converted to other energy forms (Power-to-X). The technology is thereby delivering both carbon capture and Power-to-X solutions at the same time.

Expected impact/output

The project provides a new technology which, in one process, both removes CO_2 and produces hydrogen – this reduces the cost of CO_2 reduction from exhaust gases significantly. Additionally, the process is expected to be energy neutral as it only requires electric power. The versatility of the technology means that it can also be applied to smaller emitters of CO_2. The innovation has the potential to be a game-changing disruption in carbon capture systems, as well as a catalyst for a World-leading Danish industry over the next decades.

Budget:

DKK 33,640,000

Funded by:

Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners

Partners:

Estech, PureteQ, VandCenter Syd, Danish Gas Technology Centre & Technical University of Denmark

Contact:

Søren Gert Larsen, sgl@estech.dk

Timeline:

2022 — 2024

TRL:

→8

Tags

Point source capture | Process technology | PtX | Value chain

Learn more

CAPTURE

CASPER

Cement carbon storage pilot for emission reduction

Objective and hypothesis

The objective of the project is to evaluate the whole CCS value chain by demonstrating the full CO_2 capture and storage value chain from a cement plant.

Approach

The evaluation of the CCS value chain from a cement plant entail capturing CO_2 from Aalborg Portland. The project will capture and condition at least 20 tons of CO_2 from flue gas during a campaign in 2024. Additionally, the project will measure the quality of the CO_2 and compare it with existing standards relevant in 2024 and determine necessary post-capture processes needed in the full CCS value chain. Finally, the project will evaluate the effect on impurities on CO_2 transportation in a new 50 m-long CO_2 pipe test facility owned by Evida to prepare for CO_2 infrastructure that can be implemented in 2025.

Expected impact/output

The project will provide the first-ever evaluation of the CCS value chain from a cement plant and thereby introduce new knowledge to the sector.

Budget:

DKK 14,637,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Technical University of Denmark, Aalborg Portland, Evida, Pentair Union Engineering, Technological Institute, Gas Storage Denmark & Danish Gas Technology Centre

Contact:

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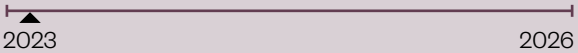
Timeline:



TRL:

4 → 7

Part of:

INNO-CCUS

Tags

Point source capture

Infrastructure

Value chain

Cement industry

Learn more

CAPTURE

CORT

Carbon capture open tests and review of technologies

Objective and hypothesis

This project will test and demonstrate solvents and process technologies for carbon capture (CC) at Aalborg Portland and Ørsted and find the best-suited solvents and processes for different CC cases. The project will provide an overview and comparison of the different CC processes that are available today.

Approach

The project takes advantage of the CC pilot system owned by DTU, which can be reconfigured for the project's purpose. Using the DTU-owned pilot, solvents (including proprietary solvents) can be tested and directly compared under different circumstances. For each solvent, a different optimal process configuration is expected, and the comparison is, therefore, not necessarily straightforward.

Expected impact/output

The optimised conditions found in this project will benefit all the solvents tested, and achieve lower energy consumption on amine-based CO_2-capture technology. The project will help CO_2 emitters choose the best-suited solution for emission reduction and may also result in more CC installations in Denmark.

Budget:

DKK 18,287,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Technical University of Denmark, Aalborg Portland, Pentair Union Engineering, FORCE Technology, Ørsted, ARC (Amager Resource Center) & Aalborg University

Contact:

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Timeline:

2022 — 2025

TRL:

3 → 7

Part of:

INNO-CCUS

Tags

Point source capture

Energy efficiency

Process technology

Cement industry

Learn more

CAPTURE

Green Twins

Data-driven digital twin platform to reduce CO_2 in industrial processes

Objective and hypothesis

Green Twins is a data-driven digital-twin platform aimed to virtually represent, optimise, and eventually control carbon capture in industrial processes and to minimise the associated energy cost. The project's emphasis is on digital-twin model development and the building of a digital-twin interface to handle data and perform control. For the duration of the project, one main (pre)industrial is envisioned: the digital twin of (defined parts of) the pilot plant for solvent-based capture of CO_2 from flue gas.

Approach

Three types of models are planned in the Green Twins project. The first model includes detailed computational fluid dynamics (CFD) models based on physical partial differential equations (PDEs). The second type of models include reduced, lumped models that simplify the detailed physical picture. The third type is full-scale plant models represented by flow diagrams in Matlab's Simulink (SimScape). These models use the above reduced models as physical inputs and can represent various virtual control scenarios. Once these controls are virtually executed, they will be put in the form of software executables to enable the driving of various active parts (pumps, valves) of the pilot plant.

Expected impact/output

The project is expected to inform operators of the plant - and of other carbon capture (industrial) units in the future - of the details of hidden dynamics of the carbon capture processes in the plant, enabling them to optimise CO_2 capture and related energy costs. In addition, the project creates new engineering jobs in the niche of green digital twins for CCUS. Finally, digital twins scale more easily than physical systems. Hence there is an opportunity for Denmark to export Green Twins rather than physical counterparts for carbon capture, with global impact.

Budget:

DKK 10,820,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Technical University of Denmark, Danish Technological Institute, FORCE Technology, Danfoss, Alexandra Institute

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Timeline:

2024 — 2026

TRL:

3 → 7

Part of:

INNO-CCUS

Tags

Point source capture

Simulation technology

Process technology

Energy efficiency

Learn more

CAPTURE

BioCO$_2$

Biogas upgrading for high-purity CO$_2$ and natural gas distribution

Objective and hypothesis

The objective of this project is to develop and demonstrate a new, more energy-efficient way of upgrading biogas for the combined production of biomethane and bioCO$_2$. The aim is to improve the profitability for biogas producers by enabling them to sell not only methane to the natural gas grid, but also high-purity CO$_2$.

Approach

Through analysis of data from existing biogas upgrading plants and experimental testing of the performance of new additives, the project will include benchmarking the anticipated technology from an energy- and cost perspective. The experimental work is done in both lab- and pilot-scale to investigate the mass transfer and reaction kinetics in the MEA-CO$_2$-H$_2$O-additive system. Based on the experience from the experimental campaigns, a mobile demonstration test unit (MTU) is constructed. The MTU will be used to test the capability of the additive-improved amine upgrading technology to produce both biomethane and bioCO$_2$ at two industrial biogas production sites.

Expected impact/output

Today, CO$_2$ from the upgrading of biogas is emitted as a waste product into the atmosphere. This project focuses on turning the otherwise emitted CO$_2$ into a valuable green product, which can be sold as an additional commercial product by the biogas producer. The financial viability of biogas production will be improved as a result of reducing the energy consumption of the amine adsorption-based biogas upgrading technique. Furthermore, the quality of the bioCO$_2$ should be high enough for food, biofuel, medicine production and welding purposes.

Budget:

DKK 13,800,000

Funded by:

The Energy Technology Development and Demonstration Programme (EUDP) & co-funding from project partners

Partners:

Technical University of Denmark (DTU Chemical Engineering), Pentair Union Engineering & Danish Gas Technology Centre

Contact:

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Timeline:

2016 — 2023

TRL:

4 → 6

Tags

Point source capture | Biogenic CO$_2$ | Biogas | Utilisation

Learn more

CAPTURE

CapSim

Optimising carbon capture simulation through advanced modelling tools

Objective and hypothesis

The objective of CapSim is to develop accurate, robust software tools to be used in and with process simulators for standard and novel carbon capture processes. The project also explores how inaccuracies in process design can impact subsequent steps in carbon capture and storage.

Approach

The project aims to improve CO_2 capture simulation technology by focusing on two key areas:

- Improving the core multiphase reactive algorithm to enable us to handle complex reactions and multiphase equilibrium efficiently and robustly.
- Better integrate thermodynamics, kinetics, and transport phenomena into the simulation, emphasising their impact on simulation results.

CapSim tackles algorithmic and thermodynamic challenges associated with CO_2 capture simulation, using tools like Aspen Plus, Pro/II, CO_2SIM, and CAPCO$_2$. It seeks to overcome challenges related to acidic gases, speciation, reactions, and thermodynamics. CapSim is structured into four work packages: addressing algorithmic challenges, thermodynamic models, process uncertainties, and optimisation. The project utilises advanced algorithms like RAND and focuses on robustness, efficiency, and accuracy.

Expected impact/output

Capture simulation is the vehicle to bring various novel ideas to industrial scale implementation. Advancement of the key capture simulation technologies will enable quicker adoption of new solvents and a more reliable optimisation towards capture with lower energy consumption. Capture is the costliest step in CCS and the bottleneck for the whole chain.

Budget:

DKK 12,592,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Technical University of Denmark, Aalborg University & Schlumberger

Contact:

Nicolas von Solms, nvs@kt.dtu.dk

Timeline:

2023 — 2027

TRL:

3 → 6

Part of:

INNO-CCUS

Tags

Point source capture | Simulation technology | Modelling | Process technology

Learn more

CAPTURE

ConsenCUS

Carbon neutral clusters through electricity-based innovations in capture, utilisation and storage

Objective and hypothesis

The project's objective is to provide an industrial roadmap to a net-zero carbon future through carbon neutral clusters by way of electricity-based innovations in Capture, Utilisation and Storage. The project will demonstrate this concept by integrating a mobile demonstration unit at major cement, magnesia and oil refining installations.

Approach

The mobile demonstration plant will capture up to 100 kg/h of the sites' CO_2 and perform various demonstration cycles to establish optimal operation conditions, considering different CO_2 concentrations and impurities. CO_2 will be captured from the flue gases using a scrubber tower with alkali solution in water. The spent sorbent will be electrochemically regenerated using a pH swing, while simultaneously separating CO_2, which can be directed towards storage or conversion. The pure CO_2 stream will be electrochemically reduced in a potassium hydroxide solution towards potassium formate. The project also presents safe cyclic loading of CO_2 into salt formations and aquifers for storage.

Expected impact/output

The project provides a holistic solution that do not sub-optimise single industries, technologies, or countries. The project develops conceptually different electricity-based capture and conversion innovations that supplement the thermal, organic solvent state-of-the-art CCU solutions. This will have an especially strong benefit in places where no waste heat is available, or where variable renewable electricity needs to be integrated. The innovative technology of the project demonstrate energy and cost-efficiency beyond the current industrial standards as the capture and conversion routes are unique in taking only electricity and water as consumables.

Budget:

DKK 104,000,000

Funded by:

European Union's Horizon 2020 research and Innovation programme under grant agreement N° 101022484 & co-funding from project partners

Partners:

New Energy Coalition, Wetsus, European Centre of Excellence for Sustainable Water Technology, Coval Energy BV, University of Groningen, Research Center for Carbon Solutions at Heriot-Watt University, British Geological Survey, Robert Gordon University, Technical University of Denmark, Energy Policy Group, Center for Research and Technology Hellas, Oil and Gas Technology Center, The Geological Survey of Denmark and Greenland (GEUS), OMV Petrom, Grecian Magnesite, Aalborg Portland, Danish Gas Technology Centre, University of Calgary, Stork/Fluor, INEOS Chemicals & Energinet

Contact:

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Timeline:

2021 — 2025

TRL:

2 → 6

Tags

Point source capture

Cement industry

Utilisation

Value chain

Learn more

CAPTURE

NEWCEMENT

CO_2 capture by oxyfuel combustion at cement plants

Objective and hypothesis

Oxy-fuel combustion, combustion in the presence of oxygen rather than atmospheric air, stands as a promising carbon capture technology to significantly reduce CO_2 emissions from cement production. However, further investigations and demonstration activities are required to mature the oxy-fuel cement process. Thus, the aim of the project is to:

- Mature oxyfuel cement plant technology for full-scale testing.
- Develop an oxyfuel pilot calcination reactor.
- Create digitalisation technologies for CO_2 emission-free cement production.

Approach

In the first part of the project, the business viability of developments will be validated and benchmarked against competing solutions. In the second part, an oxyfuel pilot will be developed to analyse the gas stream to gauge CO_2 separation ease and purity. Additionally, it will be analysed, how temperature uniformity influences calcination in the oxyfuel process, and how fuel-to-oxygen ratio impact product quality. In the third part, the project focuses on process simulation to optimise the oxyfuel cement plant layout, including preheating integration. This includes studying the effects of high CO_2 levels on calcination, the influence of oxyfuel conditions on volatile elements, and CO_2 flue gas recirculation. Lastly, the effects of CCUS on the supply chain are analysed to ensure a cost-effective, net-zero carbon energy supply and cement production.

Expected impact/output

Cement is a significant global industry, accounting for approx. 8% of current global CO_2 emissions. By developing oxyfuel cement technology, the project has potential to contribute to large global CO_2 reductions. The project is expected to obtain a fully integrated pilot plant, process knowledge, new design tools and a technical layout, including techno-economic documentation. This information will pave the way for the first large-scale industrial unit and accelerate the decarbonisation of the cement sector. The technology may also provide a basis for the market possibility of upgrading CO_2 from cement plants to e.g., methanol.

Budget:

DKK 11,364,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Technical University of Denmark, Danish Technological Institute, FLSmidth & Lhoist

Contact:

Jens Christiansen, jec@teknologisk.dk

Timeline:

2022 — 2025

TRL:

2 → 6

Part of:

INNO-CCUS

Tags

Point source capture | Cement industry | Process technology

Learn more

CAPTURE

ASGREEN

Advanced solvent with green regeneration by electrochemical energy and nanotechnology

Objective and hypothesis

The project aims to develop an optimised, cost-effective electrochemical cell for carbon capture. The novel cell configuration should display improved capture efficiencies, make use of sustainable capture solvents, and provide a commercially pure CO_2 output. Finally, the project will develop an advanced thermodynamic model to predict experimental data within 5% uncertainty during 2025-2026.

Approach

Achieving a pure CO_2 stream is difficult with current cell designs, and high gas purity is crucial for repurposing CO_2. For this reason, the ASGREEN technology entails a rethinking of membrane configurations in the cells. The novel ASGREEN technology will be optimised through both laboratory scale tests and pilot tests. Solvent composition, membrane materials and configurations, and electrode materials will be analysed and optimised. In addition, long-term application of the ASGREEN set-up will be examined in pilot.

Expected impact/output

The ASGREEN technology can help create value for customers by eliminating their CO_2 emissions in a cost-effective manner. This will have economic implications for companies by reducing the amount of regulation-imposed emission taxes they have to pay. Additionally, the scalability of the technology will make it easy for especially small- to medium-sized CO_2 emitters to implement carbon capture.

Budget:

DKK 12,345,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Technical University of Denmark, Aalborg University & Estech

Contact:

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Timeline:

2023 — 2026

TRL:

3 → 5

Part of:

INNO-CCUS

Tags

Point source capture | Process technology | Modelling

Learn more

CAPTURE

Aalborg I

Carbon capture from Aalborg Portland

Objective and hypothesis

The project is the first step in realising Aalborg Portland's vision of creating a flagship for CCUS in the industry. The project's objective is to analyse and model two different CO_2 capture technologies, with the aim of providing a decision-making basis for selecting the most cost-effective CO_2 capture technology for Aalborg Portland.

Approach

This project analyses and models the CO_2 capture technologies, Cryogenic and Amin-Based CO_2 Capture, to assess which is most the cost-effective. Subsequently, the result is used in designing the carbon capture flagship in Aalborg. The project examines the possibility of delivering system services from a cryogenic CO_2 capture facility and the potential to achieve the required purity of CO_2 from this type of facility. This is done through participation in DOE-supported experiments with cryogenic CO_2 capture at a cement factory in Missouri, USA.

Expected impact/output

The project provides a decision basis for the selection of CO_2 capture technology for Aalborg Portland based on comparative studies of the most relevant technologies. Furthermore, the project provides the design for the CO_2 capture flagship project in Aalborg, including expected operational data and economic efficiency, as well as infrastructure design with a focus on sector coupling around the CO_2 capture facility in Portland, Aalborg.

Budget:

DKK 3,070,000

Funded by:

REACT-EU (Regional Development Fund)

Partners:

Aalborg Portland, Aalborg CSP & Aalborg University

Contact:

Maria Kristiansen, mak@energycluster.dk

Timeline:

2022 – 2023

TRL:

3 → 4-5

Part of:

CO2vision

Tags

Point source capture

Cement industry

Process technology

International collaboration

Economy

Infrastructure

Learn more

CAPTURE

eDAC

Large scale integration of DAC in energy systems

Objective and hypothesis

This project's aim is to provide guidelines for stakeholders across the entire value chain, covering both technology and SSH aspects. This includes the development of an extension to state-of-the-art energy system analysis (EnergyPlan), enabling the assessment of DAC-PtX system performance in existing energy systems. Collectively, the project will assess technology, economy, business models, and regulatory issues for DAC deployment, consolidated into recommendations for how DAC can efficiently be system integrated.

Approach

The three-year project consists of three work packages, all with the same time plan, starting in the beginning of the project and finishing at the end of the project. The reason is the iterative approach between work package 1 and work package 2, where thermodynamic modelling continuously provides input to the energy system modelling. Furthermore, work package 3 will continuously work with work package 2, to assess the SSH aspects. The three work packages will, among other things, investigate DAC processes and the implementation of direct air capture modules in energy system analysis models.

Expected impact/output

DAC is regarded as an inflection point, and the deployment of DAC is a necessity to reach capture rates in the order of Gt CO_2/year, needed to deflect global CO_2 emissions. DAC can provide storage capacity and thereby increase the utilised capacity of existing and future intermittent power production. The impact on emission reduction in Denmark is long-term as DAC is not mature, but it is highly important to ramp up activities now to harvest its enormous potential in due time.

Budget:

DKK 4,400,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Aalborg University, COWI, EuroWind & Port of Aalborg

Contact:

Thomas Helmer Pedersen, thp@energy.aau.dk

Timeline:

2022 — 2025

TRL:

4 → 5

Part of:

INNO-CCUS

Tags

DAC · Energy systems · Society · Value chain · PtX · Economy

Learn more

CAPTURE

DemoBECCS

The potential and demonstration feasibility of bioenergy with carbon capture and storage

Objective and hypothesis

The experiences with BECCS from real large-scale projects are limited. Insufficient technical understanding of how biogenic CO_2 affects the CCS chain hinders the implementation of BECCS. This project aims to investigate the potential and feasibility of carrying out BECCS in both Denmark and China. The project mainly focuses on capturing CO_2 from biomass co-fired power plants and storing biogenic CO_2 in depleted oil reservoirs.

Approach

The Danish research is focused on two key BECCS areas, i.e., CO_2 capture from biomass co-fired power plant, and CO_2storage using biogenic CO_2. The project will be in close collaboration with the Chinese side, which will study the whole BECCS chain with potential applications intended for biogenic CO_2 in North China. In addition, the whole BECCS chain will be studied through collaboration.

Expected impact/output

If successful, the project will lower energy consumption of CO_2 removal to 2.3 GJ/t for capture from biomass co-fired power plants and show the feasibility of storing biogenic CO_2 in the planned Nini storage site in Denmark and other similar storage sites. The project will likely act as the first mover for the BECCS implementation in both countries, with the participating companies already engaged in CCS demonstration or planning, and eager to quantify the uncertainty of BECCS and accelerate its implementation.

Budget:

DKK 11,831,000

Funded by:

Innovation Fund Denmark & co-funding from project partners

Partners:

Technical University of Denmark, INEOS Oil & Gas DK, Wintershall Dea, Aker Carbon Capture, Institute of Rock and Soil Mechanics at the Chinese Academy of Sciences, Shanghai Advanced Research Institute at the Chinese Academy of Sciences, SINOPEC Petroleum Exploration and Production Research Institute, SINOPEC Petroleum Engineering Corporation, China University of Mining and Technology & Chongqing University

Contact:

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Timeline:

2023 — 2025

TRL:

2 → 4

Tags

Biogenic CO_2 | Point source capture | Value chain | Geological storage | International collaboration

CAPTURE

Net Zero Arc

Net zero energy carbon capture at ARC

Objective and hypothesis

The objective of the project is to investigate how to best integrate carbon capture with waste incineration and whether it can be done in an energy-neutral manner, so the excess heat from the carbon capture process is utilised for district heating. The project, therefore, aims to construct, commission and operate a cost-effective demonstration-scale Carbon Capture (CC) unit at ARC.

Approach

ARC has been conducting experiments with a smaller pilot unit since 2021. The unit has subsequently been used in several other locations in Denmark. Due to the positive results, ARC did open a larger demonstration facility in 2023 with a capacity of nearly 4 tons of CO_2 per day. The purpose of the demonstration facility is:

1. To gain a better understanding of the technology to enable the construction of the best possible full-scale plant.
2. To further reduce the energy requirements beyond what was achieved in the pilot plant.
3. To simulate the connection to the district heating network, maximising the utilisation of the heat generated.

Expected impact/output

The outcome of the project will be a complete demonstration-scale CC unit that will be constructed at ARC, integrated with the waste-to-energy plant, and optimised for net zero energy consumption. The project will be part of a decision base for ARC to decide upon an investment in a large scale CC unit to capture all the 500,000 tons of CO_2 emitted by ARC every year.

Budget:

DKK 62,600,000

Funded by:

The Energy Technology Development and Demonstration Programme (EUDP) & co-funding from project partners

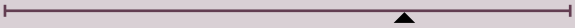
Partners:

ARC (Amager Ressourcecenter), Pentair Union Engineering, RambøllDenmarkTechnical University of Denmark

Contact:

Jannik Kappel, jkap@a-r-c.dk

Timeline:



Tags

Point source capture | Energy efficiency | Value chain | Process technology

Learn more

ARC is working towards making Amager Bakke CO_2-neutral. And the demonstration carbon capture unit is an important step towards meeting that goal.

Jannik Kappel, Project Manager for Carbon Capture, ARC

Nature-based solutions

2

Nature-based solutions for removing CO_2

Nature-based solutions for climate change involve conserving, restoring, and managing ecosystems to remove CO_2 from the atmosphere. This includes strategies like reforestation, wetland restoration, and sustainable agriculture practices. Some nature-based solutions, such as conserving existing wetlands, serve mainly to prevent greenhouse gas emissions. Others, such as restorative agriculture and regrowing forests, actively remove CO_2 from the atmosphere. The ocean and forest are examples of natural carbon sinks that absorb carbon directly from the atmosphere.

Natural biological processes, such as photosynthesis, already play a significant role in capturing and storing carbon in ecosystems. However, land management practices, crop selection, and biomass use significantly influence the effectiveness of this storage.

In Denmark, there is significant potential for increasing and strengthening contributions from nature-based carbon storage towards the 2030 and 2050 climate targets. This involves increasing carbon uptake (aditionality) and ensuring its stability in ecosystems (permanence). Denmark's expertise in land and ecosystem management forms a strong foundation for improving carbon storage in biobased systems and materials through targeted practices.

To harness the full potential of these solutions, the adoption of new measures and innovations is essential. This category includes scientific projects and activities that aim to protect, manage, enhance, and restore nature to address challenges and include reforestation and afforestation, soil carbon sequestration and biochar.

NATURE-BASED SOLUTIONS

MitiChar

Mitigation of climate impacts from plant production with biochar from straw and biogas digestates

Objective and hypothesis

The aim of MitiChar is to explore the potential of biochar to mitigate climate impacts of plant production. Agricultural plant production emits large amounts of N_2O, a greenhouse gas 300 times stronger than CO_2. Mitichar aims to identify mechanisms that allow biochar to reduce N_2O emissions and optimise them. Furthermore, the ability of biochar to store carbon and improve soil physical properties will be examined. Mitichar will also investigate barriers to biochar implementation.

Approach

Biochar pellets will be produced from straw and biogas digestates at various temperatures and their energy balance calculated. Through field experiments, the project will test the biochar's stability, effects on soil physical properties and ability to reduce N_2O emissions. Barriers to wider biochar implementation and incentive structures will also be analysed through farmer surveys and an analysis of legislation and regulations.

Expected impact/output

The project will produce knowledge about biochar production, process optimisation, N_2O-reducing properties, barriers to implementation and incentives for widespread use.
The project has potential to create an export market for pyrolysis units and knowhow on logistics, trade, use and application of biochar. A rough estimate is that full-scale implementation of biochar from straw and biogas digestate could reduce greenhouse gas emissions from Danish agriculture by 38%. It should be possible to implement 30% of this potential by 2030.

Budget:

DKK 6,850,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

University of Copenhagen, Stiesdal, HedeDanmark & Aarhus University

Contact:

Sander Bruun, sab@plen.ku.dk

Timeline:

2022 — 2026

TRL:

5 → 9

Part of:

Agrifoodture

Tags

Biochar | Agriculture | Biological storage | Pyrolysis | Biogenic CO_2 | Regulation

Learn more

NATURE-BASED SOLUTIONS

Biogas and Pyrolysis

Development of synergy between biogas and pyrolysis = Doubling of gas extraction from agricultural residues

Objective and hypothesis

At a biogas plant, biomass is converted into gas that can be used for heating. In the biogas reactor, approximately 35% of the energy content from sources like straw is utilised. The rest remains untapped in the biomass that is returned to the fields. By integrating pyrolysis into the biogas plant, it is possible to achieve an improvement in energy utilisation in a much more flexible and efficient form compared to today's standards.

