SECOND 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 second 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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Reading Guide

This publication offers a snapshot of the Danish carbon capture, utilisation and storage (CCUS) research and innovation landscape in 2025. It reflects an ambitious effort to gather and present the full scope of projects currently shaping the field across sectors and disciplines. The result is a shared view of the actors, technologies, and approaches driving efforts forward in Denmark.

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

Each of the categories are described in brief on the following pages and in more detail in their respective sections of the publication.

Additionally, you can find an overview of completed projects after the main project presentations. These projects are no longer active but are included for reference.

In the back of the publication, there is 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

To complement this publication, we have developed a digital platform which allows users to explore projects interactively.

Contents

> To reach net zero – and eventually achieve negative emissions – carbon capture, utilisation and storage (CCUS) solutions are a necessity.

Shaping the Next Generation of CCUS

The recipe for the green transition is widely agreed upon. As a society, we must change how we produce, rethink our consumption, and transition our energy system to run on renewable sources. Together, these initiatives will get us within reach of our climate goals – almost there, but not quite all the way.

Some emissions are hard to abate, and others already linger in the atmosphere. That's why we need new climate technologies to complement existing solutions. To reach net zero – and eventually achieve negative emissions – carbon capture, utilisation and storage (CCUS) solutions are a necessity.

The good news is that Denmark's CCUS landscape is thriving and advancing with impressive speed and ambition. Covering more than 100 active research and innovation projects, the second edition of 'State of CCUS' once again shows the breadth and depth of the field. From biochar to direct air capture, researchers and industry players are working together to gain ground, promote new and existing technologies, and explore scalable solutions for a more sustainable future.

We hope this publication will serve as a useful tool for stakeholders like these to find inspiration and new collaboration opportunities. Whether you're looking to understand the landscape, spot emerging opportunities, or connect with key players, State of CCUS is here to help you navigate the field.

Moreover, this publication is a key part of our work in INNO-CCUS to advance CCUS through research and innovation. As one of four mission-driven partnerships, we were created to foster cross-sector collaboration and accelerate the development of solutions that can help Denmark reach its climate targets.

To achieve this, we need a comprehensive, updated overview of ongoing efforts, emerging technologies, and the actors driving them forward. These insights are key to identifying knowledge gaps and technological needs – and to guiding future efforts and investments that will shape the next generation of CCUS solutions.

With this shared overview, we can make better decisions, forge stronger partnerships, and take meaningful steps toward a more sustainable future.

This publication would not have been possible without the many researchers and partners who generously contributed project information, feedback, and their time. We would like to thank them for their valuable input – and for the work they continue to do to advance CCUS in Denmark.

Happy reading,

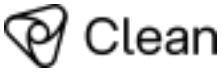
Jesper Sand Damtoft
Chairman of the Board

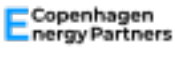
Karina Marie Søgaard
Partnership Director

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

The INNO-CCUS partnership

The INNO-CCUS partnership comprises more than 80 partners across knowledge institutions, private companies, public companies, and organisations.






The INNO-CCUS Partnership is funded by:

Innovation Fund Denmark

Funded by the European Union
NextGenerationEU

CCUS in Denmark 2025

In just five years, Denmark has emerged as a key player in European CCUS. With strong political backing, rapid project development, and broad cross-sector collaboration, the country is steadily turning strategy into practice - laying the groundwork for future CO_2 reductions.

Denmark's national commitment to carbon capture, utilisation and storage was cemented with the Climate Agreement for Energy and Industry in 2020. The agreement marked a political breakthrough, recognising CCUS as a key climate tool and setting the course for its future development. Since then, Denmark has built one of Europe's most ambitious frameworks for the development and deployment of CCUS technologies.

The pace has been remarkable. In 2023, Denmark achieved its first offshore CO_2 storage and awarded its first full-scale CCS project to Ørsted through a government-led tender. That same year, a new political agreement laid the foundation for large-scale deployment by 2029, including the capture of at least 34 million tonnes of CO_2. Further initiatives have strengthened the legal basis for infrastructure and opened the door to cross-border cooperation on CO_2 transport.