Approach

The project will develop a 15-ton pyrolysis plant that will operate in conjunction with a biogas plant in Vrejlev. The plant will contribute to an understanding of which forms of biomass are best suited for pyrolysis – and in what condition after the degassing in the biogas reactor. Furthermore, it will test which other forms the project should fully utilise in the biogas reactor.
Currently, manure is added to, for example, straw that is run through the biogas plant. If very dry straw is received, it will likely be possible to achieve an efficiency improvement by sending it directly to the pyrolysis plant instead.

Expected impact/output

Biogas represents the climate solution for the large residual fractions of agriculture and is one of the cornerstones of society's need for new sustainable energy. This project is an opportunity to bring together an existing technology (biogas) with a new one (pyrolysis). This collaboration will enhance the ability to convert biomass efficiently and retain the return of the minerals contained in the biomass to agricultural soil.

Budget:

DKK 25,406,000

Funded by:

Green Development and Demonstration Program (GUDP) & co-funding from project partners

Partners:

Vrejlev Energy, Frichs Pyrolysis & The University of Southern Denmark

Contact:

Søren Bruun, sbr@frichs.com

Timeline:

TRL:

5 → 8

Tags

Biogas | Pyrolysis | Agriculture | Value chain | Biochar

NATURE-BASED SOLUTIONS

Flash pyrolysis

Development of a system for gas-borne flash pyrolysis

Objective and hypothesis

The project's purpose is to develop a full-scale flash pyrolysis plant with a capacity of 15 tonnes of biomass per day. Frichs Pyrolysis has been working on developing pyrolysis plants for an extended period. Prior to this project, Frichs Pyrolysis received a patent for a pyrolysis method that not only produces biochar but also an excess of gas that can be utilised for energy production.

Approach

The plant will be developed based on the reactor patent the project has obtained and the knowledge which has been gained during the past approximately 10 years of gas-borne flash pyrolysis development. The project has designed a reactor model that handles biomass in a new way and optimises both the plant's capacity and energy surplus.
To contribute to the future goal of expanding pyrolysis the plant will be established at Springkilde Bio near Horsens.
The plant in this project can be fed with biomass in the form of chicken manure, straw, and manure fibres. Additionally, CO_2 is captured in the biochar at approximately 0.66 tons of CCS per ton of biomass.

Expected impact/output

The project expects to demonstrate opportunities for future scalability and replication of the plant in other contexts, such as in conjunction with biogas plants, by having the University of Southern Denmark demonstrate the potential for upgrading pyrolysis gas to a higher methane content through biomethanization. Furthermore, the project expects a development of measurement methods that can validate the impact of the biomass and the technology used on the final gas and biochar results. The key advantage of our innovation is that by conveying biomass through the pyrolysis reactor using gas, we achieve a high overall energy efficiency, allowing us to harvest the gas yield in addition to the produced biochar. Finally, it is also the purpose of the project, to develop a biochar machine, that takes the biochar, into the soil, in powder form, on fieldareas.

Budget:

DKK 30,605,000

Funded by:

The Danish Energy Agency's Pyrolysis Pool & co-funding from project partners

Partners:

Springkilde Bio, Lykkesmeden, Lisbjerregaard, University of Southern Denmark & Frichs Pyrolysis

Contact:

Søren Bruun, sbr@frichs.com

Timeline:

2022 — 2024

TRL:

5 → 8

Tags

Biogenic CO_2 | Biological storage | Biochar | Agriculture | Pyrolysis

Learn more

NATURE-BASED SOLUTIONS

FENIX

New life for biowaste as a sustainable soil improver

Objective and hypothesis

Bio-waste can contribute significantly to a more circular economy, delivering valuable soil-improving material and fertiliser, as well as biogas, a source of renewable energy. Biochar helps regenerate soils by enhancing water-holding capacity, nutrient uptake, soil fertility and acts as a carbon sink.

Project FENIX aims to develop a soil improvement product that combines:

- Biochar produced from the pyrolysis and heat treatment of park and garden pruning waste.
- Digestate from a biogas production plant that uses supermarkets food waste as organic biomass.

Approach

FENIX will demonstrate the agronomic benefits (soil fertility, water-holding capacity, nutrient uptake and stimulating microbial activity) and economic returns of its soil improver in field tests in three countries in Southern Europe, facilitating the adoption by farmers and cooperatives.

Expected impact/output

The products developed by FENIX will create an incentive for bio-waste valorisation, significantly reducing bio-waste for landfill, and improving nutrient recovery from bio-waste for soil improvers production, through the valorisation of anaerobic digestion and pyrolysis by-products.
The project will also demonstrate the environmental, health and safety performance of soil improvers from bio-waste and related production operations, including improved testing methods throughout the entire life cycle, guided by partner EAS (Eurofins Agroscience Services Regulatory).
In the long term, FENIX's ambition is to contribute to the recovery of abandoned poor soils for agriculture, increasing the EU's soil quality and water retention capacity while also contributing to climate change mitigation, secure and independent energy supply, and sustainable bio-waste management.

Budget:

DKK 24,270,000

Funded by:

European Union's Horizon Europe innovation programme under grant agreement N° 101113002 & co-funding from project partners

Partners:

C.I.R.A.D, Technical University of Denmark, Institut National de Recherche pour L'Agriculture, Ellinkikos Goergokos Organismos, TerraWatt, Eurofins Agroscience Services Regulatory, Cartago Ventures & Inrae Transfert

Contact:

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Timeline:

2023 — 2027

TRL:

→ 8

Part of:

CO2VISION

Tags

Biochar | Pyrolysis | Biogenic CO_2 | Agriculture | Environment | Biogas

Learn more

NATURE-BASED SOLUTIONS

Fluid Bed Pyrolysis

Large-scale fluid bed pyrolysis

Objective and hypothesis

The main purpose of the project is to develop, build and demonstrate the performance of a highly energy-efficient pyrolysis technology, that can convert agricultural waste and sewage sludge into high-quality carbon rich biofertilizer and district/process heat. Furthermore, a comprehensive engineering design study for an add-on syngas upgrading unit will be completed. This will enable the conversion of the resulting syngas into liquid or gaseous fuels for transportation and for integration with Power-to-X plants.

Approach

The pyrolysis plant will be based on the Low Temperature – Circulating Fluidized Bed technology invented 25 years ago. The process is very fuel flexible, and the plant will be designed to process both wet resources, such as biogas fibres and sewage sludge, as well as dry agricultural waste. The process has been tested on straw, biogas fibres and other fuels, with good results. Studies of the produced biofertilizer have shown, that it can meet requirements for distribution on farmland and growth tests have shown good plant response. The biofertilizer contains carbon and nutrients, that can enrich farmland and reduce greenhouse gas emissions.

Expected impact/output

There is a strict target for reduction of CO_2 emissions from the agricultural sector in Denmark by 2030 and beyond. Pyrolysis plants producing carbon rich biofertilizer from agricultural waste products will be CO_2 negative and contribute to national and global CO_2 emission neutrality. The preliminary market survey shows a large market for a large-scale pyrolysis technology solution for wet waste products. This project will enable the development and maturation needed to be able to offer the technology on commercial terms to future customers in the Northern hemisphere.

Budget:

DKK 208,000,000

Funded by:

The Danish Energy Agency's Pyrolysis Pool & co-funding from project partners

Partners:

Dall Energy, DIN Forsyning Esbjerg & Technical University of Denmark

Contact:

Rasmus Hauberg Møller, rhm@dallenergy.com

Timeline:

2022 2026

TRL:

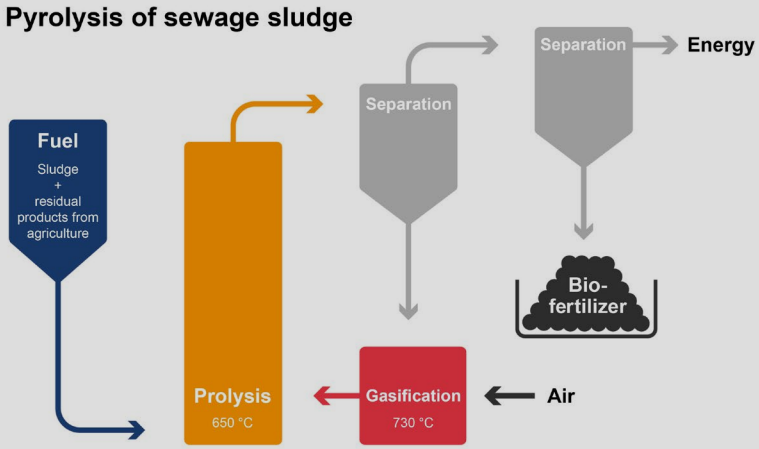
4 → 8

Tags

Pyrolysis | Biogenic CO_2 | Biological storage | Agriculture | Biochar | Utilisation

Dall Energy has developed a technology that can convert waste streams into energy and other valuable products, and with the installation to DIN Forsyning, this new, innovative solution is demonstrated excellently as it turns wastewater sludge into an environmentally friendly and efficient product for agriculture.

Jens Dall Bentzen,
CEO, Dall Energy



NATURE-BASED SOLUTIONS

SkyClean Scale-Up

Upscaling a pyrolysis plant to industrial and commercial scale

Objective and hypothesis

The core of the project is the pyrolysis technology itself and the upscaling of a pyrolysis plant to industrial and commercial scale. The SkyClean Scale-up project focuses on both the production of biochar, which captures CO_2 from the air, and the production of advanced biofuels. The project has three main objectives:

1. Mature the SkyClean technology,
2. document CO_2 storage, environmental, and fertilisation effects, and
3. develop the surrounding value chains.

Approach

In objective 1, the project will construct the first 20 MW SkyClean pyrolysis plant at Agri Energy's biogas plant in Vrå. The construction is expected to be completed in January 2024. The project also explores other potential energy products from pyrolysis.

In objective 2, the project will examine the stability and the environmental and agricultural effects of biochar in the soil, through calculations, chemical studies, lysimeter experiments, etc. Intermediate-scale field trials are also conducted under the auspices of SEGES Landsforsøg.

In objective 3, the project will gain experience in handling, storing, and spreading biochar produced in the project. The majority amount will be applied on a demonstration farm and distributed to voluntary farmers. The rest will be used for experiments in the project.

Expected impact/output

The SkyClean Scale-Up project will provide the foundation for expanding pyrolysis in Denmark. With approximately 100 plants, it will be possible to achieve an annual reduction of greenhouse gas emissions from the Danish agricultural sector of at least 2 million tons of CO_2 by 2030. In addition, the green fuels produced from pyrolysis will displace fossil fuels, resulting in an annual reduction of Danish greenhouse gas emissions of at least 1.6 million tons of CO_2 by 2030.

Budget:

DKK 200,582,000

Funded by:

The Danish Energy Agency's Pyrolysis Pool & co-funding from project partners

Partners:

Stiesdal SkyClean, Agri Energy, KK Wind Solutions, AEA (Active Energy Systems), Topsoe, Vestjyllands Andel, Energy Cluster Denmark, Technical University of Denmark (DTU Chemical Engineering), Technical University of Denmark (DTU Construct), Roskilde University, SEGES Innovation, Food & Bio Cluster, University of Copenhagen (Plant and Environment), Aarhus University (Environmental Science) & Aarhus University (Agro)

Contact:

Jesper Ahrenfeldt, jah@stiesdal.com

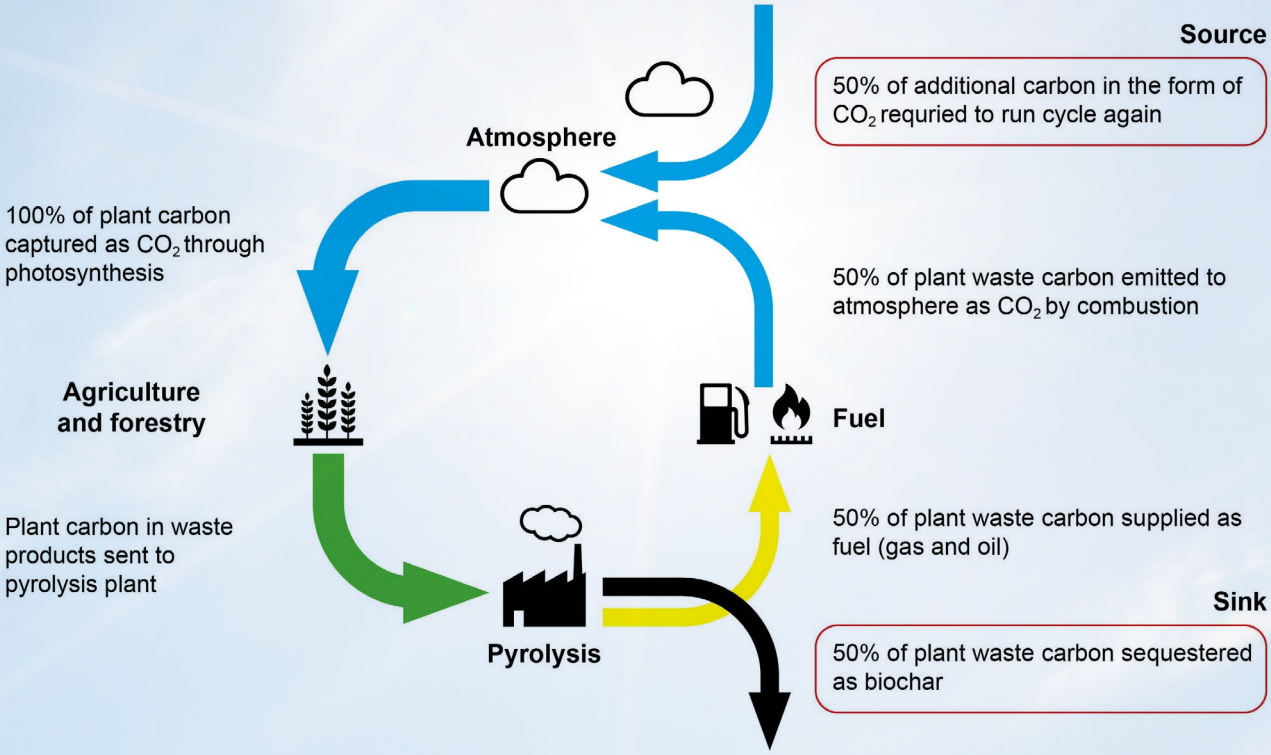
Timeline:

TRL:

6 → 8

Tags

Biogas | Biochar | Biogenic CO_2 | Biological storage | Pyrolysis | Environment | Utilisation | Agriculture



We have known and used pyrolysis for many years, among other things to produce coke for fuel. What's new is to consider pyrolysis as a source of capture CO_2, to see pyrolysis as a climate action and to leverage technology to make a positive contribution.

Jesper Ahrenfeldt, Chief Engineer at Stiesdal SkyClean

NATURE-BASED SOLUTIONS

Vesthimmerland

Agricultural innovation, CO_2 storage, and utilisation

Objective and hypothesis

This project aims to establish a test and demonstration facility for biomass separation, with a focus on creating the optimal foundation for CO_2 storage and utilisation. Today, it is considered a prerequisite to present a comprehensive business model for a full-scale plant that includes all value streams. The technology around the pyrolysis plant is already undergoing testing. However, crucial knowledge is lacking regarding value creation in the preceding process leading up to the actual pyrolysis process.

Approach

By establishing a test and demonstration facility, the project will work to uncover the entire business model to ensure that all value streams in the process are fully optimised.

Expected impact/output

The project aims to develop some of the technological potentials within the agricultural sector with the purpose of storing and utilising CO_2. This is done with the envisioning of a greener agriculture, both locally and nationally, as a catalyst for the overall effort.

Budget:

DKK 1,639,000

Funded by:

REACT-EU (Regional Development Fund)

Partners:

Vesthimmerland Biogas, Lundsby Biogas & Vesthimmerland Municipality

Contact:

Maria Kristiansen, mak@energycluster.dk

Timeline:

2022 — 2023

TRL:

7 → 8

Part of:

CO2VISION

Tags

Pyrolysis

Biogenic CO_2

Value chain

Agriculture

Biological storage

Learn more

NATURE-BASED SOLUTIONS

BioStore

Biochars for soil carbon storage and sustainable agriculture

Objective and hypothesis

In a political agreement on climate change mitigation efforts in Danish agriculture, it was decided that production and use of biochar should contribute with a reduction of 2 million tons CO_2-eq in 2030. Successful implementation requires, however, a thorough assessment of the environmental impacts of the technology. The project's aim is to investigate effects of soil amendment with high doses of biochar produced by Danish companies on carbon stability and quality aspects of agroecosystem and groundwater, combined with supporting measures on legal issues and quantification of the full system climate effects.

Approach

The project includes producing a variety of biochars from relevant feedstock materials in Denmark, while monitoring emissions and keeping track of energy and mass balances. The project will assess biochar stability in long-term soil incubation studies using Danish soils with distinct characteristics. Given the increasing irregularity of rainfall patterns and the abundance of sandy soils in Denmark, the project will also focus on biochar effects on soil hydraulic properties and crop resilience towards drought stress. An experimental platform is established in the field to test effects on crop growth and environmental functions of soil and groundwater at high biochar application rates. All data generated will be used for a quantitative assessment to determine the potential impact of widespread production and use on Denmark's climate footprint. Finally, the work will contribute to defining biochar as a visible resource within legal and economic governance practices.

Expected impact/output

The project will help to pave the way for the large-scale implementation of the production and use of biochar from relevant Danish biomasses by key Danish technology providers, in particular by defining the biochar characteristics required for a successful implementation in the agricultural sector. This will affect both the growth of the Danish pyrolysis industry and connected companies and possibilities for technology export.

Budget:

DKK 8,759,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

University of Copenhagen, Technical University of Denmark, Roskilde University, Aalborg University, Geological Survey of Denmark and Greenland (GEUS), Stiesdal, AquaGreen, Mash Makes & SEGES INNOVATION

Contact:

Dorette Müller-Stöver, dsst@plen.ku.dk

Timeline:

2022 — 2024

TRL:

6 → 7

Part of:

INNO-CCUS

Tags

Biological storage

Biochar

Biogenic CO_2

Agriculture

Learn more

NATURE-BASED SOLUTIONS

INNO4EST

Innovative forests for curbing climate change while integrating biodiversity, nutrient retention, and recreation

Objective and hypothesis

Sustainably managed forests have a potential for carbon sequestration and storage while integrating biodiversity, nutrient retention and recreation. Establishing new forests with increased attention to multifunctional services enhances their future value while still curbing climate change. The overall aim of INNO4EST is to provide and demonstrate sustainable afforestation and provide transparent and reliable methods for documentation of effects for the 4 ecosystem services in new and existing forests.

Approach

The INNO4EST project will be organised in three work packages.

- WP 1 will address the 4 ecosystem services and provide the scientific foundation for species selection, impact assessment and selection of indicators. The tasks will in addition to literature reviews draw upon data from afforestation in Denmark.
- WP 2 will have focus on the establishment of new forests while implementing the documentation methods and developing the reporting tools.
- WP 3 will be a dissemination of the projects results and increase the impact of the project through workshops and publications. All stakeholders are invited to participate and contribute to the development of the end products: scientific/technical results, new forests, the input data, expected outcome and more.

Expected impact/output

The project will in general increase the transparency and hence the willingness to invest in afforestation, for companies and individuals. Landowners and investors, private as well as public, will benefit from the knowledge for decisions on afforestation and from the needed documentation methods for the outcome. Knowledge can further be compiled for improve decision support system, given more funding for this development.

Budget:

DKK 12,177,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

University of Copenhagen, Arhus University, DHI GRAS, Agency for Data Supply and Infrastructure, HedeDanmark, Gubra, KW-Plan, Samsø Municipality, The Danish Environmental Protection Agency, NaturIT, Skovkortet.dk, Det Danske Hedeselskab, Klimaskovfonden, De Danske Skovdyrkerforeninger & The Danish Nature Agency

Contact:

Vivian Kvist Johannsen, vkj@ign.ku.dk

Timeline:

2022 — 2026

TRL:

4 → 7

Part of:

INNO-CCUS

Tags

Environment | Forest | Biogenic CO_2 | Nature | Biological storage

Learn more

NATURE-BASED SOLUTIONS

SkyClean 2MW

Combining biofuel production with CO_2 capture and storage

Objective and hypothesis

The SkyClean technology combines biofuel production with CO_2 capture and storage. The core of SkyClean is a pyrolysis process, where organic waste from agriculture and forestry is converted into biochar, gas, and oil through heating at high temperatures in the absence of oxygen. The goal of this project is to advance and de-risk the SkyClean technology sufficiently, to make a final investment decision regarding the first full-scale plant.

Approach

The project will develop, test, and optimise the SkyClean system at an existing 0.2 MW pilot plant at DTU and a 2 MW process demonstration plant at GreenLab. Based on these facilities, the project will identify the optimal design and operation of a 2 MW industrial demonstration plant, that will continuously produce biochar, bio-oil, and industrial heat in an industrial environment. This plant will be manufactured and operational for 2,000 full-load hours. Catalytic bio-oil upgrading will be tested and optimised in a pilot plant at DTU and at Topsoe. The potential for upgrading syngas to biomethane will be investigated by DGC and DTU.

Expected impact/output

The SkyClean technology has the potential to provide a reduction of 3,6 million tons CO_2 equivalents for Denmark yearly in 2030. The technology is an integrated solution to three major climate change challenges on a global scale: reduction of greenhouse emissions from agriculture, the need for capture and sequestration of atmospheric carbon, and carbon-neutral fuels for transportation. With its industrialised, relatively low-tech scalable approach, the SkyClean technology represents a climate mitigation technology with high impact available for both developed and developing economies.

Budget:

DKK 36,440,000

Funded by:

The Energy Technology Development and Demonstration Programme (EUDP) & co-funding from project partners

Partners:

Stiesdal SkyClean, Danish Gas Technology Centre, Technical University of Denmark, Topsoe, Ørsted Bioenergy & Thermal Power & Energy Cluster Denmark

Contact:

Jesper Ahrenfeldt, jah@stiesdal.com

Timeline:

TRL:

3 → 7

Tags

Fuels | Biochar | Biogenic CO_2 | Pyrolysis | Agriculture | Forest | Utilisation

Learn more

NATURE-BASED SOLUTIONS

BlueOFS

Blue Carbon - a mission to maximise C storage in Danish marine ecosystems

Objective and hypothesis

This project will identify the carbon capture/storage capacity potential in Odense Fjord, based on mitigative actions taking place both in the fjord and in it's catchment area. This project is a pilot study for national upscaling. In addition, the project will outline diverse possible scenarios to optimise the use of nature-based solutions to increase carbon capture/storage capacity catchment-fjord system. This project is developed within a consortium of diverse public and private institutions as well as NGO's and general citizens, with an interest or impact on Odense fjord (the "Odense fjord collaboration"). All activities associated to the consortium, are subjected to a co-creation process where partners are informed and contribute actively to ongoing activities. The overall aim of the present project is to create a Danish blue carbon capture roadmap, quantifying the carbon balances, as well as other positive environmental side effects generated when using native nature-based solutions (NBS).

Approach

The project combines machine learning techniques on satellite/aerial images with topographical data to classify nature maps, mapped river systems and fertilisation information obtained via the agricultural land-uses database in the catchment area of Odense Fjord. Using this method, the project can identify optimal lowland areas and buffer zones along watercourses, which are hotspots for carbon capture/storage. The project will also quantify the direct and indirect effects of the existing carbon hotspots through dynamic modelling in a pilot subarea of Odense Fjord's catchment area as well as in Odense Fjord. Finally, the project will simulate potential upscaling scenarios where NBS are implemented to different areal extent and locations.

Expected impact/output

The use of included NBS as climate tools helps reduce climate effects, not only by increasing the carbon storage capacity but also by increasing the resilience of freshwater and marine habitats. As side effect, NBS contribute positively to other National agenda's such as increasing biodiversity, contributing or reaching good quality status in Danish water bodies (WFD). Improving the existing habitats improves socio-economic conditions of the area, such as tourism and associated businesses as well as societal acknowledgement of the area, increasing the real estate demand and activating the local economy. The tool will open new markets and business areas as carbon accounting is expected to be in focus in an increasing number of marine projects. Furthermore, enhancing blue carbon capacity will increase carbon sequestration and foster balance in our coastal ecosystems.

Budget:

DKK 4,508,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

University of Southern Denmark & Danish Hydraulic Institute

Contact:

Paula Canal-Vergés, canal@biology.sdu.dk

Timeline:

2022 — 2025

TRL:

2 → 6

Part of:

INNO-CCUS

Tags

Biogenic CO_2 | Biological storage | Nature | Society | Environment | Machine learning

Learn more

NATURE-BASED SOLUTIONS

CHARBUILD

Biochar integration in building materials: Enhancing sustainability and performance

Objective and hypothesis

This project aims to demonstrate the potential of using biochar as a component in building materials. Specifically, the goal is to explore the possibility of utilising biochar for carbon-sequestering in lightweight aggregate concrete (LWAC) elements and wood-based particle boards (WPBs) – without compromising material properties such as durability, strength, and fire resistance.