These developments have not gone unnoticed internationally. In its 2023 Energy Policy Review, the International Energy Agency (IEA) highlighted Denmark's progress:

"Within a record time of three years, Denmark has created framework conditions and rules for CCS, completed a first CCS tender and allocated a first CO_2 storage licence."

Progress has not slowed since then. By 2025, several major projects are advancing from planning to implementation. Ørsted's full-scale project is expected to begin CO_2 capture from two biomass-fired power plants, Asnæsværket and Avedøreværket, by the end of the year. This marks the country's first large-scale deployment of negative emissions. Meanwhile, Aalborg Portland has secured EU Innovation Fund support for a CO_2 capture plant that will enable carbon-neutral cement production by 2030 – potentially the largest single emission reduction in Danish history.

Looking ahead, a new CCS tender worth nearly DKK 29 billion is underway, launched as part of the efforts to realise the ambitions set out in the 2023 political agreement. It has attracted strong interest from market players and is paving the way for further large-scale deployment. The outcome of this process will be critical to achieving Denmark's climate targets and establishing a mature CO_2 storage market.

Research and innovation have been essential to the Danish progress. Denmark's CCUS efforts span the entire value chain – from capture, storage and utilisation to nature-based solutions and societal integration – and involve actors from across academia, industry, and the public sector. These projects lay the foundation for new technologies while building the knowledge, skills, and collaboration needed to move CCUS from pilot to practice.

But much work still lies ahead. Challenges such as building infrastructure, developing viable business models, and ensuring public support are just some of the areas where continued research and innovation will be crucial to finding practical solutions. This publication offers an overview of the many pathways currently being pursued across the Danish CCUS landscape. The featured projects illustrate how Denmark is moving from idea to impact - while continuing to explore, adapt, and innovate in response to the challenges ahead.

National and Regional CCUS Initiatives

In addition to the many research projects and individual partners featured in this catalogue, several national and regional initiatives play a central role in shaping the Danish CCUS landscape. This section introduces five key organisations that help tie the ecosystem together. They coordinate efforts across sectors, support infrastructure and innovation, and work to ensure that Denmark's CCUS ambitions are backed by strong research environments, business models, and policy frameworks.

Use this overview to get a sense of how CCUS efforts are being structured at national and regional level - and where to look for coordination, collaboration, or strategic partnerships.

The Novo Nordisk Foundation CO_2 Research Center

The Novo Nordisk Foundation CO_2 Research Center is a mission-oriented centre based at Aarhus University, with satellite institutions in Denmark, the US, and Europe. The centre develops novel science for CO_2 capture and conversion to enable sustainable alternatives to fossil carbon. By integrating chemical and life sciences with technical disciplines, CORC creates new, cross-disciplinary approaches for CO_2 management. Research areas include direct air capture, microbial and catalytic conversion, electrochemical reduction, and novel carbonate chemistries. These efforts are supported by advanced systems-level modelling and cutting-edge research infrastructure. CORC collaborates closely with industry, RTOs, and start-ups to ensure that scientific breakthroughs can inform and inspire future technologies. The centre aims to be among the world's top three science and technology hubs for CO_2-based climate solutions, while also supporting inclusive outreach and education to maximise long-term impact.

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INNO-CCUS

INNO-CCUS is one of Denmark's four mission-driven partnerships launched in 2022 to accelerate the green transition. The partnership promotes research and innovation in carbon capture, utilisation, and storage (CCUS), supporting technologies from early proof of concept to pilot scale. With over 80 partners from academia, industry, and the public sector, INNO-CCUS supports 30 projects spanning the full CCUS value chain. Its role is to bridge knowledge gaps, foster collaboration, and help scale promising technologies. Funded by Innovation Fund Denmark and the NextGenerationEU programme, INNO-CCUS works to make CCUS more efficient, scalable, and financially viable – contributing to Denmark's climate goals through applied research and cross-sector innovation.

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CO2Vision

CO2Vision is a regional lighthouse initiative based in North Jutland that aims to build a complete and future-ready CCUS ecosystem. With a foundation in research and strong regional partnerships, the initiative combines technology development, infrastructure planning, workforce training, and tailored business support. CO2Vision connects stakeholders across the value chain and helps translate knowledge into industrial capacity and green jobs. Activities include testing and demonstrating capture, transport, utilisation, and storage technologies – supported by green education and skills development. CO2Vision is part of Denmark's national lighthouse strategy and receives funding from the EU and the Danish Board of Business Development through the Just Transition Fund. The ambition is to position North Jutland as a leading European region for CCUS innovation and implementation.

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CCS Zealand

CCS Zealand is a regional collaboration in Eastern Denmark that aims to promote the large-scale implementation of CO_2 capture, transport, storage, and utilisation. The initiative serves as a forum for gathering, establishing, and sharing experiences across the CCUS value chain. It brings together 15 regional actors, including utility companies, businesses with an interest in CCUS, and the Novo Nordisk Foundation. The initiative supports regional efforts to establish carbon capture at major point sources, develop storage facilities, promote the use of surplus heat in district heating, and connect CO_2 sources, storage sites, and Power-to-X facilities via common infrastructure. CCS Zealand also works to reduce costs through shared learnings and to maintain a strong focus on safety to help secure public acceptance of CCUS.
Through strengthened regional collaboration, the initiative contributes to positioning Eastern Denmark as a key European hub for CO_2 management.

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The CCUS Alliance

The CCUS Alliance is a national business-focused partnership working to transform carbon capture and storage into a new Danish industrial and export success. Established by leading industry organisations, the alliance connects companies, researchers, and experts across the entire value chain – from capture and equipment production to transport, storage, and regulation. It supports members with market analysis, regulatory insight, and strategic dialogue, while also advocating for favourable policy frameworks and investment models. The alliance serves as a central forum for knowledge exchange and coordination, holding regular meetings and public events. By enabling cooperation and identifying opportunities, the CCUS Alliance aims to secure Denmark's role as a leader in the growing international CCUS industry.

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Categories in this publication

Capture

CCUS starts with the capture of CO_2, which 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.

Category	Number of Projects	Accumulated Budget
Capture	17	DKK 317,487,487
Nature-based solutions	15	DKK 644,281,480
Storage	18	DKK 561,380,000
Utilisation	43	DKK 1,561,495,608
Societal Coupling	13	DKK 93,643,304

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 next couple of years, CO_2 capture in Denmark will be scaled up significantly with the first large-scale project set to capture 430.000 tons/year from 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

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:

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

Partners:

Aalborg University, ESTECH & Technical University of Denmark

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Timeline:

2023 - 2026

TRL:

3 → 5

Tags

Point source capture | Process technology | Modelling

CAPTURE

BioNETzero

Integrated oxy-combustion solutions for flexible, bio-based combined heat and power: A negative emissions technology for a net-zero Europe

Objective and hypothesis

The project aims to advance biomass-based carbon capture by focusing on three oxy-combustion technologies:

- Oxy-MILD – Moderate or Intense Low-oxygen Dilution
- CLC – Chemical Looping Combustion
- Oxy-CFB – Oxy-fired Circulating Fluidized Bed

These will be tested experimentally and analysed through computational modelling. The project also includes the development of digital tools for full-scale CHP systems. In addition, it will assess the integration of different oxygen supply solutions and evaluate environmental, technical, economic, and social impacts. The goal is to identify viable pathways for using bio-based CHP as a negative emission technology.

Approach

The project approach is comprehensive, employing mixed methods including qualitative and quantitative research. A systematic process is designed to cover the full biomass residue-to-value chain - from mapping and characterising biomass feedstock sources to applying the three oxy-combustion technologies, allowing inherent CO_2 capture. Advanced CFD models are validated through lab- and pilot-scale experiments, then scaled up using the digital platform. The showcase study method examines concepts in real-life contexts, addressing fuel flexibility, oxygen supply, CHP plant scales, and regional challenges in the transition from fossil fuels to bio-based resources.