Approach

The influence of biochar variability in terms of chemical composition, particle size distribution, morphology, etc., will be investigated by parametric lab experiments. This includes the characterisation of various biochar products by chemical analysis and physical testing of the biochar in lab-scale samples of LWAC and WFBs. Furthermore, the project will carry out experiments with crushing, milling, and sieving of biochar to investigate the effect of such pre-processing techniques on the properties of the resulting building materials. Additionally, LCA analysis will be used as an important tool to assess the environmental impact that can be achieved from using biochar in LWAC elements and WFBs.

Expected impact/output

The use of biochar as a component in building materials has several positive impacts. It achieves benefits in terms of a significantly reduced CO_2 footprint of the building sector, saving natural resources as well as beneficial properties of the resulting materials, e.g., an inherent ability to reduce harmful volatile chemicals from the indoor climate of buildings. A substitution of 10-20% of the raw materials with biochar would create a new market demand of up to 6 Gt/year on an EU scale and thus improve the market condition for biochar producers, leveraging a faster growth in capacity, and thus, in the overall capacity to store CO_2 in biochar. Finally, this project will contribute towards bringing Denmark among the frontrunners in finding solutions to reduce CO_2 emissions from the building sector significantly.

Budget:

DKK 5,813,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

AquaGreen, Danish Technological Institute, Leth Beton & Kronospan

Contact:

Søren Lundsted Poulsen, slp@teknologisk.dk

Timeline:

2023 – 2025

TRL:

3 → 6

Part of:

INNO-CCUS

Tags

Biochar | Material science | Biogenic CO_2 | Utilisation

Learn more

NATURE-BASED SOLUTIONS

WOODCIRCLES

Integrated, circular, and digitally supported sustainable solutions for waste minimization and carbon capture in buildings and the construction sector

Objective and hypothesis

This project addresses two challenges:

1. how do we make better use of construction and demolition waste-wood from demolished buildings, and
2. how do we design tomorrow's timber buildings so materials and components can be re-used in the future?

Thus, the aim of this project is to significantly increase circular use of wood in construction, reducing waste generation and resource consumption through increased use and re-use of wood.

Approach

Based on identified needs and market potentials, the project will develop new value chains for upcycling of wood waste materials. Additionally, the project will develop optimised design-for-disassembly building system solutions, to significantly increase recycling rates of wood in construction. The project will prototype an 'Urban Sawmill' sorting and production facility, that can turn in-homogenous low value wood construction waste into a standardised homogenous baseline product. The project will integrate digital tools and solutions in all developments and create digital twins for the large-scale, real-life demonstrators. The WOODCIRCLES solutions will be demonstrated in three pilot European cities (Rotterdam, Tartu and Turin).

Expected impact/output

The construction sector is responsible for over 35% of the EU's total waste generation and about 50% of all extracted resources. Large scale circular use of wood could go a long way in ensuring the green transition of the construction industry. The goal of this project is to accelerate this transition.

Budget:

DKK 66,099,000

Funded by:

European Union's Horizon Europe innovation programme under grant agreement N° 101082184 & co-funding from project partners

Partners:

Danish Technological Institute, Waugh Thistleton Architects, Stora Enso Oyj, University of Cambridge, Urbasofia, Trimble, Enemærke & Petersen, Fundacio ENT, Comune di Torino, EnviPark, Folkhem Trä, Woodfiber, Amsterdam University of Applied Sciences, Gemeente Rotterdam, Fondazione ICONS, Tartu Linn, 011h Sustainable Construction, Easyscience & Rotho & SPA

Contact:

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Timeline:

2023 — 2027

TRL:

2 → 6

Tags

Biogenic CO_2 | Biological storage | International collaboration | Material science

Learn more

NATURE-BASED SOLUTIONS

BIOCHSTA

Documentation of long-term carbon stability in biochar

Objective and hypothesis

Biochar is produced from residues and waste products from agriculture and waste sectors. Pyrolysis is used to produce biochar, a process where organic matter is heated to high temperatures in the absence of oxygen. This biological carbon dioxide removal (CDR) technique can potentially store large amounts of carbon. Currently, carbon stability in biochar is determined primarily from the elemental composition and other bulk parameters of the biochar and incubation experiments. However, this project hypothesises that it is more accurate to use well-documented methods from the field of geology. Thus, the aim of the project is to uniquely use geological state-of-the-art analysis techniques as a means of optimising the production of inert, non-degradable carbon for long-term stability in soil.

Approach

The proposed methodology stands on the shoulders of decades of in-depth geological knowledge of organic matter transformation, preservation and characterisation using organic petrographic, geochemical, and thermodynamic modelling techniques. A combination of acquired data and thermodynamic kinetic modelling will make it possible to standardise the optimal characteristics of the permanent biochar from a comparative study of the geologically preserved natural chars in carbonaceous rocks. Additionally, the project will conduct stakeholder meetings with farmers and carry out surveys among a representative sample of 2,000+ farmers. This will contribute to a virtual research gap by monitoring the willingness to apply biochar among farmers, and test how biochar familiarity, characteristics, and information support the readiness and willingness to adopt.

Expected impact/output

The result of this research has the potential to optimise biochar production to achieve the most stable carbon for long-term permanence in soil. Know-how of biochar formation technology and biochar permanence properties may have export potential, and provide a low-cost, reliable method to demonstrate long-term stability of biochar which could be a game-changer for the biochar industry. Also, biological carbon storage will likely have larger citizen acceptance if long-term stability can be demonstrated.

Budget:

DKK 6,894,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Geological Survey of Denmark and Greenland (GEUS), Aarhus University, Technical University of Denmark, European Biochar Industry Consortium (EBI), Stiesdal SkyClean, AquaGreen, Mash Makes, Organic Fuel Technology, Odsherred Landboforening, SLF, Østdansk Landboforening & Landbo Nord

Contact:

Henrik Ingermann Petersen, hip@geus.dk

Timeline:

2024 — 2026

TRL:

3 → 5

Part of:

INNO-CCUS

Tags

Biological storage

Agriculture

Biochar

Modelling

Learn more

NATURE-BASED SOLUTIONS

HydraMOF

Hydrate-MOF synergy for improved performance in gas capture and storage

Objective and hypothesis

The objective of this project is to investigate and develop hydrate-based gas collection and storage on a basic level, aiming to improve the efficiency of this technology, which is currently underdeveloped. To achieve Denmark's ambitious climate goals, there is an urgent need to develop technologies that can collect and store greenhouse gases such as CO_2 and hydrogen. One technology that can be used for this purpose is hydrate technology.

Approach

The project is about accelerating the formation of gas hydrates by adding MOFs (Metal Organic Frameworks) to the hydrate crystals. These MOFs have unique properties, including a large surface area for capturing gases like CO_2 and high gas selectivity. The project hypothesizes that incorporating MOFs will significantly enhance gas hydrate technology, making it commercially viable. This approach aims to selectively capture CO_2 and other pollutants, leaving non-absorbable gases untouched.

Exploiting the synergy between materials science and chemical engineering, the project will evaluate the performance of gas hydrate technology under various conditions, including high pressure, low temperature, and aqueous environments. The plan is to use hydrate technology for both hydrogen storage and improved CO_2 capture and storage, contributing to a substantial reduction in greenhouse gas emissions.

Expected impact/output

The results will be some of the first in the field and will serve as a benchmark and inspiration for future studies. Furthermore, the findings can be used to enhance hydrate technology, making it even more effective in the long term. By developing and improving hydrate-based gas collection and storage, the aim is to play a significant role in reducing global greenhouse gas emissions.

Budget:

DKK 1,880,000

Funded by:

Independent Research Fund Denmark

Partners:

Technical University of Denmark

Contact:

Jyoti Shanker Pandey, jyshp@kt.dtu.dk

Timeline:

2022 — 2024

TRL:

3 → 4-5

Tags

Point source capture | Material science | Utilisation | Value chain

Learn more

NATURE-BASED SOLUTIONS

ALGIECEL

CO_2 conversion to bio-based products using ALGIECEL's technology

Objective and hypothesis

The objective of this project is to demonstrate the feasibility of converting small amounts of CO_2 from industrial sites into valuable downstream B2B bio-based products.
The hypothesis is that we can efficiently convert CO_2 into biomass and bio-oil, demonstrating that water and nutrients can be reused in the process.
The aim is to collect CO_2 from Novozymes and utilize it in the ALGIECEL photobioreactor (PBR).

Approach

ALGIECEL's solution targets small and mid-sized industries, making it suitable for those considered too small for large PtX projects. The project will use photosynthesizing microalgae to efficiently convert CO_2 into valuable products for industries such as cosmetics, food, aquaculture feed, biofertilizer, and bioplastics. The project will be managed by Knowledge Hub Zealand, with the Technical University of Denmark documenting the techno-economic aspects of the technology.
By demonstrating the viability of our carbon utilization technology, the project intends to show future biogas and fermentation clients how they can benefit from valorising their CO_2 emissions throughout the value chain.

Expected impact/output

This project aligns with ALGIECEL's goal of commercially reducing carbon emissions while creating feasible business opportunities for CO_2 suppliers and downstream companies. The project will be a significant step towards delivering low-carbon, microalgae-based products to the market, contributing to sustainability. The grant from EUDP and collaboration with renowned partners like Novozymes endorse the technology and business offering of ALGIECEL.

Budget:

DKK 1,200,000

Funded by:

Innovation Fund Denmark & co-funding from project partners

Partners:

ALGIECEL, Novozymes, Technical University of Denmark, Knowledge Hub Zealand & P2CC (Power to Climate Change)

Contact:

Henrik Busch-Larsen, hbl@algiecel.com

Timeline:

2021 — 2023

Tags

Utilisation | Biogenic CO_2 | Microbiology

Learn more

NATURE-BASED SOLUTIONS

Future forests

Trees for the future forests

Objective and hypothesis

This project addresses how to support high adaptive potential of trees that can grow well in the uncertain future climate. The long-term health and fitness of our future forest trees are challenged by the predicted increasing temperatures, heavier and more frequent climate extremes. On the other hand, global warming could also lead to increased productivity if the trees can utilize longer growing seasons. This project studies how to select, improve or prepare the trees for the future forests.

Approach

This project will use genetic approaches to study adaptive processes in trees. Time series observations from a large body of existing field trials will be combined with ecophysiological tests and front edge genomic techniques in the search for new understanding.
An important part of the project involves practical applicability of identified solutions. The project will design genetic management solutions, predict their ecological and economic costs, risks, and benefits. New trials will be established and guidelines for breeding of major tree species developed. Results from the project will help guide important decisions on: Forestry practice that support on-going adaptation, Breeding for trees with high climate resilience and adaptability and development of trees with high innate robustness against pest and pathogens.

Expected impact/output

The project's expected outcomes have the potential to play a crucial role in safeguarding our ecosystems and ensuring the continued vitality of our forests in the face of a changing climate. The expected results include informing forestry practices for ongoing adaptation, developing climate-resilient trees, and creating robust defenses against pests and pathogens, ensuring the long-term health of future forests.

Budget:

DKK 5,900,000

Funded by:

Villum Fonden

Partners:

University of Copenhagen

Contact:

Erik Dahl Kjær, edk@ign.ku.dk

Tags

Forest | Biogenic CO_2 | Biological storage | Nature

NATURE-BASED SOLUTIONS

PETREA

Oaks in green transition

Objective and hypothesis

This project will examine the two types of oak trees in Nothern Europe, called Quercus robur and Quercus petraea. The two species have overlapping genetic distributions where they are known to hybridise. Q.robur is the colder tolerant of the two, and after the last glaciation most likely facilitated Q. petraea's northward spread towards colder environments. However, with increased frequency of dry summers, it may be Q. robur that can get an adaptive advantage by introgression with Q. petraea.

Approach

Based on increments cores and full genome sequences of hundreds of Danish grown oak trees, this project tests if Q. petraea was less influenced by historical dry summers compared to Q.robur. It also tests if Q. robur trees with high admixture with Q. petraea were less influenced compared to genetically pure Q.robur trees. Looking at Q. petraea samples across Europe, the project combines genomic analysis and increment cores with climate data to reveal if and how Southern origins are better adapted to warm and dry conditions compared to Northern origins of the same species.

Expected impact/output

The results of this project will guide procurement of oak trees for future large scale tree plantings programs in the green transition towards a fossil free economy.

Budget:

DKK 2,875,000

Funded by:

Independent Research Fund Denmark

Partners:

University of Copenhagen

Contact:

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Tags

Nature | Forest | Biogenic CO_2 | Biological storage

Learn more

Storage

3

Storing CO_2

The achievement of net-zero or negative emissions necessitates the permanent storage of carbon dioxide (CO_2) in geological structures. The technology for CO_2 storage has existed for more than 40 years and has been deployed in various locations worldwide since the 1970s. The applicability of this technology for Carbon Capture, Utilisation, and Storage (CCUS) is made possible through the wealth of experience and knowledge amassed by companies and scientists over decades.

The storage process becomes feasible once captured CO_2 is pressurised and transformed into a liquid state. Subsequently, it is transported via pipelines and injected into rock formations situated in reservoirs deep beneath the Earth's surface. When CO_2 is injected into a reservoir, it encounters a stratum of impermeable rock, serving as a cap that prevents the CO_2 from escaping, akin to the natural mechanisms that have retained oil and gas underground for millions of years.

Calculations conducted by GEUS indicate that Denmark's subsurface likely has the capacity to contain up to 22 billion tonnes (GT) of CO_2, which is equivalent to 500 to 1,000 years of Denmark's current total emissions. Consequently, efforts are underway to commence large-scale carbon storage in Denmark.

Pilot CO_2 injections have already been carried out, but the successful implementation of extensive CO_2 storage in Denmark necessitates upscaling efforts. This involves research into the expected behavior of injected CO_2 in the subsurface and the development of secure and cost-effective monitoring methods.

STORAGE

CarbonCuts

Import and permanent sequestering of CO_2 in Lolland, Denmark

Objective and hypothesis

Developing the value chain in the CCS sector demands insights and timing between all links in the chain. The aim of the project is to establish a permanent import facility for CO_2 in Rødby and to construct the necessary import infrastructure, including harbour terminal, intermediate storage, and pipelines connecting surface components.

Approach

The storage will be established in one of the geological structures identified as suitable for CO_2 storage by the Danish Energy Agency. The structure in Rødby consists of an underground saltwater reservoir covering a 10 x 20 km area near Rødby and Rødbyhavn. Regardless of the route through which the CO_2 arrives in Rødby, it is necessary to establish import and intermediate storage facilities to receive CO_2 in liquid form. To receive CO_2 via ship, CarbonCuts will investigate whether it is possible to establish barge storage as an alternative to the traditional land-based import and intermediate storage at the port. A barge storage is a flexible liquid intermediate storage comprising CO_2 tanks on a flat-bottomed barge, which can be placed either in the port or slightly offshore.

Expected impact/output

The goal is to develop a barge design at the 'Front End Engineering Design' (FEED) level, providing a high level of cost certainty, delivery time, and feasibility. As the project is developed as an onshore storage site, and the shipping distances within the Baltic Sea are relatively short, the estimated price for the CCS value chain is competitive, especially compared to offshore storage projects. CarbonCuts has received interest from several emitters in the Baltic Sea region where the above-stated elements, regarding onshore sites and short shipping distances, are regarded as valued qualities.

Budget:

DKK 2,833,000

Funded by:

The Danish Maritime Fund

Partners:

BlueNord, TGE Gas Engineering, Wartsila, Svanehøj & Schneider Electric

Contact:

Ken Wesnæs, ken.wesnaes@carboncuts.dk

Timeline:

2024 — 2030

TRL:

→9

Tags

Geological storage | Value chain | Economy | On-shore storage | Infrastructure

Learn more

STORAGE

MONICO

Monitoring fugitive emissions

Objective and hypothesis

The implementation of CCUS technologies poses a new risk for unwanted CO_2 emissions within the new infrastructure. One of the main challenges related to geological storage is the lack of an efficient monitoring system that can ensure environmentally safe storage and handling of CO_2. The aim of this project is to provide an efficient monitoring system that can detect and quantify fugitive CO_2 emissions from surface infrastructure as well as subsurface geological storage sites. The aim is to provide a monitoring system that can lead to reduced leakage from an estimated 5% to below 1%.

Approach

The project will combine drone monitoring, on-site monitoring, and satellite-based measurements. Additionally, the project will develop the necessary models needed for the efficient use of the three different measurement strategies. The project will be structured in the following steps:

1. Satellite data methods: Develop tools that can convert column-averaged CO_2 concentrations in the atmosphere into CO_2 emissions data, using atmospheric circulation models.
2. Use drones for quantification of single source emitters and map CO2 emissions from facilities.
3. Use well-known technologies for continuous monitoring in the vicinity of potential sources of fugitive CO_2 emissions.
4. Test the monitoring solutions under different scenarios, focusing on above-ground CO2 leaks and geological CO2 storage.

Expected impact/output

Demonstrating safe and environmentally sound storage is crucial for public acceptance of CCS, helping to mitigate 'not-in-my-backyard' sentiments. By minimising leakage, the use of CCUS will have a more significant impact on climate change. It will also reduce potential health and environmental risks associated with leakage from CCUS infrastructure. Creating a capacity consisting of satellites, drones, and in situ observations is, therefore, a critical task for obtaining net zero emissions in general.

Budget:

DKK 6,755,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

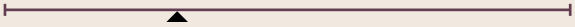
Partners:

Danish Gas Technology Center, Gas Storage Denmark, Aarhus University & Explicit

Contact:

Anna Zink Eikeland, aze@teknologisk.dk

Timeline:



TRL:

4 → 6-7

Part of:

INNO-CCUS

Tags

Geological storage | Monitoring | Storage de-risking

Learn more

STORAGE

Project Greensand

Paving the way for mitigating climate change with CCS

Objective and hypothesis

The project aims to prove that depleted oil and gas reservoirs in the Danish North Sea can be utilised for safe, long-term carbon storage. The project is currently in the pilot phase where it is being developed, tested and demonstrated. The aim is to prove that Paleocene-Eocene sands in depleted oil and gas reservoirs in Danish North Sea can be utilised for long-term safe CO_2 storage and developing new ways to monitor offshore. The project also tests the effects of 'cyclic CO_2 injection' to emulate transport of CO_2 by ship and assess the suitability of storage sites with no access to pipeline.

Approach

Storage of CO2 in depleted hydrocarbon reservoirs is a cost-effective option and can be implemented in 3-5 years. Project Greensand aims to provide the necessary insight for subsequent storage of up to 1,5 million tonnes of CO_2 per year in 2025/2026 in the Nini Field in Danish North Sea. By the year 2030 Project Greensand aim tpo safely capture and permanently store up to 8 million tonnes of CO_2 per year.
With the event "First Carbon Storage" Project Greensand Phase celebrated the worlds first cross-border offshore CO_2 storage intended to mitigate climete change.
The Project Greensand consortium consists of 23 Danish and international partners who contribute with expertise from capture, transportation, storage, and monitoring of CO_2 in the subsoil. They have delivered the required technical documentation and reports to prepare for a CO_2 Storage Site Permit Application by 2024.

Expected impact/output

The project has not only proved the technology's functionality but has also significantly boosted public acceptance of CCS. This was evident during the First Carbon Storage event in Esbjerg on 8th March 2023, where His Royal Highness, Crown Prince Frederik of Denmark, officially initiated the successfully first storage of CO_2 in the North Sea alongside a video speech from the President of the European Commission, Ursula von der Leyen. The full-scale project will be initiated to allow storage in 2025/2026. The pilot will move the CO_2 Storage in the Nini Field from its current TRL 5 to TRL 8 in 24 months. It is a challenging an ambitious timeline, but paramount for Denmark to meet the 2030 Climate Target, as well as the 50-54% midway target.

Learn more

Budget:

DKK 438,000,000

Funded by:

The Energy Technology Development and Demonstration Programme (EUDP) & co-funding from project partners

Partners:

INEOS Energy, INEOS Oxide, Blue Water Shipping, Energy Cluster Denmark, Spotlight, Danish Technological Institute, Wintershall Dea, Welltec, Semco Maritime, Noble, Geological Survey of Denmark and Greenland, Geelmuyden Kiese, Rambøll, Aker Carbon Capture, Resen Waves, TGS, Esvagt, Technical University of Denmark, Wind Power Lab, Danish Hydraulic Institute, Dan-unity CO_2, University of Southampton & National Oceanography Centre Geological Survey of Denmark and Greenland & Geological Survey of Denmark and Greenland (GEUS)

Contact:

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Timeline:

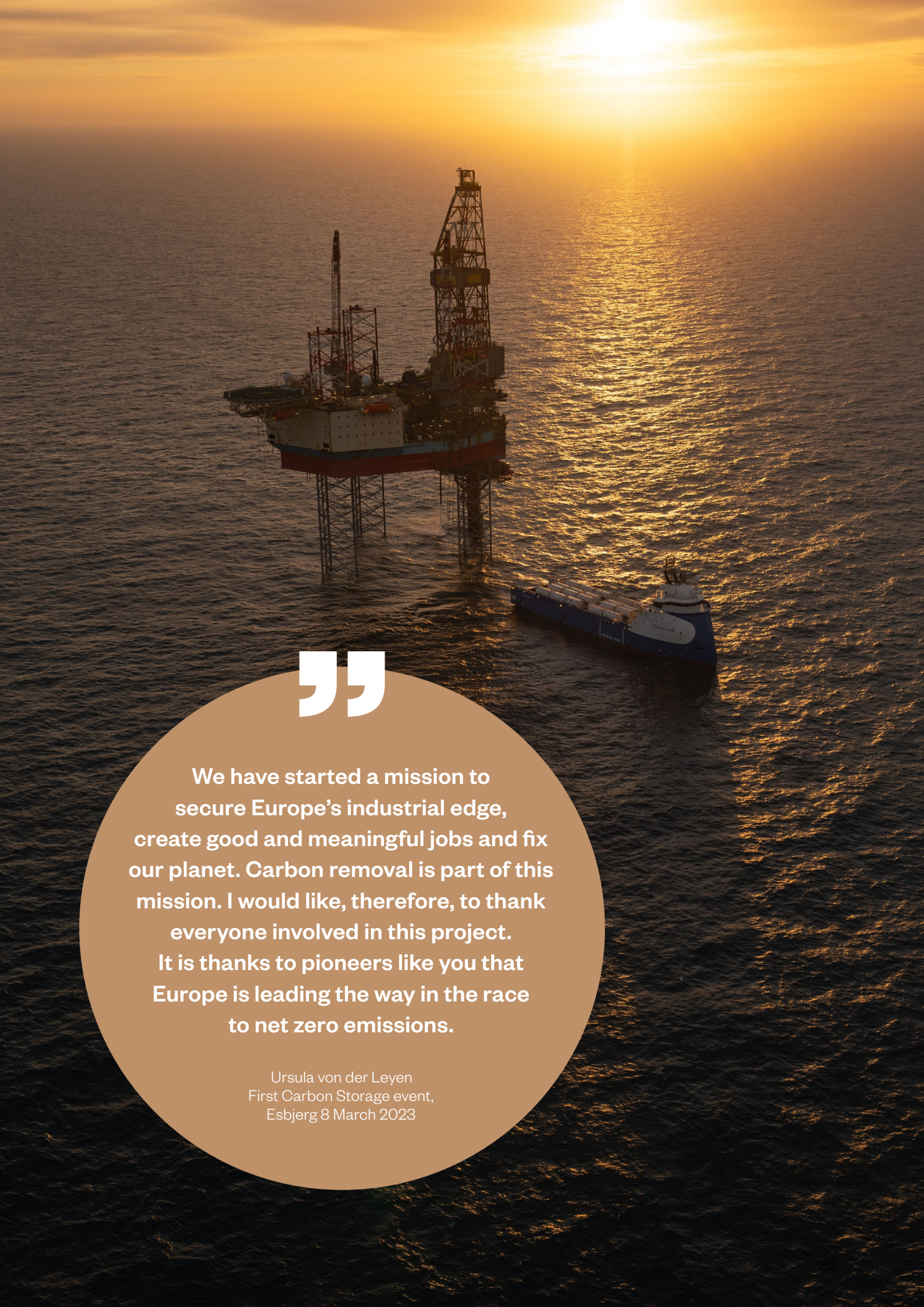
2022 — 2030

TRL:

5 → 8 (For Phase 2)

Tags

Geological storage | Geological formations | Storage de-risking | Value chain | Public acceptance | Off-shore storage | International collaboration



We have started a mission to secure Europe's industrial edge, create good and meaningful jobs and fix our planet. Carbon removal is part of this mission. I would like, therefore, to thank everyone involved in this project. It is thanks to pioneers like you that Europe is leading the way in the race to net zero emissions.

Ursula von der Leyen
First Carbon Storage event,
Esbjerg 8 March 2023

STORAGE

Project Bifrost

Scalable CO_2 storage with potential to propel Denmark towards European CO_2 Hub

Objective and hypothesis

The aim of Project Bifrost is to unlock Denmark's Carbon, Capture and Storage (CCS) potential in the Danish North Sea, by using existing offshore oil and gas infrastructure. The project leverages assets owned by DUC (Danish Underground Consortium) and Ørsted, repurposing depleted oil and gas fields and pipelines for CO_2 storage. The DUC is a joint venture comprising TotalEnergies, BlueNord, and Nordsøfonden. The project seeks to demonstrate the reusability of existing wells for CO_2 injection and storage, foster alternative CO_2 transportation options, and develop monitoring technologies.