Expected impact/output

Harnessing just 10% of Europe's accessible biomass residues for this project's solutions could unlock nearly 70 million dry tons of biomass resources. This, in turn, has the potential to remove approximately 90 million metric tons of CO_2 annually - equivalent to nearly 3.5% of Europe's total CO_2 emissions. The project is expected to strengthen Europe's scientific foundation, boost technological competitiveness and export potential in bioenergy, and reduce the cost while improving the technical performance and efficiency of bio-based CHP. In doing so, it contributes directly to the EU Green Deal.

Budget:

DKK 29,834,960

Funded by:

Horizon Europe Research and Innovation Programme

Partners:

Aalborg University, AGH University of Science and Technology, Air Liquide, CIUDEN, CSIC, SINTEF, Silesian University of Technology, Veolia Energia

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Timeline:

2024 - 2027

TRL:

oxy-CFB 6 → 7, CLC 4 → 5, oxy-MILD 2→ 4

Tags

Biogenic CO_2 | Energy systems | Environment | International collaboration | Modelling | Point source capture

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:

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

Partners:

Aalborg University, Schlumberger & Technical University of Denmark

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Timeline:

2023 - 2027

TRL:

3 → 6

Tags

Point source capture | Simulation technology | Modelling | Process technology

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:

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

Partners:

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

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Timeline:

2023 - 2026

TRL:

4 → 7

Tags

Point source capture

Infrastructure

Value chain

Cement industry

CAPTURE

CO_2MAN

Low emission CO_2 capture solvent management

Objective and hypothesis

The CO2MAN project seeks to advance CO_2 capture by developing an AI tool to screen over 1 billion solvent formulations. The tool will identify solvents with high CO2 absorption, selectivity, low energy demand, environmental impact, etc. Top candidates will be validated at lab and pilot scales, aiming for over 25% efficiency gains and 15% cost cuts.

Approach

Solvent-based CO_2 capture has proven to be one of the only capture technologies that is scalable before 2030. However, current solvent technology still faces challenges such as high energy penalty, solvent degradation, and corrosiveness. If these challenges are not solved by 2030, there is a risk that the cost of CO_2 capture plants will remain too high.
The aim of this project is to enhance an existing prediction tool with unique capabilities in pre-dicting solvent properties, to develop an artificial intelligence (AI) tool that will be used to screen more than 1 billion solvent formulations.

Expected impact/output

The developed tool will be the first to allow screening based on the overall efficiency and cost of full-scale CO_2 capture plants.

Based on the predictions, the three most promising solvent candidates will be validated at lab scale and demonstrated at pilot scale at the Skærbækværket biomass combustion facility.

The project expects the best-performing solvent to result in more than 25% improved capture plant efficiency, over 15% lower costs, and an improved corrosion and environmental profile compared to current state-of-the-art solvents.

Budget:

DKK 13,897,000

Funded by:

Energy Technology Development and Demonstration Programme (EUDP)

Partners:

Technical University of Denmark (Chemical Engineering), Hafnium Labs, Pentair Union Engineering & Ørsted

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Timeline:

2025 - 2027

TRL:

3 → 7

Tags

Biogenic CO_2

Point source capture

Simulation technology

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:

Horizon Europe Research and Innovation Programme under grant agreement No. 101022484 & co-funding from project partners

Partners:

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

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Timeline:

2021 - 2025

TRL:

2 → 6

Tags

Point source capture

Cement industry

Utilisation

Value chain

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:

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

Partners:

Aalborg Portland, Aalborg University, FORCE Technology, Pentair Union Engineering, Technical University of Denmark & Ørsted

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Timeline:

2022 - 2025

TRL:

3 → 7

Tags

Point source capture

Energy efficiency

Process technology

Cement industry

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:

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

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Timeline:

2023 - 2025

TRL:

2 → 4

Tags

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

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:

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

Partners:

Aalborg University, COWI, EuroWind & Port of Aalborg

Timeline:

2022 - 2025

TRL:

4 → 5

Tags

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

CAPTURE

ENDES

Enzyme assisted desorption of CO_2 from aqueous solvents

Objective and hypothesis

Classical CO_2 scrubbing involves reactive absorption of CO_2 in alkaline aqueous solutions, e.g., carbonates or amines. The most energy-intensive step in the cyclic capture-release process is the desorption of pure CO_2 in the so-called stripper. This project investigates whether the stripping process can be made more efficient using enzymes. Our hypothesis is that accelerated desorption can lower energy requirements for the desorption of CO_2 from aqueous solvents.

Approach

We work with the discovery, engineering, and chemical modification of enzymes in an attempt to accelerate the desorption of CO_2 from aqueous solvents. We use both previously described enzymes and sequences found through bioinformatic searches in known genomes. Promising sequences are produced and purified in the lab and tested for their catalytic performance both in bulk aqueous solutions and gas-liquid mass transfer.

Expected impact/output

Quantitative measurements of enzyme-accelerated CO_2 desorption remain sparse and the project's first goal is to provide a reliable assessment of its potential. If this proves positive, our work builds a knowledge platform for the discovery and engineering of enzymes for this purpose. Ultimately, our work can identify specific enzymes or enzyme variants that are stable and active enough to be used in industrial scrubbing processes.

Budget:

DKK 6,000,000

Funded by:

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

Partners:

Technical University of Denmark (Bioengineering), Technical University of Denmark (Biosustain) & University of Copenhagen (Chemistry)

Contact:

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Timeline:

2022 - 2027

TRL:

1→3

Tags

Process technology

Energy efficiency

CAPTURE

EnviAmin

Evaluating the Environmental Impact of Amines Emitted by Carbon Capture

Objective and hypothesis

The leading carbon capture technology employs aqueous amine solutions to bind CO_2 directly from the flue gas of large sources. However, this results in amine emissions to the atmosphere. The atmospheric fate of these emitted amines is still not clearly understood.

Approach

The project proposes to investigate the atmospheric oxidation of amines emitted from carbon capture facilities through a combination of theoretical and experimental studies. The main focus will be on understanding the OH-initiated oxidation of these amines, using approaches developed in our previous work.

Expected impact/output

Understanding the atmospheric fate of emitted amines – together with emission monitoring – is essential for guiding the selection of amines used in carbon capture. This knowledge will support the development of an appropriate regulatory framework for carbon capture facilities.

Budget:

DKK 3,163,212

Funded by:

Independent Research Fund Denmark

Partners:

University of Copenhagen

Contact:

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Timeline:

2025 - 2027

Tags

Environment

International collaboration

Point source capture

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:

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

Partners:

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

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Timeline:

2024 - 2026

TRL:

3 → 7

Point source capture

Simulation technology

Process technology

Energy efficiency

CAPTURE

GRAF2X

Carbon Capture Membranes Enabled by Graphene

Objective and hypothesis

Small and medium-sized enterprises (SMEs) account for nearly 60% of global CO_2 emissions but are largely overlooked in current carbon capture strategies. Existing technologies like amine scrubbing are too costly, complex, and space-intensive for emitters under 100 tons CO_2 per day.

This project aims to design and validate a compact, low-energy membrane-based capture system designed for SMEs. With no toxic solvents, low energy needs, and a modular footprint, we hypothesise that this solution can provide a viable, scalable alternative - unlocking emissions reductions that conventional systems can't reach.

Approach

GRAF2X is developing a container-based membrane filtration system that captures CO_2 from point source emissions using pressure-driven separation. The technology is designed for installation at emission sites, using 20- to 40-foot containers that extract CO_2 from exhaust gases and produce a purified stream containing more than 90% CO_2, ready for transport to storage or utilisation.

The system runs entirely on electricity and is based on a graphene-enhanced flat sheet membrane, which filters CO_2 more efficiently than current alternatives

Expected impact/output

With an expected capture cost of less than $25 per ton of CO_2 - when exhaust concentrations are above 10% - this compact, modular system could transform decarbonisation in hard-to-abate sectors. These include industry, buildings, transport, chemicals, metals, and cement, which together account for around 50% of global CO_2 emissions.