Approach

Project Bifrost employs a comprehensive approach, beginning with the repurposing of existing assets owned by DUC and Ørsted. Depleted offshore oil and gas fields, once serving their original purpose, are being transformed into CO2 storage reservoirs. The pipelines that once transported hydrocarbons to the coast are being adapted for CO_2 transportation. In addition to repurposing Ørsted's pipeline, the EUDP Bifrost Project is studying the use of Floating Injection Units (FSIU) as an additional and innovative transportation mode of CO_2. However, it's important to note that the FSIU is currently at a low maturity level. This approach not only maximizes resource utilization but also showcases the adaptability of infrastructure to support CCS.

Expected impact/output

The Project serves as a pivotal chapter in the Danish energy transition and addressing climate changes by exploring the potential of CCS in the Danish North Sea. Initially, Project Bifrost aims to develop a 3Mtpa storage facility around the Harald Field, with an ambition to qualify for storing up to 16Mtpa with additional CO_2 storage capacities. It leverages the country's geological advantage for secure CO_2 storage, offering a solution that can significantly contribute to Denmark's 70% reduction target and European hard to abate industries emission reduction. The collaboration between academia and industry, backed by state funding, ensures that CCS technology becomes a key tool in Denmark's climate toolkit, benefiting both the environment and society.

Budget:

DKK 157,000,000

Funded by:

Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners

Partners:

TotalEnergies EP Denmark A/S, Technical University of Denmark & Ørsted Salg & Service A/S Gentofte

Contact:

David Nevicato, david.nevicato@totalenergies.com

Timeline:

TRL:

4-5 → 7

Tags

Geological storage | Infrastructure | Storage de-risking | Off-shore storage

Learn more

Together we are establishing the foundation for Denmark to take on a leading role in the development of new energy technology.

Martin Rune Pedersen,
Country Chair and Head of CCS
TotalEnergies Denmark

STORAGE

BOMS

Borehole monitoring solutions for CO_2 storage wells

Objective and hypothesis

Several of the identified risks concerning CO_2 storage are related to the risk of CO_2 leakage in or near the well. In hydrocarbon fields, leaks have been recorded through the wellbore due to corrosion and mechanical failure of tubulars. This project concerns the monitoring that can be done inside and near onshore wells. It will consider the operational needs for monitoring and describe existing technology, such as well head monitoring (pressure, temperature, flow) and technology that could be improved or adapted for the continuous monitoring of the well.

Approach

The project will establish an overview of the existing monitoring technology and identify the most important gaps between existing technology and the operational and modelling need for data. Finally, the project will focus on the predictability of the reservoir model. A calibrated reservoir model is mandatory to interpret and predict responses from the reservoir in the injection – and post-injection periods.

Expected impact/output

Developing a good monitoring programme and suitable technologies is necessary for operating a CO_2-storage reservoir. This project is a key part of preparing for a CO_2 pilot in Stenlille, which has the potential to accelerate the implementation of full-scale CCS in Denmark by several years. The potential impact on climate is, therefore, significant. As CCS technology becomes large-scale, Denmark has a great potential for CO_2 import, and by accelerating this technology, this project has the potential to improve the economic and societal benefits of storage significantly. Resulting methods and technology will be particularly well suited to monitoring re-purposed wells, such as converted oil and gas wells.

Budget:

DKK 3,583,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Gas Storage Denmark, Geological Survey of Denmark and Greenland, BlueNord, Welltec, Technion & Technical University of Denmark

Contact:

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Timeline:

2022 — 2024

TRL:

5 → 7

Part of:

INNO-CCUS

Tags

Geological storage | Monitoring | Storage de-risking | On-shore storage

Learn more

STORAGE

INNO-SALT

Innovative strategies to address salt precipitation in CO_2 storage

Objective and hypothesis

The injecting of large quantities of CO_2 into the subsurface can only be accomplished if the transmissivity of the near well environment does not severely degrade during the injection period. Due to the risk of salt clogging, one of the important phenomena to consider when supercritical CO_2 is injected through a high-saline aquifer is salt precipitation from the formation water. However, a lack of knowledge about the process renders unreliability the prediction of the phenomena, the interplay with fluid flow, the dependence on injection scenarios and the presence of impurities in the CO_2 stream unreliable. Therefore, this project aims to establish safe operational windows for the storage site operators, where injectivity is unhampered by the precipitation processes.

Approach

To establish safe operational windows, the project obtains real-time observations of the salt precipitation in experiments. This enables the definition of mechanistically sound, mathematical descriptions for how the processes unfold and finally simulate their impact during CCS for the Stenlille storage sites and injection scenarios, as well as the outcome of possible mitigation measures. The project leverages the experience of two highly esteemed laboratories: the DTU laboratory and the GEUS Core Analysis Laboratory.

Expected impact/output

By establishing safe operational windows, the project can advance CCS standardisation for formations in Stenlille and similar locations. This project's model deepens the understanding of salt precipitation's impact on injectivity. Its successful equipment and procedures could become industry standards for CO_2 storage optimisation. Finally, optimising onshore carbon storage facilities in Denmark expands storage capacity, which enables domestic and imported CO_2 storage as well as boosting the economy.

Budget:

DKK 13,412,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

The Geological Survey of Denmark and Greenland (GEUS), Technical University of Denmark & Gas Storage Denmark

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Timeline:

2023 — 2027

TRL:

3 → 6-7

Part of:

INNO-CCUS

Tags

Geological storage

On-shore storage

Storage de-risking

Geological formations

Learn more

STORAGE

CarbonAdapt

The adaption of existing infrastructure for CO_2 storage in reservoirs

Objective and hypothesis

The aim of this project is to measure the corrosion effect of liquid or supercritical CO_2 in the presence of impurities and provide a mathematical model to predict this corrosion on existing and new infrastructure. The projects will examine possible CO_2 impurity monitoring systems, both sample-based (off-line or at-line) and in-line measurements and establish a relationship between the CO_2 impurities and material corrosion in the pipelines/wells and associated equipment.

Approach

The aim is pursued by applying an existing flow-loop facility at Welltec, specifically realised for corrosion testing in a liquid/supercritical CO_2 environment. This facility will simulate corrosion conditions like those expected in CO_2 transportation pipelines and injection wells. The lab facilities at AAU will be used to validate the different monitoring units in a controlled environment. Welltec's flow-loop facility will demonstrate the application in an industrial environment utilising the monitoring units after validation. The applicability of in-line measurement technologies, such as spectroscopic methods for monitoring CO_2 contaminants, will be investigated and validated against conventional analytical methods.

Expected impact/output

Since the transportation and injection of captured CO_2 is an essential part of any CCUS strategy, the project's impact is significant: If corrosion in the carbon storage system is left unchecked, the entire strategy of injecting CO_2 into the offshore reservoirs will result in excessive OPEX to such a degree that it may never be financially feasible. The project can contribute to Danish job creation as the addressed problem must be handled to ensure a safe and reliable injection of CO_2 in the existing offshore infrastructure. The learning in this project will be used to identify requirements for qualifying existing infrastructure for CO_2 injection in relation to carbon storage both on a technical as well as legislative level.

Budget:

DKK 12,310,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Aalborg University, Welltec, Gas Storage Denmark, Rambøll & FORCE Technology

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Timeline:

TRL:

4 → 6

Part of:

INNO-CCUS

Tags

Geological storage | Corrosion | Monitoring | Infrastructure | Material science

Learn more

STORAGE

CeMetCorr / ML-CorrModel

Investigation of cement-metal barrier performance and machine learning based corrosion prediction model for CO_2 storage applications

Objective and hypothesis

When injecting CO_2 in an existing oil and gas reservoir the legacy wells are the main risks for potential future leakage. It is therefore important to understand how the legacy well barriers will behave over time. The casing/cement interphase at the top of the reservoir will be exposed to the CO_2 and this project is looking into the potential degradation of the cement/metal interface under CO_2 storage conditions. In addition, a data driven machine learning (ML) based model will be built for CO_2 storage related corrosion prediction, based on empirical data (incl data from the CO_2 Corr project). The model will include parameters such as material aspects, as well as exposure condition variations in relation to CO_2 storage.

Approach

Planned activities in the project include:

1. Testing of cement degradation as a function of CO_2 parameters and investigation of cement permeability change due to degradation.
2. Testing of degradation of Cement-Metal interface under CO_2 storage conditions
3. Flow loop testing of both cement and cement/metal interphase using critical parameters from lab tests.
4. Building a ML model based on empirical data from experiments, through iterative work and testing the model predictability using experiments and vice versa.

Expected impact/output

The project will enable companies and industries to predict possible corrosion levels of metallic materials and Casing/cement interface degradation when injected CO_2 chemistry and material parameters are known. The final outcome of this project will be a Python scripted user-friendly software.

Budget:

DKK 5,200,000

Funded by:

Danish Offshore Technology Center

Partners:

Technical University of Denmark, Aarhus University & Danish Offshore Technology Center

Contact:

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Timeline:

2022 — 2024

TRL:

3 → 6

Part of:

Danish Offshore Technology Center

Tags

Geological storage | Off-shore storage | Machine learning | Corrosion | Material science | Storage de-risking

STORAGE

CROSS

Cheap, reliable optical sensors for digital monitoring of CO_2 leakage undersea

Objective and hypothesis

The objective of this project is to design and test a cheap, reliable optical sensor (CROSS) for offshore CO_2 monitoring around a CO_2 storage site. The underlying challenge is to find an ideal dye chemical with no leaking, no bleaching, and good linking capability.

Approach

The CROSS system will be an integration of an optical CO_2 sensor with a self-developed digital control platform. Via lab experiments, the project will demonstrate that the CROSS solution can be the best available technology (BAT) for improving CO_2 monitoring at the CCS site. The project includes the following steps:

1. Build and optimise a prototype optical sensor for robust CO2 measurements underwater.
2. Develop a digital control system to demonstrate the efficiency and robustness of the CO_2 sensor.
3. Integrate the developed optical sensor and digital control platform with optimal adjusting and test the online monitoring of CO_2 in a mimic offshore environment.
4. Design a deployment strategy for the CROSS system to monitor CO_2 leakage near a CCS site (e.g., abandonment well).

Expected impact/output

The project will provide the first sensor design enhancing the CO_2 measurement while excluding the interference from H2S. The CROSS project will yield an eco-technological solution for CO_2 leakage monitoring at an injection site and will have a substantial and positive effect towards CCS. The CROSS is also a platform that can be easily adopted to measure other parameters like pH, NH3, O_2, etc.

Budget:

DKK 2,500,000

Funded by:

Aarhus University, Unisense & Danish Offshore Technology Center

Partners:

Aarhus University, Unisense & Danish Offshore Technology Center

Contact:

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Timeline:

2022 — 2024

TRL:

3 → 6

Part of:

Danish Offshore Technology Center

Tags

Geological storage | Monitoring | Storage de-risking | Off-shore

STORAGE

CTS - CO_2 Transport

Flexible and cost-effective solutions for European offshore storage

Objective and hypothesis

The project's main objective is to demonstrate the techno-economic feasibility of using ships for transport and as injection vessels to ensure flexible and cost-effective solutions for European offshore storage. The project also aims to make further steps towards piloting the technology and increase CCUS awareness and acceptance in the selected regions among stakeholders.

Approach

CTS, coordinated by NORCE under Clean Energy Transition Partnership (CETP) program, will identify the best conditions along the value chain for the application of ship injection technology and screen for optimal candidates for application in the North Sea, Black Sea, Baltic Sea and Atlantic coast of Portugal. Further, the project designs and evaluates CCS value chains with direct injection from ships in the above-mentioned regions and evaluates their potential against existing scenarios or traditional approaches where ships are simply used for transportation. In addition, dialogue with stakeholders is established towards the implementation of the technology in the selected regions

Expected impact/output

Direct injection from ships will unlock CCS potential for the industry by increasing the flexibility and versatility of the CCS value chain while simultaneously reducing costs. In addition, it is expected to enhance CCUS adaptation by smaller emitters/storage operators and ease creation of a European (and global) on-demand CO_2 storage market.

Budget:

DKK 3,460,000

Funded by:

Energy and Technology Development and Demonstration Programme & The Clean Energy Transition Partnership

Partners:

Technical University of Denmark, WellPerform, Norce, GeoEcoMar & University of Èvora,

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Timeline:

2023 — 2025

TRL:

5 → 6

Tags

Geological CO_2 storage | Off-shore storage | Value chain | International collaboration | Infrastructure

Learn more

STORAGE

Methane and CO_2 detection

Sensors for methane and CO_2 detection in water column

Objective and hypothesis

According to regulations all CO_2 storage projects need to have monitoring in place to ensure containment. However, there is a lack of sensors able to detect CO_2 and CH_4 leaks in the water column. Existing CO_2 sensors have slow response rates, limiting their use to stationary landers on the seabed. This project aims to develop sensors to fill this gap considering the complex interplay between CO_2, CH_4, and O_2 levels to reduce false positives.

Approach

The project will develop chemical sensors using adsorbant materials, which offer high surface area for selective gas isolation. The project chooses materials based on chemical interactions and pore engineering and employs quartz crystal microbalance (QCM), electrochemical, and optical methods. The prototype sensor for dissolved CH_4 detection achieves sub-parts-per-million detection limits and rapid responses and a patent application process is ongoing.

Expected impact/output

The project has two expected impacts. First, the line-of-sight device attaches to autonomous underwater vehicles for on-demand water column surveys. Second, the project will develop a semi-distributed fiber optic sensor network using functionalized Bragg gratings. These gratings reflect light based on their spacing and are transformed into chemical sensors by coating them with adsorbant materials. This allows multiple sensors on a single cable, eliminating the need for sensitive electronics underwater. The goal is to create long-term seabed sensor networks, including O_2 and marine nutrients for ocean health monitoring.

Budget:

DKK 4,000,000

Funded by:

Danish Offshore Technology Center

Partners:

Danish Offshore Technology Center

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Timeline:

2021 — 2024

TRL:

1 → 6

Part of:

Danish Offshore Technology Center

Tags

Geological storage | Monitoring | Off-shore storage | Storage de-risking | Material science

STORAGE

CO_2RESHC

Evaluation of residual hydrocarbons effect on CO_2 injectivity in depleted chalk reservoirs

Objective and hypothesis

The main purpose of this study is to examine the effect of residual hydrocarbons in non-flooded and water-flooded chalk reservoirs on supercritical (sc) CO_2 injectivity. This will be achieved through a thorough characterisation of the residual hydrocarbons in core and cuttings samples from the Maastrichtian chalk reservoir of the Halfdan and Dan chalk fields. The project will in detail investigate the distribution of residual oil fractions in the reservoir, and the effect of the residual hydrocarbons in non-flooded and water-flooded chalk reservoirs on $scCO_2$ injectivity. The project will help de-risk depleted oil field CO2 storage sites and may have a substantial impact on CO_2 and emission reduction.

Approach

In WP1, the project will conduct $scCO_2$-flooding experiments on core samples at reservoir conditions at GEUS Core Analysis Laboratory. The flooding experiments will, in combination with laboratory analyses before and after flooding, investigate the impact of $scCO_2$ interaction on the residual hydrocarbons in the chalk matrix of rock samples. WP2 will analyse core and cuttings samples at AU's LOC laboratory and compare pre- and post-flooding samples to quantity movable, semi-movable, and non-movable oil fractions and solid bitumen in the reservoir together with detection of changes in hydrocarbon composition induced by $scCO_2$ flooding. Finally, WP3 will prepare sample pellets for reflected light microscopy to describe residual hydrocarbons in pre- and post-flooding samples.

Expected impact/output

The results on specific risks for residual hydrocarbons movability/clogging will translate directly into the decision-making process of the applicability of a depleted chalk reservoir as a storage site. It will further address issues related to potential leakage due to CO_2-induced hydrocarbon movability. The project will help de-risk depleted oil field CO_2 storage sites and may thus have a substantial impact on emission reduction and thus on reaching the goal of atmospheric CO_2 reduction in Denmark.

Budget:

DKK 4,289,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Geological Survey of Denmark and Greenland (GEUS), Aarhus University & TotalEnergies

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Timeline:

2022 — 2024

TRL:

3 → 5

Part of:

INNO-CCUS

Tags

Storage de-risking

Off-shore storage

Geological storage

Geological formations

Learn more

STORAGE

CO_2 Corr

Investigation of corrosion issues and developing empirical prediction model

Objective and hypothesis

Non-producing oil and gas wells have great potential to be used as medium for CO_2 injection and storage. Large volume of CO_2 can be injected and stored in the depleted reservoirs. However, injection and storage of CO_2 in existing wells also introduce several challenges, such as the corrosion of the tubing. The objective of CO_2 Corr is to investigate these issues specifically in connection with the purpose of CO_2 injection and storage. Meanwhile the project will develop an empirical model for predicting the corrosion level based on sequence of operational parameters.

Approach

Experimental Activities in the project will focus on three aspects:

1. Understanding corrosion due to supercritical CO2 due to CO_2 impurities,
2. Corrosion under aqueous+CO_2 conditions after CO_2 injection, and
3. Vapour phase corrosion due to evaporation of water together with CO_2

For 1, 2 and 3, lab scale testing will be carried out followed by flop loop testing using bench marked parameters from lab testing.

Expected impact/output

This project will develop knowledge that can be used at industrial scale for safely injecting CO_2 while maintaining integrity of the well tubing. The empirical model developed from this project can be used for predicting corrosion progression based on operational parameters. This will help in optimising operations and preventive measures to be taken. Furthermore, the project will develop novel test methods in relation to vapour phase corrosion and special flow loop test method mimicking exact well conditions that are useful beyond the scope of this project.

Budget:

DKK 3,500,000

Funded by:

Danish Offshore Technology Center

Partners:

Technical University of Denmark, IKM Ocean Team & Danish Offshore Technology Center

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Timeline:

2021 — 2024

TRL:

2 → 5

Part of:

Danish Offshore Technology Center

Tags

Modelling | Corrosion | Geological storage | Infrastructure | Storage de-risking | Material science

STORAGE

CO_2 flow

Experimental study and modelling of CO_2 propagation in geological storage

Objective and hypothesis

This project aims to enhance our understanding of CO_2 storage by developing standardised laboratory procedures for critical parameters like relative permeabilities and capillary pressure curves. The project seeks to shed light on the physical mechanisms governing CO_2 sequestration. Hypotheses include the feasibility of these procedures and their applicability in predicting CO_2 plume migration.

Approach

The project includes conducting CO_2-brine core flooding experiments using X-ray CT monitoring and acoustic two-phase separation on samples from the Stenlille gas storage site. Core-scale numerical simulations will help derive relative permeability and capillary pressure functions. Laboratory procedures for two-phase miscible flows will be established, and the domain of applicability for both methods identified. Additionally, analytical models for CO_2plume migration will be developed based on these measurements.

Expected impact/output

CCUS is a critical element in achieving Denmark's target of a 70 % reduction in greenhouse gas emissions by 2030. The project is of particular importance for existing onshore gas storage sites, such as Stenlille, which has been used as natural gas storage for decades. According to the roadmap ´Mission CCUS-a roadmap for carbon capture, utilisation and storage´, the questions on de-risking the reservoir will be answered to a great extent after completing this study. The results of this project will contribute to better estimates of the efforts needed to meet CO_2 emissions reduction targets, both for Denmark and globally. The main innovation within the project is related to developing a procedure at GEUS which is tailored towarvds experiments with supercritical CO_2 to be able to measure the flow functions (relative permeability parameters).

Budget:

DKK 4,221,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Geological Survey of Denmark and Greenland (GEUS), Technical University of Denmark, Gas Storage Denmark & TotalEnergies Upstream Danmark A/S

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Timeline:

2023 — 2026

TRL:

3 → 5

Part of:

INNO-CCUS

Tags

Geological storage · On-shore storage · Modelling · Monitoring · Simulation technology · Geological formations

Learn more

STORAGE

CO_2 Seal Integrity

Shale as a barrier

Objective and hypothesis

The CO_2 Seal Integrity project aims at securing long-term well barrier seal integrity for CO_2 storage sites in North Sea Oilfields. The project investigates mechanisms to promote expansion of natural occurring clays/shales to create a lasting seal and prevent CO_2 leakage. Due to their low permeability, shales naturally provide a seal to the subsurface for the lifetime of the storage site and over geological time.

Approach

The project examines the geological formations in the overburden interval and identifies the distribution of expansive clays above the Danish fields, highlighting intervals with the highest swell potential. Then, the project finds the optimum fluid to swell them and achieve a permanent seal and measures confined and free swelling on shale analogues manufactured starting from cuttings. It is then tested how diffusion of pore-fluids affects the pore size distribution in time to document the effectiveness of various fluids to induce swell quickly and maintain swelling over time. The methodology employed uses a combination of petrophysical characterisation, oedometer and Constant Rate of Strain equipment, transient low field NMR T2 relaxation methods.

Expected impact/output

Restoration of the natural sealing formation will first and foremost create a barrier that is chemically more stable upon exposure to CO_2 and has a lower permeability than cement. Using the shale as a barrier could also be less time consuming and cheaper than standard operations, especially when annular cement must be repaired through perf-and-wash and cement squeeze jobs.

Budget:

DKK 2,400,000

Funded by:

Danish Offshore Technology Center

Partners:

Technical University of Denmark & Danish Offshore Technology Center

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Timeline:

TRL:

3 → 5

Part of:

Danish Offshore Technology Center

Tags

Geological storage | Geological formations | Storage de-risking

STORAGE

CompReact

Compositional simulation of reactive transport in CO_2 storage

Objective and hypothesis

CO_2 injection into geological formations triggers complex physical and chemical interactions at different time and length scales. These interactions are critical to the evaluation of subsurface capacities, operational risks, and storage safety. This project aims to develop a next-generation compositional CO_2 storage simulator with multiphase geochemical reactions. The simulator can be used in evaluating both the injection and the post-injection periods.

Approach

The project will develop the simulator using the novel RAND-based algorithms. The current multiphase geo-chemical equilibrium module will be extended by including kinetics and a database for relevant geochemical reactions. The module will be further improved with its code efficiency and reliability and integrated into an in-house compositional simulator for analysis of injection and storage problems at relatively short timescales. In collaboration with Stanford, the project will couple the simulator with the GEOSX simulator. The new GEOSX simulator will be applied to long time-scale post-injection simulations with coupled geomechanics.

Expected impact/output

The project will advance the simulation technology for geological CO_2 storage. Furthermore, the project directly contributes to the de-risking of CO_2 injection into different types of reservoirs, helping an early decision on the implementation of CO_2 storage. The post-injection analysis will build public confidence in the long-term safety of CO_2 storage, accelerating its implementation. The developed simulator will be disseminated as open-source code, thus benefiting the whole CCUS community. Industrial partners will benefit from the analysis of specific storage sites of their interest, helping decision-making on their investment in CO_2 storage.

Budget:

DKK 10,704,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Technical University of Denmark, TotalEnergies, INEOS, BlueNord & Stanford University

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Timeline:

2023 — 2027

TRL:

2 → 5

Part of:

INNO-CCUS

Tags

Geological storage | Storage de-risking | Simulation technology | Geological formations | Modelling

Learn more

STORAGE

$LoCo_2$

A journey from storage to seabed - impact of future large scale offshore CO_2 storage on the marine environment

Objective and hypothesis

The number of large-scale subsurface CO_2 storage sites is expected to increase considerably in the years to come. There will always be a risk (albeit small) of leakage from the underground stores to the seabed sediments. Other than CO_2, the leaking fluids may contain various impurities and accompanying formation fluids. Supported by VELUX FONDEN, project $LoCo_2$ studies the (bio)chemical processes the leaking fluids go through in the leakage path and assesses the ecological effects of the fluids leaking to the seabed environment.

Approach

In combination with laboratory experiments, $LoCo_2$ will utilise the previously generated data on the effects of CO_2 on life in seabed sediments to fill the gaps in the data. These will be used by a predictive tool that couples with Thermo-Hydro-bio-Chemical (THbC) models of the flow of contaminants from the storage reservoir through the overburden layers to the seabed sediments. The final predictive tools will be made freely available.

Expected impact/output

$LoCo_2$ will be able to answer the following questions:

- What is the chemical composition of the fluids reaching the marine environment (that need to be monitored), considering (bio)chemical processes through the leakage path?
- What are the implications for monitoring methods?
- What is the fraction of leaked CO_2 retainable in the overburden?
- What are the likely impacts and their magnitude on life in the seabed in various possible leakage scenarios?

Budget:

DKK 6,900,000

Funded by:

VELUX FONDEN & Danish Offshore Technology Center

Partners:

Technical University of Denmark, TotalEnergies & Danish Offshore Technology Center

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Timeline:

2024 — 2028

TRL:

2 → 5

Part of:

Danish Offshore Technology Center

Tags

Environment | Monitoring | Geological storage | Off-shore storage

STORAGE

SEABAS

Understanding the offshore environmental baseline prior to initiating a CO_2 injection project.