At such a low cost, carbon capture becomes not only viable, but potentially profitable - especially as new tax incentives and emissions trading systems emerge. This could drive widespread adoption and unlock large-scale emissions reductions that are currently out of reach.

Budget:

DKK 4,600,000

Funded by:

Villum Fonden/VELUX Fonden

Partners:

Technical University of Denmark

Contact:

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Timeline:

2023 - 2025

TRL:

3 → 5

Tags

Biogas | Cement industry | DAC | Material science | Point source capture

CAPTURE

HYPER-CAP

Searching for new thermodynamic hydrate promoters to reduce the energy penalty of gas hydrate-based CO_2 capture technology

Objective and hypothesis

This project aims to develop an alternative carbon capture method using Gas Hydrate-Based CO_2 Capture (GHBCC) technology. The goal is to reduce the energy use of carbon capture by up to 50% compared to conventional methods. Unlike amine-based systems, GHBCC has the potential to reuse waste heat from flue gas, improving overall efficiency.

To make this technology viable at scale, the project will explore ways to improve operating conditions through the use of chemical promoters. By overcoming current limitations, the research seeks to make GHBCC a more practical and cost-effective option for industrial carbon capture.

Approach

A major challenge in gas hydrate-based CO_2 capture is the high pressure typically required - around 100 bar - which limits its suitability for post-combustion use. Recent advancements have introduced chemical promoters that can reduce this pressure to 5–10 bar, improving process viability. This project focuses on finding a promoter that can lower the CO_2 capture pressure to below 5 bar while raising the operating temperature to 20–30°C. This would allow the process to make use of flue gas waste heat, reducing overall energy demand. A techno-economic assessment will also evaluate whether the process can be scaled up cost-effectively for industrial applications.

Expected impact/output

If successful, the project will introduce a new promoter that allows CO_2 capture under milder conditions, significantly reducing energy requirements. It will also generate experimental data on hydrate formation under these conditions, providing a foundation for future studies on kinetics, reactor design, and process optimisation.

By operating more efficiently and using available waste heat, GHBCC has the potential to become a cost-effective alternative to conventional capture technologies. The results will support continued development towards pilot-scale demonstration and contribute to broader decarbonisation efforts.

Budget:

DKK 2,857,757

Funded by:

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

Partners:

Aarhus University (BCE)

Contact:

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Timeline:

2023 - 2025

TRL:

2 → 3

Tags

Energy efficiency

Point source capture

Process technology

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 emissi-on-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:

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

Partners:

Danish Technological Institute, FLSmidth, Lhoist & Tech-nical University of Denmark

Contact:

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Timeline:

2022 - 2025

TRL:

2 → 6

Tags

Point source capture | Cement industry | Process technology

CAPTURE

REUSE

Enzymatic CO_2 Capture in a Rotating Packed Bed and Electrocatalytic CO_2 Reduction to Useful Products

Objective and hypothesis

CO_2 capture is a key part of the green transition, but current technologies are often too complex, inefficient, or immature for large-scale use. The REUSE project addresses this challenge by advancing an integrated solution that captures CO_2 from biomass combustion and converts it into valuable products.

The project will build an advanced CO_2 capture and utilisation solution by combining a biotechnological approach, where carbonic anhydrase (CA) is immobilised into cellulosic fibres in a rotating packed bed reactor (RPB), and advanced solvents to transform CO_2 into carbon monoxide or formic acid in a CO_2 reduction cell.

Approach

The project will build upon existing technologies and projects and converge these experiences into the development of an integrated system combining a biomass combustion unit, a rotating packed bed reactor, and a CO_2 reduction cell. Given the complexity of the process, a multi-disciplinary approach will be used to overcome limitations and optimise critical parts of the system, including the biomass combustion step, the rotating packed bed reactor, and enzyme-mediated CO_2 capture. Finally, the full system will be tested in a pilot plant to develop an appropriate model that captures the complexity of mass transfer and includes non-ideal thermodynamic modelling to assess overall performance.

Expected impact/output

REUSE's main contribution is the development of an integrated and efficient system that captures CO_2 from biomass combustion and converts it into formic acid.

The system combines enzyme-based capture, a rotating packed bed reactor, and a CO_2 reduction unit, and will be demonstrated at technology readiness level 5.

To improve integration between the system components, the project will consider ways to reduce flue gas variability and toxicity, such as using novel catalysts or blending different types of biomass. Immobilising the enzyme is expected to enhance its stability and absorption kinetics, enabling reuse. The development of a cost-effective supply of renewable energy carriers will further support circularity.

Budget:

DKK 28,000,000

Funded by:

Horizon Europe Research and Innovation Programme under grant agreement No. 101172954

Partners:

Centre for Research and Technology Hellas (CERTH), Clean Energy Solutions GmbH, ETA Florence Renewable Energies, Manchester Metropolitan University, Newcastle University, Novonesis, TBW Research GmbH, University of Aveiro, University of Leicester & Y Squared

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Timeline:

2024 - 2027

TRL:

3 → 5

Tags

Biogas | Biogenic CO_2 | Energy efficiency | Material science | Process technology | Modelling

CAPTURE

SSCC

Small-Scale Carbon Capturing System for Decentralized CO2 Point Sources

Objective and hypothesis

The project focuses on improving carbon capture solutions for small-scale, decentralised CO_2 sources - particularly those linked to agricultural biogas plants. It will demonstrate a fully integrated and automated carbon capture system in a real operational setting (TRL 7), capturing CO_2 from biogas combustion at the Greenfarm plant at Gråsten Agricultural School.

The aim is to reduce CO_2 emissions and support the circular economy by enabling the conversion of biogenic CO_2 into e-fuels.

Approach

The project brings together partners covering the full carbon capture value chain—from technology development and testing, to real-world application and infrastructure support.

The project's innovative strength lies in its pioneering approach to decentralise carbon capture technology for point source emissions, enabling decarbonisation of hard-to-abate sectors like agriculture. A decentralised approach also opens up opportunities for smaller players such as farmers to participate in the carbon credit market by offering a biogenic CO_2 solution that is integrated with their facility.

To enable capture in small-scale post-combustion systems, the project will evaluate temperature swing adsorption (TSA) using metal-organic frameworks (MOFs) - a material known for its strong CO_2 uptake, easy regeneration, and operational stability.

Expected impact/output

Aligned with Danish energy policy objectives, this project contributes to reducing dependence on fossil fuels and supports the circular economy by enabling the sustainable reuse of biogenic CO_2. As a result, the project will deliver a CO_2 capture technology that is effective, energy-efficient, cost-competitive, scalable, regulation-compliant, and has minimal environmental impact.

Budget:

DKK 28,858,558

Funded by:

The Energy Technology Development and Demonstration Programme (EUDP) and Green Labs DK programme (GLDK)

Partners:

Aalborg University, Technical University of Denmark, Esbjerg Havn, Greenfarm, SINEF & Welltec Manufacturing Center Completions ApS

Contact:

Lia Khasanova, lkhasanova@welltec.com

Timeline:

2024 - 2026

TRL:

4 → 7

Tags

Point source capture | Biogenic CO_2 | Process technology | Utilisation

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

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:

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

Partners:

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

Contact:

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Timeline:

2024 - 2026

TRL:

3 → 5

Tags

Biological storage

Agriculture

Biochar

Modelling

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:

Frichs Pyrolysis, University of Southern Denmark & Vrejlev Energy

Contact:

Søren Bruun, sbr@frichs.com

Timeline:

2023 - 2025

TRL:

5 → 8

Tags

Biogas | Pyrolysis | Agriculture | Value chain | Biochar

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:

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

Partners:

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

Contact:

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Timeline:

2022 - 2026

TRL:

6 → 7

Tags

Biological storage

Biochar

Biogenic CO_2

Agriculture

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:

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

Partners:

Danish Hydraulic Institute & University of Southern Denmark

Contact:

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Timeline:

2022 - 2025

TRL:

2 → 6

Tags

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

NATURE-BASED SOLUTIONS

BUHPC

Development of climate-enhanced high-strength concrete for wind turbine foundations based on biochar from pyrolysis

Objective and hypothesis

Biochar is a by-product of pyrolysis and is typically used to improve soil quality in agricultural settings. Biochar from sources such as sludge from households may contain harmful substances and can therefore not be used unhindered. It is the objective of the project to incorporate biochar into ultra-high performance concrete (UHPC) – a particularly strong and durable type of concrete commonly used in demanding infrastructure applications.