Objective and hypothesis

The SEABAS project focus on understanding the offshore environmental baseline prior to initiating a CO_2 injection project. In another ongoing study (SEEP) a baseline is being created for Natural Hydrocarbon Seepage around offshore installations and the aim of SEABAS is to extent the SEEP study to potential leakage of CO_2. The hypothesis is, that an early indicator of CO_2 leakage from an existing oil and gas reservoir, will be increased methane in the sediments and water column. Generating baseline knowledge is key in order to understand a CO_2 storage project monitoring data and determine if a 'leakage signal' is originating from the storage reservoir or another source.

Approach

The objectives will be pursued by integrating and interpretating newly collected seabed data to understand the induced and natural seepage of both methane and CO_2 on a regional scale in the North Sea. Thereby unfolding the knowledge from the running SEEP project to a wider regional scale. The project will test the possibilities for proxy-based identification and development of toolboxes for identifying both methane and CO_2 seepages in abandoned reservoirs and new CO_2 storage sites. Data will be mined from a wide suite of geophysical surveys, sediment data and ecological studies. Parts of the data are already present from the ongoing multiproxy studies SEEP and SEEP-Ecology.

Expected impact/output

Comparing with present studies on leakage, SEABAS goes a step further, focusing on the interaction between CO_2 and methane seepages. The project aims at integrating data and results from the SEEP studies with new regional collected data (high resolution seismic data and sediment cores from other projects). Based on this, the project will define the applicable methods and develop a possible toolbox for identifying greenhouse gas leakages.

Budget:

DKK 10,000,000

Funded by:

Danish Offshore Technology Center

Partners:

Technical University of Denmark & Aarhus University & Geological Survey of Denmark and Greenland (GEUS)

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Timeline:

2021 — 2024

TRL:

1→5

Part of:

Danish Offshore Technology Center

Tags

Off-shore storage | Storage de-risking | Monitoring | Environment | Geological storage

STORAGE

SHARP Storage

Enhancing CO_2 storage safety and monitoring

Objective and hypothesis

Storage of CO_2 in the subsurface is considered pivotal to reducing CO_2 emissions during the energy transition. The project SHARP Storage aims at developing methods that will accelerate safe and cost-efficient CO_2 storage. The primary objective of the project is to improve the accuracy of subsurface CO2 storage containment risk management. The project aims to achieve this by integrating observations and models related to subsurface stress, rock mechanical failure, and seismicity.

Approach

To achieve the defined objectives, the subsurface stress state model will be improved by implementing tectonic, glacial and sediment compaction data and defining fault slip using new integrated earthquake catalogues. New experimental data will be combined with existing rock rheology site data to define rock strain and identify failure attributed suitable for monitoring and risk assessment. Finally, monitoring design will be "sharpened" based on the updated rock failure models providing input for right time and place monitoring systems and containment risk quantified based on updated stress and failure models. The results of the project will be communicated to industrial stakeholders and regulators to foster impact creation.

Expected impact/output

The innovative approach of this research will provide stakeholders (e.g. industry and regulators) with a better framework for addressing and understanding containment failure risk. Using the project outcomes, site operators will be able to utilise the new approaches and findings for optimisation of site development plans and sensing methods in a cost-efficient way, mitigating critical risks. Quantifying uncertainty for containment risk and advancing risk assessment methods will be demonstrated for the study sites building confidence in the development of future CCS initiatives.

Budget:

DKK 5,500,000

Funded by:

Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners

Partners:

Norwegian Geotechnical Institute, Geological Survey of Denmark and Greenland (GEUS), British Geological Survey, NORSAR, University of Oxford, Technical University Delft, Norwegian University of Science and Technology, Indian Institute of Technology Bombay, Equinor, Shell, INEOS Oil & Gas Denmark, Wintershall Dea, bp, Rockfield, Risktec & ASN Alcatel

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Marie Keiding, mke@geus.dk

Timeline:

2021 — 2024

TRL:

2-3 → 5

Tags

Geological storage | Storage de-risking | Regulation | Monitoring | Modelling | International collaboration

Learn more

STORAGE

THERMOCO2WELL

Risk assessment of the CO_2 injection well damage due to thermal stresses

Objective and hypothesis

CO_2 injection in the subsurface can experience intermittent behaviour during the well start-up/shut-in, due to fluctuations in CO_2 supply, or due to undesired events. The aim of the project is to tailor a numerical simulation model which will consider single- and multiphase mixtures of CO_2 and CO_2-rich mixtures in well configurations, including friction and heat transfer. To account for the induced thermal stresses in the cement and the reservoir, the model will be coupled to geomechanical simulators.

Approach

The first key milestone is to deliver a first version of a standalone software tool. This will allow for offline forecasts of the anticipated pressure and temperature profiles along the well, and the associated thermal stresses in the near-wellbore area. Based on iterations between the project team, the simulator will be loosely coupled with a geomechanical simulator. The planned functionality will include elaborate formulation of the geomechanical simulator, results of the calibration on the field data from Stenlille, and a GUI/web interface. Ultimately, the project will provide an assessment of the impact of thermal stresses on wellbore integrity, near-wellbore stability, and reservoir and caprock behaviour.

Expected impact/output

The project is addressing one of the key challenges of the CCUS Roadmap by INNO-CCUS, namely the maturation and de-risking of large potential storage sites. Choosing the right design of a well is key to mitigating some of the risks concerning well integrity. To be able to do this, it is necessary to know the environment around the well in detail. The results of this project are, therefore, crucial in the preparation for a CO_2-pilot in Stenlille, which has the potential to accelerate the implementation of full-scale CCS in Denmark.
The methods and tools developed in this project can be generalised to usage for other storage sites. Therefore, this project has the potential to significantly improve the economic and societal benefits of storage.

Budget:

DKK 3,022,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Technical University of Denmark, Geological Survey of Denmark and Greenland (GEUS) & Gas Storage Denmark

Contact:

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Timeline:

2023 — 2025

TRL:

3 → 5

Part of:

INNO-CCUS

Tags

Geological storage | Monitoring | Infrastructure | Storage de-risking | On-shore storage | Simulation technology

Learn more

STORAGE

WellCS

A multiphysics informed risk assessment framework for CO_2 leakage through wells

Objective and hypothesis

Depleted hydrocarbon reservoirs are considered a viable solution to the CO_2 storage challenge. Nevertheless, the leakage of CO_2 through wells is a concern in geological CO_2 storage. In this regard, whether the wells are properly sealed is a big concern, as CO_2 can react with and leak through the cement layer and back to the atmosphere. The aim of this project is to develop an assessment tool capable of assessing containment risk through wells.

Approach

The project will:

- Develop a numerical modelling framework, to investigate the integrity of wellbore cement throughout its lifetime, considering Multiphysics processes for CO_2 leakage.
- Assess the probability of leakage along well cement for the entire well, including the potential flow zones.
- Identify weak spots for possible restoration.
- Develop an assessment tool capable of assessing containment risk through wells.

Expected impact/output

The developed framework will enable studies of the risk of CO_2 leakage through the wellbore in long time scales. It will also help decision makers choosing an appropriate mitigation method such as conventional approaches (perforate and squeeze cementing operations and cutting-pulling or section milling of the casing plus recementing) or alternative approaches (for example by deforming the casing pipe and permanently expanding it to close fractures and other cement defects). The tool will be essential for assessing both plugged (exploration) wells and injection wells for containment risk under CO_2 storage conditions.

Budget:

DKK 1,500,000

Funded by:

Danish Offshore Technology Center

Partners:

BetterWells & Danish Offshore Technology Center

Contact:

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Timeline:

2023 — 2024

TRL:

3 → 5

Part of:

Danish Offshore Technology Center

Tags

Geological storage | Storage de-risking | Simulation technology | Monitoring | Modelling

STORAGE

4D observation

In-situ 4D observation of chalk modification during CO_2 injection

Objective and hypothesis

The project combines experiments and modelling at different scales to assess the feasibility of injecting CO_2 in chalk reservoirs from the Danish Underground Consortium Area in the North Sea.
In doing so, the project aims to answer the following questions:

- Will dissolution occur during CO_2 injection in DUC sector chalk at reservoir conditions? Will this lead to the collapse of the pore network? What effect will it have on injectivity and storage capacity?
- Can substantial flow of CO_2-saturated brine occur in fracture networks driven by density differences, and with what consequences?

Approach

The project employs a multi-disciplinary approach that combines in-situ CT imaging experiments on reservoir chalk samples with geochemical and plume migration calculations. Chalk samples from actual reservoir rocks in the North Sea basin are used for the experiments, which are conducted under conditions that simulate those in the field. A tri-axial in-situ chamber for CO_2 injection has been designed for dynamic CT, enabling the observation of potential changes in chalk properties under reservoir conditions (temperature and pressure) in 3D during the injection of CO_2 in the reservoir core plug. With this setup and advanced image analysis, a 3D image of the core can be obtained every 10 minutes during injection, with a resolution of 50 to 100 microns.

Expected impact/output

Through this project, it will be possible to identify if the storage of CO_2 in (old) oil fields in the North Sea is safe or if significant dissolution would be a risk. Such knowledge will further enable the storage potential of the ageing fields in the DUC sector in the North Sea.

Budget:

DKK 2,300,000

Funded by:

Danish Offshore Technology Center

Partners:

Danish Offshore Technology Center, Technical University of Denmark & The Geological Survey of Denmark and Greenland (GEUS)

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Timeline:

TRL:

2 → 4

Part of:

Danish Offshore Technology Center

Tags

Modelling | Geological storage | Geological formations | Storage de-risking | Off-shore storage

STORAGE

Cement durability

Experimental and numerical studies of microstructure and durability for cement

Objective and hypothesis

A significant number of wells are planned to be permanently plugged and abandoned in the upcoming decades and some of these wells will either be re-used for CO_2 injection or will be legacy wells for a CO_2 storage project. An important aspect of abandonment is ensuring long term well integrity after abandonment. The aim of this project is, therefore, to explore the key parameters that determine the durability and permeability of cement paste that is used as barrier material in a typical offshore well including the effect of stored CO_2.

Approach

The main part of the project will focus on well-known blends based on conventional cementitious systems.
The investigation includes understanding the interactions with CO_2, present in the well at end-of-life scenario. The project will also investigate the interaction with CO_2 through CCS activities in higher concentrations, as its impact needs to be understood in greater detail. The project will also employ reactive transport modelling to estimate the physical properties of the cement paste on a prolonged time scale.

Expected impact/output

The impact of this project lies in its potential to enhance the sustainability and safety of offshore well abandonment including a CO_2 storage scenario. After sealing the well, the construction should not require further service or maintenance. By determining the key parameters affecting the durability and permeability of cement paste, it will become possible to develop improved materials that ensure long-term well integrity. This will, in turn, contribute to safer and more environmentally friendly well abandonment processes.

Budget:

DKK 4,700,000

Funded by:

Danish Offshore Technology Center

Partners:

Aarhus University, Technical University of Denmark & Danish Offshore Technology Center

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Timeline:

2021 — 2024

TRL:

3 → 4

Part of:

Danish Offshore Technology Center

Tags

Geological storage | Storage de-risking | Geological formations

STORAGE

CO_2 injection in chalk

De-risking CO_2 injection and storage in chalk

Objective and hypothesis

CO_2 flooding in chalk under different in-situ conditions have been conducted to characterise the response of chalk to CO_2 injection under various reservoir conditions. The aim of this project is to understand the impact of CO_2 injection on the flow and geomechanical behaviour of chalk.

Approach

To better understand the processes triggered by CO_2 injection in chalk formations, the project has carried out SEM analyses, CT imaging, and chemical analyses. The project has applied numerical simulations to upscale the observed behaviour to field scale. The simulations will allow assessing the short- and long-term responses of chalk formations to CO_2. Particularly, the project will characterise the role of

1. porous media heterogeneity on enhancing/hindering CO_2 movement in reservoirs under chemical stresses.
2. possible alterations of mechanical properties on controlling reservoir deformation.
3. the transport and trapping mechanisms contributing to two-phase flow in chalk formations.

Expected impact/output

The project aims to advance our understanding of CO_2 injection into chalk and identify potential risks. The generated knowledge will 1) reduce uncertainties for CO_2 storage in Danish chalk reservoirs and 2) determine safe operational conditions.

Budget:

DKK 2,000,000

Funded by:

Danish Offshore Technology Center

Partners:

Danish Offshore Technology Center

Contact:

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Timeline:

TRL:

2 → 4

Part of:

Danish Offshore Technology Center

Tags

Geological storage | Infrastructure | Off-shore storage | Simulation technology | Storage de-risking

STORAGE

CO_2Plus

Phase behavior of CO_2+X in CO_2 storage

Objective and hypothesis

Geological CO_2 storage involves complex phase behaviour of CO_2+X (X being either impurity in the injected CO_2 stream or the in-situ fluids that interact with CO_2). Detailed knowledge of this behaviour is crucial to many aspects of CO_2 storage. The aim of this project is to acquire systematic knowledge and develop the essential modelling approach for analysing the complex phase behaviour of CO_2+X in injection and storage.

Approach

The project will:

- Establish a comprehensive database for the phase behaviour of CO_2+X and make a systematic evaluation of the existing models.
- Measure the data for critically selected properties and conditions, particularly those directly related to the Danish storage sites.
- Develop a portfolio of models for the equilibrium and physical properties of CO_2+X, which can be used for accurate analysis of wellbore and near-wellbore phenomena related to injection and for reservoir-scale simulation analysis. The project will study non-cubic equations of state for high accuracy modelling of equilibrium and physical properties.
- Develop systematic methods to integrate the knowledge of CO_2+X into the simulation analysis of injection risks and storage issues.

Expected impact/output

Geological CO_2 storage will play a significant role in the green transition. It is, however, challenging in its scale and urgency. Even so, if implemented, it also presents significant opportunities for new businesses and secure jobs in the related areas. This systematic solution will help to de-risk the decision-making and implementation of CO_2 storage by improving the evaluation of injection risk, storage capacity, and storage safety. The ability to handle various complex phase behaviours also enables the potential utilisation of all types of reservoirs to maximise the storage potential.

Budget:

DKK 8,270,000

Funded by:

Innovation Fund Denmark & co-funding from project partners

Partners:

Technical University of Denmark, TotalEnergies, BlueNord, Gas Storage Denmark & INEOS, Wintershall Dea

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Timeline:

2023 — 2027

TRL:

2 → 4

Tags

Geological storage | Storage de-risking | Simulation technology | Modelling

Learn more

STORAGE

Effect of CO_2 injection

Effect of CO_2 injection on chalk properties - phase II

Objective and hypothesis

The project objective is to quantify effects on petrophysical, geochemical, rock mechanical and rock physical properties due to calcite dissolution from CO_2 injection and storage in Danish chalk reservoirs. This Phase II is designed to address uncertainties identified during Phase I with respect to suitability of CO_2 storage in Danish chalk reservoirs and potential showstoppers.

Approach

The project addresses the objective within cross-disciplinary collaboration between Geo, GEUS, and DTU-Sustain. Thus, it comprises theoretical and experimental work in rock mechanics, geochemistry, petrophysics and rock physics, as well as state-of-the-art laboratory equipment. Investigating the consequences of supercritical CO_2 injection as well as alternating supercritical CO_2 and water injection enables evaluation of a scenario with chemical disequilibrium and presumably more calcite dissolution. The experiments are split into these two parallel experimental directions to optimise gained knowledge and value within a short time frame.

Expected impact/output

The project aims to extend the current knowledge, reduce uncertainties, and identify potential for CO_2 storage in Danish chalk reservoirs. This includes, among other things, a description of the change in geomechanical properties and CO_2 saturations due to cycles of CO_2/water flooding and an investigation of the overall suitability of chalk reservoirs for CO_2 storage.

Budget:

DKK 5,600,000

Funded by:

Danish Offshore Technology Center

Partners:

Geological Survey of Denmark and Greenland (GEUS), Technical University of Denmark & Danish Offshore Technology Center

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Timeline:

TRL:

3→4

Part of:

Danish Offshore Technology Center

Tags

Geological storage | Geological formations | Storage de-risking

STORAGE

ChalkCO_2

Chalk–CO_2 reactions at reservoir conditions

Objective and hypothesis

The aim of the project is to de-risk CO_2 storage in chalk reservoirs by quantifying the magnitude of dissolution/precipitation and predicting its sector-scale location in carbonate reservoirs during and after CO_2 injection. The project will establish a sector model which can be applied to chalk fields to predict dissolution/precipitation.

Approach

The project follows a new approach based on flooding and reactor experiments designed specifically to quantify dissolution/precipitation as a result of variable pressure, temperature, lithology, and brine chemistry. The project will determine effects on porosity, permeability and injectivity, coupled to a petrographic characterisation of lithological features induced by dissolution/precipitation. These results will be geochemically modelled on the core-scale to determine the conditions leading to dissolution/precipitation, allowing us to establish a sector-scale model identifying sites of potential dissolution/precipitation at varying injection conditions. Experiments will be based on reservoir core samples and analogues if necessary. Modelling will be performed on a conceptual model based on a well-described field in the North Sea.

Expected impact/output

The most important outcome of the project is to provide the fundamental knowledge necessary to decide to further progress the TRL of CO_2 storage in depleted chalk reservoirs. The project increases the potential for CO_2 injection as an integral part of abandonment strategies for operators in the North Sea and increases the potential for CO_2 import as a business model. In addition, the know-how created can be exported to other countries with hydrocarbon fields in chalk or other tight carbonates.

Budget:

DKK 8,270,000 DKK

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Aarhus University, Technical University of Denmark, TotalEnergies, Nordsøfonden & BlueNord

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Timeline:

TRL:

2 → 3

Part of:

INNO-CCUS

Tags

Geological storage | Off-shore | Storage de-risking | Geological formations | Modelling

Learn more

STORAGE

CORROPro

Corrosion protection for CO_2 storage facilities using nanofilament coatings

Objective and hypothesis

The project will test whether newly developed silica nanofilaments (SNF) can protect well pipes and reservoir sediments from corrosion by highly acidic liquid CO_2 solutions. This could potentially reduce corrosion inside of tubes and pipes but also the intricate hydromechanics within pumps, the inside of tanks and pipes. The project will help de-risk and reduce uncertainties with respect to the reuse of existing infrastructures for CO_2 storage.

Approach

Silica nanofilaments (SNF) have been developed into reliable liquid-repelling coatings over the past years with applications in medicine, material science and the food industry. The project has been developing coatings for corrosion and scale inhibition. Furthermore, it is put forward to develop and test SNF coatings which can be applied as anti-corrosion coatings in Danish CO_2 storage facilities. The project will fine-tune the coating procedure for the needs within Danish reservoirs (sediment types, steels alloys, corroded steel) and rigorously test the stability and effectiveness of the coating technology using in-house high-pressure reactors and the new large-scale testing facility.

Expected impact/output

The aim for this project is to be able to 'spray' the coating inside the new tubing before installed in an CO_2 injection well. Hereby a significant extended lifetime of the CO_2 injection well is expected and hereby reduce the number of workovers.

Budget:

DKK 1,918,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Aarhus University, Technical University of Denmark, TotalEnergies, Nordsøfonden & BlueNord

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Timeline:

2022 — 2024

TRL:

2 → 3

Part of:

INNO-CCUS

Tags

Geological storage | Infrastructure | Corrosion | Material science

Learn more

STORAGE

CO_2Impure

Effects of impurities on CO_2 storage in chalk reservoirs

Objective and hypothesis

This project focuses on CO_2, that contains varying degrees of impurities and how they affect storage scenarios. The aim of this project is to contribute to the de-risking of storage of impure CO_2 in chalk reservoirs. Furthermore, the project will identify the geochemical effects of high concentration impurities and limitations of low purity CO_2 sources on storage.

Approach

This project will deliver batch and core flood tests of the response of reservoir chalk to relevant CO_2/impurity mixtures and rank the impurities with respect to risk in connection with storage in chalk. The learnings from laboratory experiments are used in numerical simulations to evaluate the short- and long-term impact of the injection of CO_2 with various impurity levels at the field scale for a Danish chalk reservoir. Through utilisation of coupled reservoir simulations, we will seek safe operational windows that could allow maximum impurities to be injected in the chalk field.

Expected impact/output

Based on the project's outcome, the project will propose guidelines for the impurities level that can safely be injected into chalk reservoirs. Legislators and operators considering chalk reservoirs for CO_2 storage will benefit from the knowledge.

Budget:

DKK 3,400,000

Funded by:

Danish Offshore Technology Center

Partners:

Danish Offshore Technology Center

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Timeline:

TRL:

2→3

Part of:

Danish Offshore Technology Center

Tags

Geological formations | Geological storage | Off-shore storage | Simulation technology | Storage de-risking

Utilisation

4

Utilising CO_2

The utilisation of CO_2 for chemicals and carbon-rich materials constitutes a crucial aspect of CCUS and is anticipated to be one of the key components in achieving the net-zero 2050 target within the carbon cycle. Utilisation has gained traction due to the expectation that in the future, CO_2 will become a valuable resource that should not only be captured and stored but also utilised in various ways as part of climate action.

Carbon Capture and Utilisation will play a role in mitigating climate change by reducing CO_2 emissions and, at the same time, using CO_2 as a raw material for producing valuable products. Biogenic carbon that is captured can be synthesized into green fuels, which have the potential to power aircraft and future maritime fleets. By reusing captured CO2, this process prevents additional emissions originating from fossil fuels.

As we aim to expand carbon capture technologies, CO_2 utilisation presents a promising avenue that can help balance the costs associated with CO_2 capture and conversion. Even as recycling processes for materials are expected to improve significantly, there will still be a continuous demand for carbon-based materials such as chemicals and plastic. The CO_2 utilisation industry is poised for growth, and Denmark has the potential to emerge as a global leader in this field, sharing its expertise with Europe and beyond. The projects within this sector will serve as concrete examples of this potential.

UTILISATION

NEOSUCCES

Upscaling and market introduction of simultaneous biogas upgrading and bio-succinic acid production

Objective and hypothesis

Biogas plants turn organic waste into biogas, primarily methane, through anaerobic digestion. Although quite promising, the process is still rather costly and inefficient, inhibiting more widespread implementation.
The NEOSUCCESS project aims to utilise biogas plants and, at the same time, benefit the environment by creating a simple plug-and-play technology that enables the simultaneous production of biomethane and bio-succinic acid (BioSA).

Approach

The projects consortium is formed by two well-established engineering firms and two world-class universities situated at the forefront of technical innovations. The project has validated and patented a prototype from real sugar-rich waste side streams (41.5 L of fermentation broth), and the project partners are now capable of building and fine-tuning the first NEOSUCCESS industrial unit. The unit will have a capacity of 12,000 Nm3 of BioM and 47,000 kg of BioSA.

Expected impact/output

The expected output of the project is to make a commercially available technology which is based on a containerised plug-and-play system. The technology is conceived to be integrated into biogas plants' operational workflow, making the investment in biogas upgrading profitable because of its complementary BioSA exploitation. Both Biogas upgrading and BioSA markets have a double-digit growth, which strikes as a great opportunity for Europe to leap forward. The project will achieve a successful market launch by 2023 and install 40 NEOSUCCESS units in 11 countries by 2027, contributing to the European transition towards a sustainable Bio-based Economy.

Budget:

DKK 18,220,000

Funded by:

Horizon Europe & co-funding from project partners

Partners:

Ingeniería Verificaciones Electromecánicas y Mantenimientos, Norvento Enerxía, Technical University of Denmark, Aristotle University of Thessaloniki, AINIA & BiotechPRO

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Timeline:

2020 — 2023

TRL:

→9

Tags

Biogas | Utilisation | Biogenic CO_2 | Process technology | International collaboration

Learn more

UTILISATION

$CAPCO_2$

Capturing and valorisation of CO_2 through photobioreactors to drive the green transition

Objective and hypothesis

Currently, there are no real carbon capture and utilisation (CCU)-solutions or low-carbon technologies suitable for small and mid-sized companies. Therefore, there is an urgent need to develop new processes, technologies, mechanisms, and energy systems that are economically feasible and realistic for small and mid-size industries. The purpose of this project is to demonstrate that even smaller amounts of CO_2 from small-scale industrial sites can feasibly be transformed into algae-based biomass for further utilisation, as there is a large potential for high-quality low-carbon ingredients now and in the future.

Approach

The project intends to demonstrate how future biogas and fermentation clients of the ALGIECEL carbon capture as a service technology can valorise their CO_2 emissions to the benefit of the whole value chain. Within the project, the consortia-partners will thus set up a photobioreactor (PBR) in collaboration with NOVOZYMES, supplying their CO_2 into the photobioreactor. The algae-based broth will be directed into an up-concentration container, where the water will be separated, to demonstrate that it can be reused.

Expected impact/output

$CAPCO_2$ aims to demonstrate a breakthrough concept for CCU. The solution is highly modular and scalable, allowing cost neutrality (short-term) and profitability (long-term) to the clients implementing the technology. There is a great commercial opportunity for the solution based on:

- A market anchored in the reduction of greenhouse gas emissions
- A growing demand for sustainable bioproducts
- New methods
- CO_2 prices and the voluntary carbon market.

Budget:

DKK 32,950,000

Funded by:

The Energy Technology Development and Demonstration Programme (EUDP) & co-funding from project partners

Partners:

ALGIECEL, Technical University of Denmark, Novozymes, P2CC (Power to Climate Change) & Knowledge Hub Zealand

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Timeline:

2023 — 2026

TRL:

4 → 8

Tags

Utilisation | Process technology | Value chain | Biogas

Learn more

UTILISATION

Marine Renewable Hub

Establishing production facilities for bunkering 100% green fuels from Hirtshals Havn

Objective and hypothesis

Port of Hirtshals is working towards becoming Northern Jutland's regional centre for CO_2-neutral shipping by 2050 and has therefore established an independent development company - Greenport North.
The initial project phase is focused on establishing production facilities for bunkering 100% green fuels from the port. Through the Nordic Transport Policy Network and the Trans-European Transport Network (TEN-T), Port of Hirtshals has the potential to become the crucial link between North Jutland producers of PTX fuels and maritime consumers.

Approach

A series of initial analyses suggest that decentralized carbon capture at biogas and incineration plants in North Jutland, in combination with the potential renewable energy resources and future port facilities in Hirtshals, can form the basis for producing and delivering competitive PTX fuels to meet the goal of CO_2-neutral shipping. The project consists of several sub-projects, including an investment in a demonstration plant for methanisation (conversion of CO_2 into methane, and thus CO2 capture) and a hydrogen production plant (electrolysis), which will be part of the process of using CO_2 to produce additional amounts of methane that can be converted into LBG. at GrønGas Hjørring, a business case for establishing a 30-70 MW methanol plant at Port of Hirtshals , as well as an analysis and optimization of carbon capture and efficient carbon transport to Port of Hirtshals.

Expected impact/output

One of the key achievements during the project period is the successful establishment of Biocarb Solution, a new company collectively owned by five local biogas plants. Biocarb will transport and store biogenic CO_2 from biogas plants. During the project period, the Greenport Scandinavia partnership has been formed with the purpose of establishing one of Europe's largest CO_2 import and export hubs in the Port of Hirtshals. Initially, Greenport Scandinavia focuses on establishing a full value chain for carbon capture and storage while longer-term ambitions include usage of biogenic CO_2 for production of green fuels. The project is expected to continue in a phase II, where the vision is to establish a methanol plant at the expanded Port of Hirtshals. The facility will include an electrolysis plant for hydrogen and oxygen production based on new renewable energy sources in the area, a facility to receive and purify carbon dioxide from point sources in the region, including a network of CO_2 pipelines, facilities for hydrogen synthesis with carbon, including storage and shipping, and various auxiliary facilities.

Budget:

DKK 76,220,000

Funded by:

REACT-EU (Regional Development Fund)

Partners:

Greenport North, GrønGas Hjørring, Grøn Brint Hjørring & University of Aalborg

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Timeline:

2022 — 2023

TRL:

3 → 7

Part of:

CO2VISION

Tags

Infrastructure | Utilisation | Fuels | Biogas | Biogenic CO_2 | PtX

Learn more

Project funds have enabled a 70 million DKK private investment in a CO_2 utilisation facility at GrønGas, uniting five biogas plants, resulting in a new CCUS company, Biocarb Solution and facilitated the Greenport Scandinavia partnership who aspire to position Northern Jutland as one of Europe's leading CO_2 hubs.

Hanne Skovby,
Project Director, Greenport North

UTILISATION

BE Clean

Biogas electro clean

Objective and hypothesis

For power to x technologies, high quality biogenic CO_2 is necessary. In the BE Clean project, a power-to-x gas cleaning technology is being developed to purify a CO_2 rich gas. The technology is currently being developed for biogas purification, where 40 % of the gas is CO_2. The target is to remove unwanted impurities such as hydrogen sulfide (H_2S) in a sustainable way. Hydrogen sulfide is a major concern for catalytic conversion of CO_2. Even parts per billion (ppb) level concentrations of H_2S is an issue for the catalysts. The BE Clean technology aims to remove H2S down to below the ppb level. BE Clean aims to demonstrate the new purification technology for biogas. While the technology has been developed for desulfurisation, removal of several other types of impurities will also be looked at in the project.

Approach

The project will:

- Demonstrate a new disruptive full-scale biogas purification process that will enable biogas facilities to achieve >98% uptime, thereby increasing bioenergy production.
- Develop an electro-scrubber technology to make it possible to produce sulfur and reduce the oxygen content in the purified biogas to below 2000 ppm (current technologies are >20,000 ppm).
- Create a business model for the application of the new biogas purification process using simulation and optimisation.

Expected impact/output

The goal of the project is to demonstrate sulphur removal technology full scale within the next 3 years. This power-to-x process is cheaper than current technologies and uses electricity instead of chemicals, which is an advantage. Additionally, the project expects to establish a business model that will allow biogas producers to utilise this new process, which is more flexible, requires less maintenance, and provides cost-effective bioenergy production. The business model is expected to reduce capital expenditures associated with biogas energy production by over 20% for biogas purification.

Budget:

DKK 23,000,000

Funded by:

The Energy Technology Development and Demonstration Programme (EUDP) & co-funding from project partners

Partners:

Technical University of Denmark (Chemical Engineering), Elplatek, Pentair Union Engineering & Danish Gas Technology Centre

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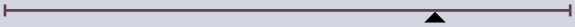
Timeline:



TRL:

6 → 7

Tags

PtX | Biogenic CO_2 | Process technology | Utilisation | Biogas

Learn more

UTILISATION

FrontFuel

Pilot-scale demo of CO_2 to SAF process

Objective and hypothesis

This research project will design, test, and install the world's first demonstration plant that showcases the entire value chain to produce sustainable aviation fuel based on CO_2 and renewable energy. The green transformation of the aviation sector is today challenged by, among other things, immature technologies with high costs, lack of scalability, and high raw material costs. If society is to sustain the sector in the future, it requires net-zero solutions with liquid drop-in fuel sources available on a large scale.

Approach

Power-to-X has its justification in the hard-to-abate sectors, where it is difficult to convert away from fossil fuels. The aviation sector is a good example because jet fuel is the most energy-dense fuel we have and the most difficult to make synthetically. Aarhus University's research centre in Foulum, AU Viborg, will host the complete technology package for the production of CO_2-neutral jet fuel. The project will work with the technologies on an industrially relevant scale, where it can show that it works, and demonstrate a solid business case.

Expected impact/output

The project is an exciting step forward in the commercialisation of new technologies for the production of sustainable jet fuel and will make a significant contribution to decarbonising the aviation sector. It is expected that this will pave the way for the first commercial plants.

Budget:

DKK 26,900,000

Funded by:

The Danish Energy Agency, The Energy Technology Development and Demonstration Programme (EUDP)

Partners:

Topsoe A/S, Aarhus University & Sasol

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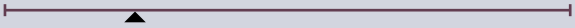
Timeline:



2023 2026

TRL:

5 → 7

Tags

Utilisation | PtX | Value chain | Biogenic CO_2 | Energy systems

UTILISATION

PROFIT

Protein revolution: Obtain feed ingredients from wastes for green transition

Objective and hypothesis

Currently, food wastes and residues arising from agriculture, are either not properly utilised or only used for electricity, heat production or transport fuel. In the forthcoming future, both renewable electricity and heat can be produced more cheaply by other sustainable routes. Therefore, PROFIT proposes to convert CH4 and CO_2 from biogas to a valuable product, namely feed in the form of SCP. The aim of the project is to develop an integrated technology for organic waste treatment.

Approach

The project will address three objectives:

- Technical: Electrochemical N and P recovery from digestate, and systems analysis of the proposed technology for the process.
- Social: By accepting to collaborate in the development and acceptance of PROFIT, the agricultural sector becomes part of the community. In this respect, PROFIT contributes to the social dimension of sustainability, since it provides new opportunities to the agricultural sector, namely its involvement in the co-creation of a product that benefits the economy and the environment.
- Economic: The sustainability and economic feasibility of PROFIT will be evaluated using life cycle, techno-economic assessment, and market penetration actions at each level of development.

Expected impact/output

PROFIT will provide the basis for policies and regulation to promote green transition and circular economy. PROFIT answers public concerns about green transition and provides a technical solution to support the public to have a greener lifestyle. Consequently, PROFIT will create social value as it will contribute to sustainable solutions, create new types of jobs, and promote Danish research institution and technology consultancy as pioneers in technology for green transition. The value proposition of the PROFIT project will derive from the sustainable supply of protein ingredients. During the project ongoing negotiations will be performed for the commercialisation of the product for target applications.

Budget:

DKK 14,300,000

Funded by:

Innovation Fund Denmark & co-funding from project partners

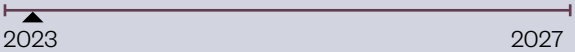
Partners:

Technical University of Denmark, ARC (Amager Ressourcenter), Knowledge Hub Zealand, Copenhagen Municipality, Unibio A/S & Roskilde University

Contact:

Irini Angelidaki iria@kt.dtu.dk

Timeline:



TRL:

3 → 7

Tags

Utilisation | Biogenic CO_2 | Biogas | Process technology | Agriculture | Public acceptance | Regulation

UTILISATION

SEMPRE-BIO

Securing domestic production of cost-effective biomethane

Objective and hypothesis

In March 2022, the European Commission announced a target to produce 35 billion cubic metres of biomethane within the EU by 2030. Today, the EU produces 3 billion cubic metres of biomethane. Plans to scale up require the mobilisation of sustainable biomass feedstock. In this context, the aim of SEMPRE-BIO is to demonstrate novel and cost-effective biomethane production solutions and pathways.

Approach

The project will set up three European Biomethane Innovation Ecosystems (EBIEs), based in Adinkerke (Belgium), Baix Llobregat (Spain) and Bourges (France), which are representative of the different baseline situations for biomethane production across Europe. Those initial EBIEs will facilitate long-term replication by creating an active flow of information and resources for ideas to transform into reality. The project will build a process by which more innovators and entrepreneurs will be able to more quickly develop and launch solutions to solve problems related to the larger-scale and cheaper production of biomethane. This process will create new technical expertise, help diversify the technology portfolio, and will allow businesses to know their potential customers better. Additionally, the EBIEs will provide the means to create economic stability and resource sharing.

Expected impact/output

The value of the EBIEs lies in the access to resources for the start-ups and the flow of information for the ecosystem's stakeholders. This information flow will create more future investment opportunities for the right institutions to connect with the right ideas for their businesses and portfolios at the right time and for the right reasons.

Budget:

DKK 74,076,000

Funded by:

European Union's HORIZON-CL5-2021-D3-03-16 program under grant agreement No 101084297

Partners:

CETAQUA, Aigües de Barcelona, CRYO inox, Deutsches Biomasseforschungszentrum, Technical University of Denmark, Inveniam Group, ProPuls, SINTEF, TeraWatt, Transports Metropolitans de Barcelona, Universiteit Gent, Beta Technological Center, Biogas-e, Innolab, Naturgy & NV De Zwanebloem

Contact:

Irini Angelidaki, iria@kt.dtu.dk

Timeline:

2022 — 2026

TRL:

→7

Tags

Utilisation | Biogenic CO_2 | Biogas | International collaboration | Process technology

Learn more

UTILISATION

CO_2Fix

Sustainability and permanent CO_2 removal: Using geocatalysts to mineralise CO_2 and convert waste to a valuable product

Objective and hypothesis

CO_2Fix is based on the idea that biogenic molecules can act as catalysts to control mineral-water-gas reactivity. This paves a way for fast, permanent conversion of CO_2 to solid, locally, at the factory chimney with no safety risks associated with CO_2 transport and long-term monitoring at storage sites. Specifically, CO_2Fix offers an end-of-life solution for large volumes of waste building materials, such as stone wool, that end in landfills each year.

Approach

The process targets a new market, with no known competitors, and the case for invention protection is strong. The leading CO_2Fix scientists, with colleagues who have strong commercial experience, will form a startup, which will market systems solutions, offer consulting and service worldwide, generating Danish jobs in manufacturing, R&D and sales. The industry partners, ROCKWOOL, ARGO, and IBF, represent the full value chain.

Expected impact/output

The project will provide immediate solutions. It will avoid the need for disposing of large volumes of waste building materials, it will remove and solidify CO_2 directly at factory chimneys and it will provide a valuable, new material for low CO_2 concrete. On the longer term, the project can be a step towards Danish leadership in a new, CO_2 mineralisation market through the knowledge gained about mineral-water-gas-organic molecule interactions.

Budget:

DKK 26,097,301

Funded by:

Innovation Fund Denmark & co-funding from project partners

Partners:

Technical University of Denmark, ROCKWOOL International, ARGO (Roskilde Energitårnet) & Ikast Betonvarefabrik

Contact:

Susan Stipp, stipp@dtu.dk

Timeline:

2022 — 2025

TRL:

4 → 6

Tags

Material science | Process technology | Utilisation

Learn more

UTILISATION

CooCE

Harnessing potential of biological CO_2 capture for circular economy

Objective and hypothesis

The overall aim of the project is to accelerate the use of CCUS and revolutionise CO_2 capture and utilisation by closing carbon loops in a circular economy approach. The project therefore aims to develop and demonstrate a novel biotechnological platform in which CO_2 (from biogas or exhaust gasses) is converted into (a) upgraded biofuels for flexible on-site hybrid energy storage and (b) high market value platform chemicals, namely biosuccinic acid and polyhydroxyalkanoates, that form the building blocks of various biopolymers and bioproducts.

Approach

The project consists of 7 work packages:

- WP1 focuses on the management and coordination of the project.
- WP2 develops a pilot system for biological methanation using CO_2 from fuel gases/biogas.
- WP3 involves the production of succinic acid and the evaluation of target applications.
- WP4 focuses on the bioconversion of CO_2 to PHA.
- WP5 assesses the sustainability and socio-economic impact of the project.
- WP6 focuses on the market potential and replicability of the project.
- WP7 ensures that the project objectives, milestones, and societal impacts are communicated strategically.

Expected impact/output

The project will contribute to the shift towards a resource-efficient, low-carbon and climate-resilient economy. This is due to the expected savings of greenhouse gas emissions from the proposed system, which will be higher than 100%, compared to those generated during the production of conventional gasoline as fuel or corresponding chemicals for polymers. The project will also contribute to the enrichment of professional curricula with the principles of CCUS by piloting a programme, "CooCE- Training Programme", to personnel from industries and SMEs as well as young professionals.

Budget:

DKK 5,297,000

Funded by:

ACT ERA-NET Cofund under the European Union's Horizon 2020 Research and Innovation programme (Project No 327331 CooCE) and Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners

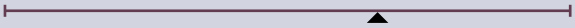
Partners:

University of Padua, BTS Biogas, Euronewpack, Hellenic Agricultural Organization – Demeter, Technical University of Denmark, Lemvigbiogas, Imperial College London, Qlab Analytical Laboratory & Pond

Contact:

Irini Angelidaki, iria@kt.dtu.dk

Timeline:



TRL:

→6

Tags

Biogas | Utilisation | Biogenic CO_2 | Fuels | Capacity building | International collaboration

Learn more

UTILISATION

Acetate Consortium

CO_2 as a sustainable raw material in our future food production

Objective and hypothesis

Food insecurity is a rising global problem. A recent UN-led report shows that more than 250 million people faced severe hunger during 2022, which was an increase of 65 million compared to the year before. To counteract this development, this project aims to contribute to the establishment of a sustainable, safe, and stable food production that can feed a growing world population. The aim is to help fight the rising global problems with food insecurity and greenhouse-gas emissions from agriculture.

Approach

The project will provide a more sustainable way of producing proteins through fermentation – a way of producing food we have been using for millennia.
By using biological and electrochemical processes, the project will process CO_2 and turn it into acetate, which is vinegar – a well-known substance already present in the metabolism of the microorganisms used for fermentation. The acetate can then be used to produce proteins that can be used directly in food for humans.

Expected impact/output

By creating alternatives to animal proteins, the project will reduce the need for meat and dairy production, which puts a significant strain on natural resources by using land for the animals and growing crops to feed them. In addition, using acetate derived from CO_2 directly in the fermentation process will eliminate the need to use sugar, which is a big part of fermentation processes. This will free up substantial agricultural areas currently used for sugar production.

Budget:

DKK 200,000,000

Funded by:

Novo Nordisk Foundation & Bill & Melinda Gates Foundation

Partners:

Novozymes, Topsoe, Washington University St Louis & Novo Nordisk Foundation CO_2 Research Center at Aarhus University (CORC)

Contact:

Alfred Sporman, aspormann@corc.au.dk

Timeline:

2023 – 2025

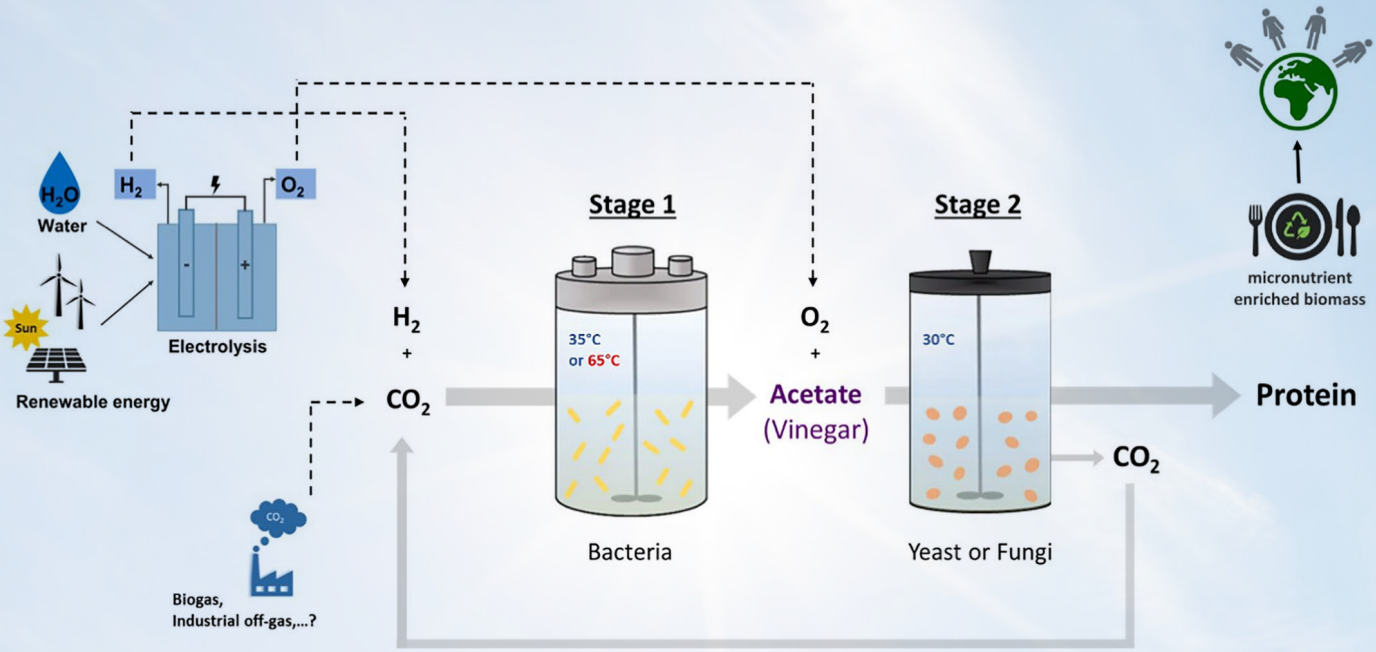
TRL:

→6

Tags

Microbiology | Utilisation | Process technology

Learn more



The Acetate Consortium' at CORC and AU is exploring a fundamentally new way to produce nutritious protein directly from CO_2 without the need for agriculture and animal farming. This makes our agriculture much more sustainable and greatly avoids the waste of land, water, nutrients, as well as the release of a lot of CO_2. With this technology platform, we can produce sustainable eatable protein anywhere in the world just with CO_2, water and electricity, even in arid land in low-income countries.

Alfred Spormann,
Executive Director, CORC

UTILISATION

FRESH

Formate for renewable energy storage

Objective and hypothesis

The purpose of the FRESH project is to develop, operate and validate an integrated, cost-competitive process for conversion of CO_2 to potassium formate (PF) using an electrocatalytic process powered by renewable electricity. The project aims to develop, construct and operate a prototype for renewable energy storage technology that will convert green, carbon-neutral energy, water, and carbon dioxide into a renewable fuel used as an energy carrier for electricity production.

Approach

The highly stable PF (Electrolyser) aqueous solution generated by the reactor will be stored safely for long periods in tanks. The subsequent conversion of the stored PF to electricity on demand will use a direct fuel cell system, and the subsequent conversion of the stored PF to electricity on demand will use a direct fuel cell system. The developed FRESH system will be sited at a single location for validation, and two key research objectives are CO_2 conversion to PF (Electrolyser) and PF reconversion to electricity (fuel cell).

Expected impact/output

The project will contribute to the development of a cost-competitive, flexible, and decentralised energy storage solution, making renewable energy more accessible and reliable. The role of DTU KT will be to perform laboratory experiments to optimise carbon capture for the utilisation of CO_2 in the flow battery.

Budget:

DKK 20,000,000

Funded by:

European Union's Horizon research and innovation Programme under the grant agreement No.HORIZON-RIA-101069605

Partners:

Coval Energy, Engie Laborelec, eRisk Group, Forschungszentrum Jülich, Hysytech, Technical University of Denmark & The Institute of Chemistry of OrganoMetallic Compounds (ICCOM)

Contact:

Sebastian Nis Bay Villadsen, snbvi@kt.dtu.dk

Timeline:

2022 — 2025

TRL:

4 → 6

Tags

Utilisation | Fuels | Process technology | International collaboration | Energy systems

Learn more

UTILISATION

SynoProtein

Carbon capture from syngas to Single Cell Protein (SCP) and use as fish feed ingredient

Objective and hypothesis

The SynoProtein project aims to develop, mature, and demonstrate a novel carbon-negative process that enables high value creation of SCP from sawmill by-products through carbon capture and use (CCU). The project fits strongly with the mission of the CBE JU (Circular Bio-based Europe Joint Undertaking), which is to "advancing a competitive bioeconomy for a sustainable future".

Approach

With this project, SynoProtein will demonstrate that 1.25 tons (t) of CO_2-e can be captured from syngas via CCU for each dry-ton sawmill by-products processed. The consortium has developed an innovative process for the vertical integration of by-products from sawmill industry, i.e., feedstocks comprising only residues (no sawlogs), and conversion into fish feed ingredients, i.e., single cell protein (SCP), along with the production of biochar for animal feed. The process can provide novel, sustainable protein sources, as opposed to conventional energy- and climate-intensive soybean and resource-limited wild fish protein production routes to meet future demands.

Expected impact/output

Overall, the project expects carbon capture of 200kt of CO_2-e from syngas annually within the process by 2033, recovering 160kt/year of forest residues and producing 120kt/year of fish/animal feed for industry, valued at €175m. This also represents 260 jobs created in EU and reduced 120kt per year imported feed ingredient from other continents. Compared to fish feed production from soybeans, the project is also expected to save carbon emission of 458kt CO_2-e, land use of 147km2, and water use of 630,700m3 by 2033.

Budget:

DKK 44,967,000

Funded by:

European Union's Horizon Europe JU Research and Innovation Actions programme under grant agreement N° 101112345

Partners:

WAI Environmental Solutions AS, Technical University of Denmark, Sintef AS, Sintef Energi AS, Norsk institutt for bærekraftsforskning AS, Nofima AS, RISE Research Institutes of Sweden, Bergene Holm AS, Skretting Aquaculture Research Centre AS, DECHEMA & Gesellschaft für Chemische Technik und Biotechnologie e.V.

Contact:

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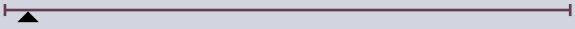
Timeline:



TRL:

4 → 6

Tags

Point source capture | Utilisation | Biogenic CO_2 | Value chain | International collaboration | Process technology

Learn more

UTILISATION

UC-DC

Utilisation of carbon for decarbonisation project

Objective and hypothesis

This project will convert waste CO_2 and CO_2 captured directly from air into commodity chemicals for replacing petrochemicals, thus unlocking a sustainable and future-proof carbon source for decarbonising the chemical industry.

Approach

UC-DC will develop a CCU technology using bacteria for biological CO_2 capture. The technology will be able to convert the CO_2 into commodity chemicals which fit the existing chemical supply chain. To further expedite the potential applications of CCU, the project will demonstrate the conversion of the produced commodity chemicals into monomers for further polymerisation. This will provide valuable plastic pellets, demonstrating a value chain spanning from carbon capture to a final plastic material.

Expected impact/output

Combining environmental and socio-economic studies with technological advances, UC-DC will pave the way for a more sustainable, non-fossil-based chemical industry. This integration will bring value-creation for the consortium partners, enabling them to unlock a million-dollar market upon commercialisation 5 years following project completion. Part of this value will be realised immediately as the environmental, socio-economic, and technological advances will guide strategic choices of Again and Pond. The achieved results will be implemented at the UC-DC companies directly, thereby accelerating the global transition from petrochemicals to CCU-based chemicals.

Budget:

DKK 10,562,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Danish Technological Institute, SecondCircle ApS, Pond A/S & Technical University of Denmark

Contact:

Line Rold Tousgaard, lrto@teknologisk.dk

Timeline:

2023 — 2025

TRL:

3 → 5-6

Part of:

INNO-CCUS

Tags

DAC · Utilisation · Microbiology · Process technology · Value chain

Learn more

UTILISATION

CRONUS

Capture and reuse of biogenic gases for negative-emission - sustainable biofuels

Objective and hypothesis

The overall ambition of the CRONUS project is to significantly advance the current state of the art in biofuels production and the utilisation of biogenic effluent gases. CRONUS will introduce effective technologies with high-potential innovations (techno-economic feasible solutions), thus accelerating the green transition and associated transformation of our economy, industry, and society with a view to achieving climate neutrality in Europe by 2050.

Approach

The overall CRONUS project approach is built on insights from research on 'sustainability transitions' that analyse innovation within socio-technical systems. More specifically, CRONUS will deliver a unique platform of novel technologies suitable for easy integration into the existing biofuels production plants, able to upcycle dissimilar kinds of biogenic effluent gases to biofuels. These will be ready for distribution within installed grids and biochar as biogenic carbon sink. The establishment and activities of "Communities of Practice" will ensure the active involvement and engagement of key stakeholders in performing, demonstrating, and assessing the proposed technologies leading to the sustainability of biofuels value chain and active involvement of society.

Expected impact/output

The project aims to increase public acceptance and awareness of biofuel technologies, identifying and communicating their advantages to the general population. CRONUS seeks financing schemes to make its solutions more attractive and cost-effective, overcoming economic challenges and fostering sustainable biofuel transition. Through targeted policy briefs and active involvement of key policy actors, CRONUS aims to influence policy landscapes and secure political support for biofuel technologies at the local scale.
The project's impact extends beyond technological advancements, as it strives to shape a sustainable energy landscape with the broad adoption of carbon-negative biofuels.

Budget:

DKK 37,309,000

Funded by:

European Union's Horizon Europe research and Innovation programme under grant agreement N° 101084405

Partners:

National Technical University of Athens, Hellenic Agricultural Organisation, Technical University of Denmark, Biotech Pro, University of Padova, Agricultural Research for Development, Cartif Technology Center, AlgEn, Novel Environmental Solutions, Brunel University London, Autonomos University of Barcelona, Madisi & UT SMIDE

Contact:

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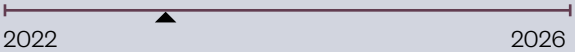
Timeline:



TRL:

2 → 5

Tags

Fuels | Economy | Biogenic CO_2 | Value chain | International collaboration | Public acceptance | Regulation

Learn more

UTILISATION

eTecFuels3

Production of e-methanol in one-step by the phosphate process

Objective and hypothesis

The objective of this project is to develop a novel electrolysis technology, operating at 240-300°C, enabling the production of methanol from H_2O and CO_2 in a one-step process. This allows for the creation of cost-effective green methanol for use as fuel in shipping and other heavy transport.

Approach

The research project eTecFuels3 concerns an entirely new electrolysis technology that DTU Energy and the other partners have developed on a laboratory scale. In this process, electrolysis occurs at temperatures ranging from 240 to 300 degrees, the same temperatures typically used for the chemical synthesis of methanol and other simple organic products.
DTU Energy has been collaborating with CO_2Techn and Blue World Technologies for several years on the phosphate electrolysis process, and with Elplatek on electrode materials and surface coatings. Moving forward in the project, Blue World Technologies, will contribute by conducting a techno-economic analysis of green methanol as a sustainable fuel.

Expected impact/output

From a Danish perspective, there is a need for technologies that can both utilize CO_2 emissions from industry and biomass and harvest electricity from wind power in the North Sea. This is essential for reducing CO_2 emissions through electrochemical conversion. Additionally, several sectors like shipping and heavy transport are unlikely to be directly electrified and will continue to rely on fuels in the future.
The fact that the process can occur in a single step, rather than first splitting water into oxygen and hydrogen and then reacting hydrogen with CO_2 in a chemical reactor to produce methanol, potentially makes it more energy-efficient. If the project is successful, it could have a significant impact.

Budget:

DKK 10,224,000

Funded by:

Innovation Fund Denmark & co-funding from project partners

Partners:

Technical University of Denmark (DTU Energy), Blue World Technologies, Elplatek, CO2Techn & Mærsk (A.P. Møller-Mærsk)

Contact:

Erik Christensen, erchr@dtu.dk

Timeline:

2023 — 2026

TRL:

3 → 5

Tags

Utilisation | Fuels | Process technology | Energy efficiency

Learn more

UTILISATION

METHARC

Wellbore hydrogen production with CCUS

Objective and hypothesis

Today, vast amounts of time, money, and energy are spent trying to recapture less than 100% of the carbon released into the atmosphere. However, as it is more efficient to capture it all at source, the project has patented a process and is developing wellbore hydrogen production technology in this form of a completion tool. The tool adapts the carbon production cycle to create replacement revenue sources while utilising, capturing and storing carbon as a part of the Metharc process.

Approach

The developed completion tool is run inside a well, down to the depth of the geological reservoir being exploited. As methane is drawn from a geological reservoir into the wellbore, it flows into the tool where it is gasified, to generate hydrogen, CO_2, and other products. To improve overall resource efficiency, the same process can be equally applied to onshore Geothermal wells when utilising the surface injection of biogas. Once these gasification reactions are performed, the reactants are separated within the wellbore tool, with the hydrogen produced to surface. Simultaneous to this, the CO_2 and other 'waste' reactants exiting the downhole tool are immediately re-injected back into the surrounding geology, into a reservoir of choice.

Expected impact/output

This process future-proofs hydrocarbon assets (both Natural Gas and Biogas) and provides economic longevity through adaption and reuse of existing infrastructure (wells, pipelines etc.). It is an environmentally responsible way to enable the continued exploitation of known methane resources through a climate-beneficial method.

Budget:

DKK 750,000

Funded by:

Project partners

Partners:

FORCE Technology

Contact:

Stuart Gillick, info@metharc.com

Timeline:

TRL:

2 → 5

Tags

Geological storage | Infrastructure | Process technology | Utilisation

Learn more

UTILISATION

Microbial electrosynthesis

Accelerating technology development of microbial electrosynthesis to convert CO_2 to natural gas (methane) at scale

Objective and hypothesis

Electromethanogenesis involves the production of methane from CO_2 and electricity using methanogenic microorganisms. This is a promising biotechnology because of its resilience to intermittent power supply and reliable long-term operation, as shown by lab studies. The goal of this project is to provide the necessary engineering optimisation of the laboratory-based insights and derive the engineering parameters necessary for testing electromethanogenesis at an industrial scale.

Approach

This project will design and test new efficient and scalable electromethanogenesis cells. In addition, different microbial strains will be examined to optimise gas production rates. Furthermore, modelling of microbial kinetics and the new cell designs will be included to evaluate their performance.

Expected impact/output

This project will provide essential engineering improvements to optimise electromethanogenesis. This will fast track the lab-scale process to an early-stage technology, ready for industrial upscaling.

Budget:

DKK 7,000,000

Funded by:

Novo Nordisk Foundation

Partners:

Aarhus University, Stanford University (USA), The Pennsylvania State University (USA) & CORC (Novo Nordisk CO2 Research Center)

Contact:

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Alfred Spormann, aspormann@corc.au.dk

Timeline:

2023 — 2025

TRL:

4 → 5

Tags

Microbiology | Utilisation | Process technology

UTILISATION

RD-BECCUS

Research and development platform for flexible BECCU/S

Objective and hypothesis

Available CCU technologies require year-round, constant operation to be commercially viable. The reality is, however, that an energy system is characterised by increasingly larger fluctuations. Thus, this project will investigate, design, and plan a research platform to enable the development of second-generation technologies for flexible carbon capture and utilisation/sequestration in combination with bioenergy (BECCU/S). In addition, the project will model both a full scale and pilot plant.

Approach

The project consists of two stages:

- The first stage implies the design of a 100-kW research platform. The platform will be complete with biomass combustion and carbon capture, the partial commissioning of the plant and the creation of digital models for flexible BECCU/S. This will also include an upscaling of a co-electrolysis process for chemicals from captured CO_2. Data from a combined heat and power plant and electricity grid data will be used to digitally scale up BECCU/S technologies and prepare for the physical testbed.
- The second stage of the project is the completion of the physical testbed/pilot plant, including coupling with an improved co-electrolysis process.

Expected impact/output

Flexibility in operation is key to applying CCU in a PtX framework. Current CCU technologies are not economically attractive for medium-sized, combined heat and power plants as they are operated following heat demand or participate in grid balancing. CO_2 from these plants is thus not accessible as an energy carrier or material in PtX-concepts. This research platform will be an important step in closing this gap as it integrates well with fluctuating energy and CO_2 availability.

Budget:

DKK 7,742,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

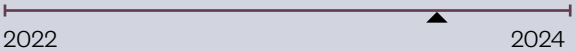
Partners:

Technological Institute, Alexandra Institute, Verdo, CO2Techn.com, Technical University of Denmark, Ammongas & Hafnium Labs.

Contact:

Lars Schwarzer, lars@teknologisk.dk

Timeline:



TRL:

3 → 5

Part of:

INNO-CCUS

Tags

Point source capture

Utilisation

Biogenic CO_2

Value chain

Energy systems

Process technology

Learn more

UTILISATION

BIG

Biocatalyst interactions with gases

Objective and hypothesis

Reducing carbon emissions and developing alternative routes for fertiliser production are increasingly urgent challenges facing our world. This project aims to uncover new biology-based methods for CO_2 management and sustainable fertiliser production.

Approach

The project will fundamentally investigate enzyme-catalysed gas reactions involving carbon dioxide (CO_2) and nitrogen (N_2). The project team will develop insights on complementary enzyme-based approaches for transforming abundant CO_2 and N_2 gas molecules in Earth's atmosphere into small water-soluble compounds – bicarbonate, formate and ammonia. The transformation will improve gas molecule conversion efficiency, which will help advance greenhouse gas reduction technologies while creating useful precursors for cement, fuels, chemicals, and fertilisers.

Expected impact/output

Studying these life-essential bio catalysed gas reactions will lead to new innovations that contribute to global sustainability solutions. The five-year BIG Collaboration will prepare students for careers where they can make a significant impact on greenhouse gas emissions and support the bioeconomy. Carbon management is a rapidly growing field, creating a high demand for skilled scientists with experience advancing these technologies.

Budget:

DKK 50,000,000

Funded by:

Novo Nordisk Foundation

Partners:

North Carolina State University & Technical University of Denmark

Contact:

Peter Westh, petwe@dtu.dk

Timeline:

2022 – 2027

TRL:

1 → 4

Tags

Utilisation | Process technology | Agriculture | Capacity building

Learn more

UTILISATION

BioTechCCU

Biotechnology for converting CO_2 to platform chemicals

Objective and hypothesis

This project aims to build on the biomethanation platform as CO_2 capture and integrate it with the utilisation pathways. This will be done by developing biological technologies to produce platform and value-added chemicals. The project has three objectives for this integration:

- To develop biomethanation using Power-to-X for diverse CO_2 point sources and demonstrate at TRL4.
- To integrate acetic acid production at TRL4.
- To develop integrated fermentation of biomethane for bioplastics at TRL4.

Approach

The innovative method of the project is to integrate the promising biomethanation technology with biochemical utilisation technologies. The project will unfold in three operational work packages (WP). In WP1, work will be done to optimise the process for diverse CO_2 point sources, e.g., CO_2 flue gas from biomass-fired power plants. The main aim of WP2 is the design and operation of a bioreactor that can produce acetate from CO_2 and H_2. WP3 is focused on developing microbial reactors for methanotrophs, understanding the metabolic limitations, and conducting lab-scale demonstrations integrated with biomethanation.

Expected impact/output

It is expected that renewable feedstock availability for fuels, chemical processes, and materials will become a limiting factor for the green transition. Capturing diverse CO_2 point sources and utilising them to produce chemicals can provide a sustainable alternative. The maturation of biomethanation technology is, therefore, a crucial technology that can enable the production of value-added chemicals in the future.

Budget:

DKK 5,128,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

University of Southern Denmark, Aarhus University, Nature Energy & Danish Gas Technology Centre

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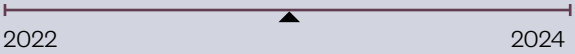
Muhammad Tahir Ashraf, muta@igt.sdu.dk

Timeline:



TRL:

3 → 4

Part of:

INNO-CCUS

Tags

Utilisation | Biogas | Biogenic CO_2 | Value chain

Learn more

UTILISATION

ReFuel

Harnessing archaeal processes to capture carbon dioxide into alkanes as renewable fuels and energy storage agents

Objective and hypothesis

ReFuel investigates the feasibility of the microbial-mediated process, alkanogenesis, which is the proposed formation of higher alkanes mediated by Archaea. The vision is to harness alkanogenesis as a fundamental platform for the development of green, circular biotechnologies. ReFuel aims to explore the Archaeal alkane oxidation and tackle alkanogenesis by gaining a deeper understanding of the phylogenetic and functional diversity of alkane-oxidising Archaea.

Approach

Biological formation of higher alkanes is supported by physiology and isotope labelling experiments showing a backflux of CO_2 to alkanes, and by in situ geochemical studies showing the presence in gas reservoirs of alkanes depleted in 13C – an indication of biological origin. To meet the goals of the project, ReFuel will use a combination of microbial physiology experiments, stable isotope probing, single cell chemical imaging and metagenomics approaches. When demonstrated, alkanogenesis will offer an organismic explanation to sedimentary geochemical observations like natural gas micro-seepage or isotopically depleted gaseous alkanes.

Expected impact/output

The project expects to define an archaeal-mediated hydrocarbon cycle in anoxic sedimentary basins, and to expand our fundamental understanding of the metabolic potential of Archaea and their environmental function and impact. The project aims to develop green technologies that will produce renewable fuels (zero net CO_2 emissions). The target alkanes, like butane, have high energy density, are easily liquefied, stockpiled, and can drop-in directly in existing infrastructure.

Budget:

DKK 24,992,842

Funded by:

Novo Nordisk Foundation

Partners:

Aarhus University

Contact:

Florin Musat, florin.musat@bio.au.dk

Timeline:

2023 – 2030

TRL:

2 → 4

Tags

Microbiology | Capture | Storage | Utilisation | Fuels | Process technology

Learn more

UTILISATION

Waste plastics

CO_2 capture by waste plastics

Objective and hypothesis

Every year nearly 400 million tonnes of non-biodegradable materials, such as plastics and textiles, are produced. These materials generally have a short lifetime use, resulting in vast amounts of plastic waste accumulation. The ambition of the project is to expand plastic upcycling technologies to provide possible solutions for supporting household and community-level activities for carbon capture.

Approach

The project's research efforts are focused on the investigation of whether some of the most common and abundant plastic wastes can be upcycled into useful materials through simple and efficient chemical modifications for expediting the capture and sequestration of CO_2 directly from air or point sources.

Expected impact/output

The successful realisation of waste plastic for carbon removal provides an opportunity with economic benefits. The chemical industry will experience a boost in their production of highly useful platform and bulk chemicals from CO_2 through catalytic or biological processes.
End-of-life plastics provide a unique opportunity for carbon capture, not only because their chemical modification to capturing agents can potentially be done in only a few chemical steps. More importantly, the tremendous quantities of such materials could allow for the goal of CO_2 sequestering at a gigaton scale to be potentially achievable.

Budget:

DKK 20,000,000

Funded by:

Novo Nordisk Foundation

Partners:

Novo Nordisk Foundation CO2 Research Center at Aarhus University (CORC)

Contact:

Troels Skrydstrup, ts@chem.au.dk

Timeline:

2023 — 2026

TRL:

1 → 4

Tags

Utilisation | Process technology

UTILISATION

MES-MODEL

A mathematical model to improve microbial electrosynthesis

Objective and hypothesis

Microbial electrosynthesis (MES) reduces CO_2 with renewable electricity into valuable C_2 chemicals (mainly acetate and ethanol) using acetogenic bacteria. The major open question is, however, how acetogenic bacteria acquire electrons from a cathode. It was recently hypothesised that microorganisms stimulate cathodic H_2 evolution by consuming H_2. This project aims to develop a mathematical model to describe the complex processes occurring at the cathode during MES.

Approach

The model will incorporate microbial kinetics, electrochemical processes, and mass transport. The model will be calibrated with parameter values obtained from state-of-the-art microbial and electrochemical characterisations and validated by bioelectrochemical experiments. In addition, the project will apply the model to develop guidelines for the selection of the most optimal cathode materials and acetogenic strains for MES.

Expected impact/output

This mathematical model will be the first theoretical description of MES. The model will become a valuable tool for the research community and contribute to the optimisation of MES towards its use at an industrial scale.

Budget:

DKK 2,878,000

Funded by:

Indenpendent Research Fund Denmark

Partners:

Aarhus University

Contact:

Jo Philips, jo.philips@bce.au.dk
Jacopo Catalano, jcatalano@au.dk

Timeline:

TRL:

2 → 3

Tags

Utilisation | Microbiology | Modelling | Process technology

Learn more

UTILISATION

Bio-hydrogen production

Decarbonisation of CO_2 storage platforms by bio-hydrogen production

Objective and hypothesis

The main objective of the project is to develop an efficient bio-hydrogen production system for a target field in the Danish North Sea. The project will thereby evaluate the applicability of in-situ bioproduction of hydrogen to reduce the environmental footprint of an existing platforms being re-utilised for CO_2 storage by using onsite hydrogen production as the source of energy for the injection process.

Approach

The method relies on biological processes capable of converting hydrocarbons to hydrogen in the reservoir. In doing so, depleted petroleum reservoirs are exploited as hydrogen without getting the hydrocarbons to surface. Such reservoirs, depending on the subsurface temperature gradient and their depth, can have temperatures suitable for thermophilic or hyperthermophilic biohydrogen production. Provided that fermenting microbes could consume hydrocarbons as the sole substrate to produce H_2, the 'left-over' energy in depleted oil reservoirs could be exploited to produce a clean energy carrier for running the CO_2 injection process offshore.

Expected impact/output

By successfully developing an efficient bio-hydrogen production system, the project contributes to the reduction of the environmental footprint of CO_2 storage platforms.

Budget:

DKK 2,300,000

Funded by:

Danish Offshore Technology Center

Partners:

Technical University of Denmark & Danish Offshore Technology Center

Contact:

Hamid Nick, hamid@dtu.dk

Timeline:

2023 — 2024

TRL:

2 → 3

Part of:

Danish Offshore Technology Center

Tags

Utilisation | Microbiology | Process technology | Value chain

UTILISATION

Let-them-stick

Increasing *Sporomusa ovata* cell numbers on cathodes

Objective and hypothesis

Microbial electrosynthesis is a novel biotechnological process for the conversion of excess renewable electricity and CO_2 into biofuels or other organic compounds, using electrons delivered by an electrode. This process relies on acetogenic bacteria, such as *Sporomusa ovata*. The microbial electrosynthesis production rates of the bacteria, however, are too low to enable the development beyond lab-scale. This project hypothesises that the production rate of microbial electrosynthesis can be improved by increasing the number of cells on the cathode.

Approach

This project will explore two different strategies to increase cell numbers of *S. ovata* cells on cathodes. First, natural biofilm formation will be stimulated by condition selection and adaptation. Second, artificial biofilms will be created by immobilising cells in different polymeric matrices. With these natural and artificial biofilms, we will be able to increase and control the cell numbers on cathodes and assess the effect of attached cell numbers on microbial electrosynthesis rates. Several state-of-the-art methods and techniques will be applied to characterise the two biofilm types.

Expected impact/output

This project forms a new approach for the optimisation of microbial electrosynthesis by focusing on improving biofilm formation on the cathode surface.

Budget:

DKK 2,935,000

Funded by:

Novo Nordisk Foundation

Partners:

Aarhus University

Contact:

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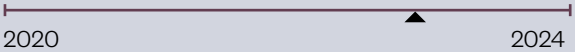
Klaus Koren, klaus.koren@bio.au.dk

Timeline:



TRL:

1→3

Tags

Microbiology | Process technology | Fuels | Utilisation

Learn more

UTILISATION

BIFUNC

Bifunctional homogeneous catalytic CO_2 hydrogenation

Objective and hypothesis

For a method to efficiently facilitate classical carbon capture storage and utilisation, it must be excellent at both sorbing and desorbing the CO_2. This is inherently thermodynamically difficult to achieve. Thus, BIFUNC aims at skipping the storage element and developing an alternative route where the CO_2 is directly utilised subsequently to the capture step (CCU). The project hypothesises that a bifunctional homogeneous catalyst will realise this endeavour.

Approach

BIFUNC employs bifunctional homogeneous catalysis to secure well-defined catalyst structures and thus an excellent level of mechanistic insight and reactivity control. We work on lab-scale with focus on the fundamental developments towards an unprecedented approach to CO_2 uptake and valorisation. Hence, we develop, characterise, and analyse new catalysts as well as determine their CCU power.

Expected impact/output

The project contributes to a fundamental understanding of CO_2 capture and utilisation with homogeneous catalysis. BIFUNC is expected to raise the bar for the efficacy of CCU.

Budget:

DKK 4,000,000

Funded by:

VILLUM (YIP+)

Partners:

Technical University of Denmark

Contact:

Martin Nielsen, marnie@kemi.dtu.dk

Timeline:

2023 – 2025

TRL:

→1

Tags

Point source capture | Utilisation | Process technology | Value chain

UTILISATION

BioReFuel

Biogas upgrading for high-purity CO_2 and natural gas distribution

Objective and hypothesis

The initial phase of the BioReFuel project developed a novel catalytic technology, which has been successfully tested and fine-tuned in lab-scale. The main objective of this project is to execute the second phase of the project, which includes constructing and testing a biogas-to-methanol demonstration unit.

Approach

The demonstration unit will be dimensioned for processing 240 m3 of biogas per day. The unit will be designed and tested to run efficiently with or without external addition of hydrogen. If hydrogen is added, extra methanol can be produced. Without the addition of hydrogen, the unit will only be slightly less efficient, but it will significantly reduce the acquisition and operating costs. The demonstration unit will be fitted into a standard ISO-size container.

Expected impact/output

The project expects to produce a unit that can efficiently convert biogas into methanol. Today, biogas is either converted into electricity/heat or upgraded to methane. Methanol has a higher value than both solutions. According to estimates, up to 50% of the energy demand for transportation in Denmark can be met with methanol produced from biogas. Furthermore, the size of the unit will enable easy transportation on European highways, facilitating scaling up and mass production of the technology based in Denmark.

Budget:

DKK 17,000,000

Funded by:

Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners

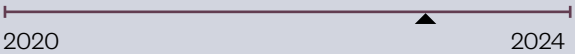
Partners:

Technical University of Denmark (Center for Energy Resources Engineering), Elplatek, Unicat Catalyst Technologies, Lemvig Biogas & Pentair Union Engineering

Contact:

Philip Loldrup Fosbøl, plf@kt.dtu.dk

Timeline:



Tags

Biogas | Biogenic CO_2 | Fuels | Process technology | Utilisation

Learn more

UTILISATION

CO_2Valorize

Valorization of CO_2 for low carbon cement

Objective and hypothesis

This project are a doctoral education and postdoctoral training programme. The objective of this project is to contribute to the reduction of CO_2 emissions generated by cement production. The project proposes an innovative approach to drastically reduce CO_2 emissions by partly replacing the limestone content with supplementary cementitious materials, that are carbonated using captured CO_2. The project will set the scientific foundations to create fundamental knowledge on the mechanisms, reaction kinetics, physico-chemical subprocess and performance of the modified cement and demonstrate the feasibility of 50% CO_2 reduction per tonne of produced cement.

Approach

The project is driven by leading companies, representing important parts of the value chain, ensuring rapid adoption of results with the potential for commercialisation of new equipment, processes, and software. The project follows a structured approach combining complementary research for each individual project in the academic and industry sector. This is accompanied by a balanced mix of high-level scientific courses and transferable skills delivered by each partner locally and in dedicated training schools and workshops at network level. This way, each doctoral candidate builds up deep scientific expertise and interdisciplinary knowledge to deliver game-changing cleantech innovations during and after the project.

Expected impact/output

The project's results are expected to be transferred into first-of-its-kind engineering solutions to advance the next generation of cement processes aimed at mitigating climate change. Also, the project is impact driven and strives for portfolios of high-class joint publications in leading journals and patents.

Budget:

DKK 14,429,000

Funded by:

Horizon Europe - Marie Skłodowska-Curie Actions (MSCA) & co-funding from project partners

Partners:

Participants:
Norwegian University of Science and Technology, University of Padua, Karlsruhe Institute of Technology & Technical University of Denmark, Helmholtz-Zentrum Dresden-Rossendorf Innovation
Partners:
Technical University of Dresden, Cemmac AS, Helmholtz-Zentrum Dresden-Rossendorf & Siemens Process Systems Engineering Limited

Contact:

Lars Skaarup Jensen,
larsskaarup.jensen@flsmidth.com

Timeline:

Tags

Utilisation | Cement industry | International collaboration | Material science | Capacity building

Learn more

UTILISATION

InjectMe

Injection technology for H_2-mediated methane production

Objective and hypothesis

The purpose of InjectMe is to develop a cost-effective system for biogas methanation on a pilot scale. Additionally, the project will evaluate its application as a stand-alone or coupled with other PtX-technologies. The technology is based on methane production, using Landia's injector technology, which allows the utilisation of both the existing infrastructure and reactor biology present in already existing biogas plants.

Approach

The project's experimental work will be conducted on a pilot scale to determine the system's methane production capacity along with its flexibility to operate during periods of low electricity prices, and its cost-effectiveness in improving the production of renewable fuels through PtX conversion.
As part of the latter, the project will analyse the technical and commercial potential by exploring the possibilities of coupling the InjectMe system with various PtX-technologies. This includes chemical methanation, biological methanation, chemical power-to-methanol, and the standalone application of the InjectMe system. This approach is intended to develop new technology within the InjectMe project, while laying the groundwork for making informed decisions about the future of integrated PtX systems.

Expected impact/output

With this project, the partners hope to reduce the costs associated with PtX technology. Biomethane can play a crucial role in the green transition as it can directly replace fossil natural gas in the gas grid and be used in the production of green fuels for the transport sector.

Budget:

DKK 12,160,000

Funded by:

The Danish Energy Agency, Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners

Partners:

Landia, Aarhus University & University of Queensland

Contact:

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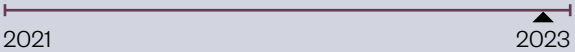
Michael Kofoed, mvk@bce.au.dk

Timeline:



Tags

Biogas · PtX · Utilisation · Infrastructure · Fuels · Process technology · Value chain · International collaboration

Learn more

UTILISATION

Methane electroconversion

Methane activation to methanol

Objective and hypothesis

This project takes a novel approach to addressing the pressing issue of methane emissions and their significant contribution to climate change. The project aims to develop novel hybrid catalysts to promote the electroconversion of methane to methanol to counteract methane accumulation in the atmosphere.

Approach

The primary strategy involves the development of innovative hybrid catalysts for the electroconversion of methane to methanol. This approach differs from traditional thermal catalytic methods, which have proven challenging due to the low reactivity of methane. The aim is to unlock the transformation of methane into a more manageable and usable liquid fuel, addressing methane emissions at their source within the energy sector.

Expected impact/output

The expected outcome of this project is to demonstrate the feasibility and scalability of electrocatalytic systems for the conversion of methane to methanol under ambient conditions. The project seeks to prove that this technology can be industrialised, offering a sustainable alternative to the environmentally harmful practices of flaring, and venting in the oil and gas supply chain. Successful development of efficient catalysts for methane conversion would significantly reduce methane emissions, mitigating their impact on climate change. This approach has the potential to revolutionise the energy industry by providing a more eco-friendly and easily transportable fuel source, thereby supporting the transition to clean energy.

Budget:

DKK 7,400,000

Funded by:

Novo Nordisk Foundation

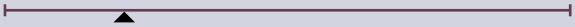
Partners:

Novo Nordisk Foundation CO_2 Research Center at Aarhus University (CORC)

Contact:

Alonso Rosas-Hernández, arosas@chem.au.dk

Timeline:



Tags

Fuels

Utilisation

Societal coupling

5

Coupling CCUS with societal needs

Societal Coupling comprises a set of interdependent upstream and downstream activities. The rapidly growing CCUS industry will be an integral part of the larger energy system, and decarbonization efforts and climate goals make it clear that the sector needs scaling up and attention. To succeed, the CCUS sector will not only require technological solutions and innovation but also the development of appropriate economic, regulatory, business models, and policy frameworks, as well as public acceptance.

To gain political and public acceptance and support it will require more coordinated development on both the supply and demand sides to show decisionmakers and the general public that CCUS is not science fiction. It is a necessary part of our effort to combat climate change and we are already well underway with the implementation of CCUS-based solutions both in Denmark and at European level.

The projects in this category will help to further the understanding of the barriers and the opportunities for developing and commercialising the full CCUS value chain.

The success of CCUS will require an interdisciplinary, long-term cooperation model involving public, private, and other stakeholders. Efforts to reduce uncertainty and de-risk the sector will positively influence the willingness to invest and the cost of capital in this sector. These are the aspects and subjects studied in the research projects of this category.

SOCIETAL COUPLING

CCUS

INFRASTRUCTURES

Objective and hypothesis

The aim of the project is to investigate how national CO_2 and carbon capture, utilisation, and storage (CCUS) infrastructure is impacted and impacts different energy system transition pathways, including impacts on the carbon balance and economic efficiency. This means that geographical placements of CO_2 infrastructure such as pipes, storages, capture and utilisation units will be investigated in combination with geographical knowledge of the surrounding energy infrastructure.

Approach

To investigate CCUS infrastructure, the project will analyse the location aspects of the technologies. This includes both onshore and offshore infrastructure. This is included as it is highly relevant for optimising large-scale CO_2 storage, to understand the demand for carbon capture, as well as the potential infrastructural synergies between CCUS infrastructure and the energy infrastructure.

Expected impact/output

The project will contribute with the following results which create societal impact in terms of future implementation of CCUS infrastructures:

- This will include the placement of CCUS infrastructure based on location analyses considering costs for point sources, CO_2 transport, storage facilities, utilisation and synergies with the surrounding energy system.
- An assessment of different CCUS infrastructure configurations in combination with the surrounding energy infrastructure. This enables the project to identify the best solutions for CCUS implementation to achieve carbon neutrality and potentially a carbon negative society.

Budget:

DKK 4,430,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Aalborg University, Ørsted & TotalEnergies

Contact:

Jakob Zinck Thellufsen, jakobzt@plan.aau.dk

Timeline:

2023 — 2027

TRL:

3 → 7

Part of:

INNO-CCUS

Tags

Infrastructure | Energy systems | Value chain | Economy

Learn more

SOCIETAL COUPLING

CO_2 Hub

Hanstholm

Objective and hypothesis

Port of Hanstholm is aiming to become Europe's first CO_2-neutral fishing port. Thisted Cogeneration Plant also wishes to contribute to the climate goals. This project aims to prepare Thisted Cogeneration Plant and Port of Hanstholm to participate in future development driven by the following five elements:

- Implementation of the upcoming national CCUS strategy.
- PTX projects at Port of Hanstholm.
- Large-scale CO_2 storage in the seabed off Hanstholm.
- Expansion of CO_2 capture from biogas plants and an increased number of biogas plants in Denmark.
- Establishment of national infrastructure for hydrogen and CO_2.

Approach

Thisted Cogeneration Plant will conduct a technical and economic feasibility study for full-scale CO_2 capture at Thisted Cogeneration Plant and pipeline transport to Port of Hanstholm. In collaboration with specialised shipping companies, the CO_2 can be transported to competitively selected sites for storage and utilisation of CO_2. Additionally, a feasibility study for a CO_2 pipeline network will also be conducted.

Expected impact/output

Capture and storage of CO2 in the underground is an essential pathway to achieve the national and international climate goals. Thisted Cogeneration Plant and Port of Hanstholm will take the lead in developing an integrated value chain to inspire other small and medium-sized players to deliver CO_2 at prices competitive with those of major players.

Budget:

DKK 4,940,000

Funded by:

REACT-EU (Regional Development Fund)

Partners:

Thisted Cogeneration Plant, Thisted Heat Supply, Port of Hanstholm, FORCE Technology, Evida & Thisted Municipality

Contact:

Maria Kristiansen, mak@energycluster.dk

Timeline:

2022 — 2023

TRL:

3 → 4

Part of:

CO2VISION

Tags

Point source capture | Infrastructure | PtX | Value chain

Learn more

SOCIETAL COUPLING

EnCO$_2$age

A framework for energy and environmental assessment of a european carbon capture, transport, and storage network

Objective and hypothesis

CCS can have a positive environmental impact only if it is scaled up from megatonne-scale national projects to gigatonne scale cross-border networks. This project aims to assess the feasibility of large-scale European CCS by designing a capture and transport network that collects CO_2 from the flue gas of industrial emitters across Europe and stores it in selected offshore locations in the North Sea. The project considers the interplay between the boundaries and specification of the system, current technology, and geotechnical constraints to design a CCS network to minimize cost, energy demand, and environmental footprint.

Approach

The project develops a Python package for analysing European emitters databases and suggesting fit-for-purpose mature capture processes and transport technologies with the lowest energy demand and CO_2 footprint. As for storage, the project analyses offshore subsurface storage in the North Sea region (including Denmark) relying on subsurface models and Life Cycle Assessment (LCA). The energy demand of the CO_2 capture is modelled by a combination of published data and thermodynamic models. For transport, the project designs an optimised pipeline network between the emitters and storage sites, including the design of compression equipment and pipelines, considering the geographical and technical constraints. The package also performs a preliminary minimisation of costs, CO_2 emission, and energy consumption of the network.

Expected impact/output

The findings of the project evaluate the feasibility, benefits, and disadvantages of an optimised CCS network that can reach gigatonne scale storage for a measurable climate change mitigation impact. Additionally, the project provides open-source Python software for designing and optimising CCS networks. The software facilitates the implementation of efficient carbon capture and storage solutions to reduce emissions from known emission sources and storage locations.

Budget:

DKK 1,700,000

Funded by:

Danish Offshore Technology Center

Partners:

Technical University of Denmark & Danish Offshore Technology Center

Contact:

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Timeline:

2023 — 2024

TRL:

2 → 4

Part of:

Danish Offshore Technology Center

Tags

Point source capture | Infrastructure | Society | Economy | Modelling

SOCIETAL COUPLING

CARMA-Green Fuels

Cross mission carbon management

Objective and hypothesis

The aim of this project is to further develop the existing theoretical understanding of the concept of sustainable biomass with GHG neutrality when applied with a holistic integration across sectors such as agriculture, forestry, and transport. Furthermore, the aim is to develop crosscutting society system analysis methodologies, tools, and models allowing for an overarching holistic co-optimisation of the carbon balance across these sectors.

Approach

The project unites essential partners from academia and industry and develops a management strategy for the use of biomass and biogenic carbon capture. The project will use inputs from three of the Danish Innomissions as well as state-of-the-art studies carried out by the project participants within the respective sectors of CCUS, Green Fuels, Agriculture, Forestry, and Materials.

Expected impact/output

The project will contribute with a broad range of results outlining the potential future development of sustainable use of biomass. These include:

- Potential quantities of additional agricultural and forest biomass that can be produced sustainably within Denmark under different scenario conditions.
- Optimised use of forest biomass, integrating temporal aspects of the allocation of carbon to the forest ecosystem, materials, energy products and permanent underground storage.
- Which other policies and ecosystem services can be supported by a transition of Danish agriculture and forestry facilitated by an integration with the energy, material, and carbon markets.
- Technology scenarios for the best utilisation of our biomass resources into various materials, energy products and carbon storage via cascade utilisation.

Budget:

DKK 4,900,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

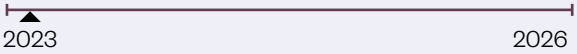
Partners:

Aalborg University, Aarhus University, University of Southern Denmark, University of Copenhagen, Mærsk, Mærsk-Mckinney Møller Center for Zero Carbon Shipping, Ørsted, Arla Foods, BioRefine Denmark, Stiesdal SkyClean, Vestjyllands Andel, Nature Energy, Novo Nordisk Foundation CO2 Research Centre & Crossbridge

Contact:

Henrik Lund, lund@plan.aau.dk

Timeline:



Part of:

MissionGreenFuels

Tags

Value chain | Agriculture | Society | Modelling | Regulation | Biogenic CO_2

Learn more

SOCIETAL COUPLING

COLLATE

IKUM CCUS test center

Objective and hypothesis

IKM Group have been designing, building, and utilising unique CO_2 processing equipment for more than 10 years and has been actively involved in CCUS development projects since 2019. The overall mission is to strengthen the upscaling, maturation, and commercialisation of CCUS on a global scale. Through partnerships and collaborations, IKM aims to bridge technical knowledge gaps, educate and train needed personnel, conduct risk assessments and much more.

Approach

IKM have equipment and methods available that allow the conduction of a wide variety of different experiments to mimic realistic dynamic or static operational conditions related to CCUS applications all along the full value chain from capture to utilisation or storage. Through variable inputs such as pressure, temperature, and chemical compositions, IKM's live simulations are able to provide valuable data for techno-economic decisions, chemical reactions, corrosion rates and much more.

Expected impact/output

The impact of COLLATE is to assist partners in achieving their goals related to developing CCUS technologies. By providing state-of-the-art live simulations, IKM can enhance the research process for projects and companies. A few of the many studies the testing system can perform, include:

- Multiphase behaviour: Gas, Liquid, Supercritical phase
- Material compatibility analysis
- Analysis of mechanical properties as a result of exposure conditions.
- Dynamic corrosion analysis

Budget:

DKK 20,110,000

Funded by:

Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners

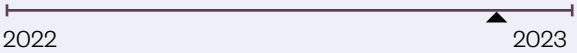
Partners:

DIN Forsyning Esbjerg & Technical University of Denmark

Contact:

Benjamin Lorenzen, bel@oceanteam.eu

Timeline:



Tags

Capacity building | Simulation technology | Process technology | Material science | Corrosion

Learn more

SOCIETAL COUPLING

MISSION-CCS

Material science innovation for accelerated, sustainable and safe implementation of carbon capture and storage

Objective and hypothesis

To adequately address CCS-related challenges and ensure safety and effectiveness around CCS-facilities, there is a need to develop capacity and capability of researchers and entrepreneurs. The aim of this project is to:

- Provide technical and professional training to foster world leading, industry ready experts, capable of delivering next generation solutions to CCS systems.
- Provide DCRs with subject-specific, inter-sectorial knowledge and innovation skills needed to accelerate the uptake of CCS technology.

Approach

The aims of the project will be achieved through a combination of extensive experimental research in leading international research centres and enriched mobility through secondments to industry partners at the forefront of CCS technology. Furthermore, wide-ranging workshops covering technical, professional, and transferrable skills will be held. The project will develop a comprehensive understanding of materials and solvent degradation mechanisms, new measurements, new test methods and innovative mitigation techniques. The outcomes will be exploited to increase the safety, sustainability, and cost-effectiveness of CCS. This will be conducted with strong industry input from industrial experts in every DCR supervisory team.

Expected impact/output

MISSION-CCS brings together high-quality professional development that reflects market requirements and helps address one of the key priorities in the EU Strategic Agenda 2019-2024. The project's aim is to develop new systems, approaches, and technologies for material degradation assessment in CCS combined with the exploration of innovative control strategies, and an appreciation of the associated techno-economics. This can pave the way in the application of material science in CCS to develop safe, optimum and sustainable performance for existing and future facilities, accelerating the CCS uptake, which is vital for a net-zero future.

Budget:

DKK 21,849,000

Funded by:

Horizon Europe

Partners:

University of Leeds, Norwegian University of Science and Technology, National Institute of Applied Sciences of Lyon, Technical University of Denmark, Oil and Gas Corrosion, Shell International , Global Solutions, NPL Management, Alleima Tube, LBBC Baskerville, Institute for Energy Technology (Norway), Wood Group UK, Baker Hughes Energy Transition LLC, TotalEnergies, SINTEF, Equinor Energy & Schlumberger Cambridge Research

Contact:

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Timeline:

2024 — 2028

Tags

Point source capture

Geological storage

Material science

Capacity building

Infrastructure

Learn more

SOCIETAL COUPLING

LSICC

Large scale integration of carbon capture in energy systems

Objective and hypothesis

The aim of the project is to investigate the role of point source carbon capture and direct air carbon capture in the energy system. Point source capture of CO_2 plays an important role in both CCS and CCU, as it provides a higher concentration of CO_2 than is the case of direct air capture of CO_2. Additionally, the project will geographically locate the carbon capture units and how they relate to carbon point sources as well as district heating grids and electricity grids.

Approach

The technological performance of carbon capture will be considered in an energy system analysis. This will be supported by spatial analyses supporting the resource assessment and an assessment of economic impacts. By assessing scenarios for a decarbonised energy system in Denmark in 2045, these analyses will work with the potential of the technology by assessing the amount of CO_2 that can potentially be captured. Furthermore, the project will discuss the feasibility and compare the strategies of carbon capture through point source capture and direct air capture. Additionally, the analyses will work with an assessment of the demand for carbon, both for CCS and CCU.

Expected impact/output

The project will result in a strategy for carbon capture, highlighting the potential for the technology in terms of CO_2 but also in relation to CCS and CCU. The roadmap will be consolidated into recommendations for how carbon capture can efficiently be system integrated.

Budget:

DKK 3,524,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

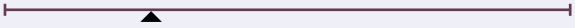
Partners:

En2Save, Greenport North & Aalborg University

Contact:

Jakob Zinck Thellufsen, jakobzt@plan.aau.dk

Timeline:



Part of:

INNO-CCUS

Tags

Energy systems | Society | Modelling | Value chain | Point source capture | DAC

Learn more

SOCIETAL COUPLING

PAoCCUS

Public acceptance of CCUS

Objective and hypothesis

Practical deployment of CCUS rests on both acceptance and demand for the technologies and their associated products. Detailed information on consumers' willingness to accept and pay for CCUS technologies and products will help gear the green energy transition. The aim of the project is to investigate the factors deciding public acceptance and legitimacy in the placement of far-shore, near-shore and on-shore CCUS and related infrastructure.

Approach

Several approaches will be incorporated and triangulated to investigate public acceptance of carbon storage. Economic and behavioral research will be applied to understand the occurrence of conflict situations. Furthermore, the project will investigate the general public's perception of carbon storage and how this can be affected through targeted information. This project will build on surveys, focus group interviews, data collection, and the estimation of acceptance and preference relations for diverse types of CCUS technologies. The survey will use a CE/CVM to elicit the preference for the use and location of carbon storage facilities. Through case studies, the project will enhance the understanding of involvement processes to ensure legitimacy in decisions regarding carbon storage.

Expected impact/output

The project will contribute with a better understanding of how to secure public acceptance of carbon storage both in terms of choosing the right location, communicating effectively about risks and benefits and by outlining optimal processes for citizen involvement to ensure legitimacy. As public acceptance is a prerequisite for successful carbon storage projects in Denmark, the impact of this project is of immense importance to realise CO_2 emission reductions.

Budget:

DKK 5,120,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

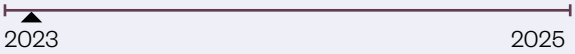
Partners:

Copenhagen Business School, Technical University of Denmark & Aalborg University

Contact:

Manuel Llorca, mll.eco@cbs.dk

Timeline:



Part of:

INNO-CCUS

Tags

Public acceptance | Citizen involvement | Society

Learn more

SOCIETAL COUPLING

SIMPLY

Supporting implementation of pyrolysis via constructive alignment of climate impact assessment methods, goals, frameworks, and incentives

Objective and hypothesis

The main objective of this project is to support and accelerate the deployment of Danish biomass pyrolysis to contribute to the following climate goals:

- INNO-CCUS climate targets: Contribute to a reduction of 0.2 m. ton CO_2e per year in 2025 and 2-4 m. ton CO_2e per year in 2030.
- Achieve 2 m. tonnes of CO_2e in 2030 from a starting point in 2023 around zero, as stated in political agreements on the agricultural area.

Approach

The project is designed to support the realisation of political PyCCS/BCR climate goals by:

- Mapping and characterising the relevant resource base, value chains and market opportunities for deploying Danish biomass pyrolysis at sufficient scale.
- Analysing barriers, bottlenecks and drivers related to planning, constructing and operating Danish pyrolysis plants in different configurations and context.
- Identifying potentials to accelerate planning and deployment procedures based on historical experience with bio-energy technology and the current political landscape.
- Determining the climate- and environmental impact potentials of Danish biomass pyrolysis and securing constructive alignment between impacts and representation in various accounting and certification schemes.
- Analysing key stakeholder incentives in relevant biochar-production-and-use value chain configurations and increasing awareness and knowledge among key stakeholder groups.

Expected impact/output

Societal impacts are obtained through the acceleration of deployment. Substantial impacts are related to avoiding direct GHG emissions, production of bioenergy and from soil effects. Economic impacts that can be highlighted include revenue from energy, climate impact, and benefits in the agricultural sector as well as the development of new value chains for a more circular and more bio-based economy. Also, large-scale deployment of pyrolysis in Denmark could potentially create up to 12,000 jobs. Finally, The Danish pyrolysis industry will benefit from the project as pyrolysis impact potentials are qualified by independent research institutions and barriers and bottlenecks are identified and addressed. The success of the project increases the possibility of making Denmark a leading exporter of pyrolysis technology.

Budget:

DKK 8,263,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Roskilde University, Stiesdal SkyClean, Ringkjøbing-Skjern Municipality, Central Denmark Region & CLEAN

Contact:

Tobias Pape Thomsen, tpapet@ruc.dk

Timeline:

2023 — 2026

Part of:

INNO-CCUS

Tags

Pyrolysis | Biogenic CO_2 | Society | Regulation | Economy | Agriculture | Biochar

Learn more

Pyrolysis technology for Biochar Carbon Removal (BCR) has been in development for decades has reached a high level of maturity. However, the societal structures for implementation have not. In this interdisciplinary project, we aim to develop the knowledge needed to accelerate deployment of a Danish pyrolysis sector.

Tobias Pape Thomsen, Associate Professor,
Department of People and Technology
at Roskilde University.

SOCIETAL COUPLING

VALCCAP

Local value creation in carbon capture, storage and use: the development of cross-sectorial business set-ups and pathways

Objective and hypothesis

The main objective of the project is to understand how integrating CCUS pathways into a preexisting energy system can accelerate the green transition across different sectors. This includes bringing value to public-private partnerships by using local actors such as municipalities, companies, and citizens as a case. The aim of the project is, thereby, to co-create business set-ups and pathways with a high degree of local support and involvement.

Approach

The project applies a collaborative approach bringing together local business actors, industries, local authorities, and citizens, taking point of departure in concrete local networks and project groups. This approach can provide answers to the challenges and opportunities in the CCUS value chain, including resource allocation, balancing of the local distribution grids, use of waste heat in district heating or the integration with carbon producers. The project will analyse the market potential of CCUS in the Thy-Mors area, map CO2 resources, and explore interested stakeholders and potential investment plans for CCUS in the local area.

Expected impact/output

The motivation for this project is to accelerate the Danish development of CCU/CCS in a locally and socially acceptable way, supporting a just transition of the energy system. The project shall contribute to local development and improve the social acceptability of these new technologies. The project will, therefore, also help accelerate the development and implementation of CCUS pathways by making them adaptable to the local context. By developing these value-creating, cross-sectorial solutions, the project aims to develop generalisable knowledge that can bring clarity to the development of national regulatory frameworks.

Budget:

DKK 3,357,000

Funded by:

Innovation Fund Denmark, NextGenerationEU & co-funding from project partners

Partners:

Aalborg University, University of Copenhagen, Thy Mors Energy & Thisted Municipality

Contact:

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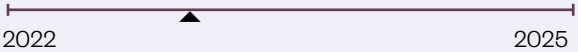
Timeline:



Part of:

INNO-CCUS

Tags

Value chain | Society | Energy systems | Economy

Learn more

Project titles

Akronym	Title	Page
eTecFuels3	Production of e-methanol in one-step by the phosphate process	110
FENIX	New Life for Biowaste as a sustainable Soil Improver	39
Flash pyrolysis	Development of a system for gas-borne flash pyrolysis	38
Fluid Bed Pyrolysis	Large-scale Fluid Bed Pyrolysis	40
FRESH	Formate for Renewable Energy Storage	106
FrontFuel	Pilot-scale demo of CO_2 to SAF Process	99
Future Forests	Trees for the Future Forests	54
Green Twins	Data-driven digital twin platform to reduce CO_2 in industrial processes	21
HydraMOF	Hydrate-MOF Synergy for Improved Performance in Gas Capture and Storage	52
InjectMe	Injection technology for H_2-mediated methane production	124
INNO4EST	Innovative forests for curbing climate change while integrating biodiversity, nutrient retention, and recreation	46
INNO-SALT	Innovative Strategies to Address Salt Precipitation in CO_2 Storage	67
Let-them-stick	Increasing Sporomusa ovata cell numbers on cathodes	120
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LSICC	Large Scale Integration of Carbon Capture in Energy Systems	136
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SEMPRE-BIO	Securing domestic production of cost-effective biomethane	101
SHARP Storage	Enhancing CO_2 Storage Safety and Monitoring	80
SIMPLY	Supporting Implementation of Pyrolysis via constructive alignment of Climate impactAssessment Methods, Goals, Frameworks, and Incentives	138
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SynoProtein	Carbon capture from syngas to Single Cell Protein (SCP) and use as fish feed ingredient	107
THERMOCO2WELL	Risk assessment of the CO_2 injection well damage due to thermal stresses	81
UC-DC	Utilisation of Carbon for DeCarbonisation project	108
VALCCAP	Local value creation in carbon capture, storage and use: the development of cross-sectorial business set-ups and pathways	140
Vesthimmerland	Agricultural innovation, CO_2 storage, and utilisation	44
Waste plastics	CO_2 capture by waste plastics	117
WellCS	A multiphysics informed risk assessment framework for CO_2 leakage through wells	82
WOODCIRCLES	Integrated, circular, and digitally supported sustainable solutions for waste minimization and carbon capture in buildings and the construction sector	50
Aalborg I	Carbon Capture from Aalborg Portland	27

Project Partners

Project tags

Denmark: State of CCUS Research and Innovation. 2023, 1st Edition