By doing so, potentially harmful substances will be encapsulated in UHPC and thereby stored safely even after later demolishment of the UHPC material. At the same time, it is the objective to create a UHPC material with a lower environmental footprint by using biochar as a cement replacement and as a carbon capture medium.

Approach

The project will evaluate biochar from different sources supplied by our partner. Through a variety of laboratory analyses, grout materials will be developed with focus on use in the offshore wind market. A selected UHPC grout product with incorporated biochar will be designed for eventual DNV Offshore Certification. An environmental assessment will also be carried out to document the carbon footprint of the UHPC grout material. This will be done by preparing an Environmental Product Declaration (EPD), which provides verified data on the material's climate impact.

Expected impact/output

By incorporating biochar into a UHPC grout material of similar or better performance than existing UHPC grout materials, the offshore wind sector will have the opportunity to reduce the overall CO_2 footprint of the wind turbine foundation and at the same time introduce an alternative CO_2 storage possibility.

Budget:

DKK 3,876,000

Funded by:

The Energy Technology Development and Demonstration Programme (EUDP)

Partners:

Springkilde Bio ApS, Y-MatTec A/S

Contact:

Elo Yde, ey@ymattec.com

Timeline:

2024 - 2025

Tags

Biochar | Biological storage | Off-shore storage

NATURE-BASED SOLUTIONS

CaSiCarbon

Potential for long-term CO_2 storage through enhanced weathering of Ca-silicate minerals and materials

Objective and hypothesis

The objective of the project is to assess whether calcium-rich silicate minerals can act as a sink for atmospheric CO_2. Thermodynamic models suggest that calcium-rich plagioclase (anorthite) dissolves at rates similar to magnesium-rich olivine - a mineral already proven effective in enhanced rock weathering.
The study is motivated by growing interest in anorthite mining in Southwest Greenland, which produces calcium-rich materials such as finely crushed anorthite - ideal for this purpose. These materials could provide an abundant source for CO_2 offsetting strategies.

Approach

The project will test the ideal parameters for when calcium-rich anorthosites (made up of more than 90% plagioclase) dissolve, causing chemical changes in pore water that result in the safe storage of CO_2. This will be done through experiments where initial conditions such as reaction temperature, pH, and CO_2 concentration will vary, favouring conditions that can be applied in nature or in industry.

The experiments will also examine the effect of possible secondary mineral formation and reaction time as factors that might influence the overall efficiency of long-term CO_2 storage. The anorthosites used are sourced from the Fiskenæsset Anorthosite Complex in Southwest Greenland, which is dominated by calcium-rich plagioclase. The results can therefore be used to evaluate the Fiskenæsset Anorthosites as a resource and as a means for CO_2 storage under conditions relevant for potential use in nature.

Expected impact/output

The outcome of this project will demonstrate the potential use of calcium silicate minerals as an enhanced, nature-based solution for CO_2 capture and storage. The conditions used in the experiments will allow for future estimates of the CO_2 capture capacity of calcium-rich anorthosites under scenarios relevant for specific industrial or nature-based applications.
The results may also encourage the use of readily available mineral resources and mining waste in strategies to mitigate CO_2 emissions.

Budget:

DKK 2,879,480

Funded by:

Independent Research Fund Denmark

Partners:

University of Copenhagen

Contact:

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Timeline:

2023 - 2026

Tags

Geological formations

Geological storage

Nature

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:

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

Partners:

AquaGreen, Danish Technological Institute, Kronospan & Leth Beton

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Timeline:

2023 - 2025

TRL:

3 → 6

Tags

Biochar | Material science | Biogenic CO_2 | Utilisation

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:

CO2Vision, Horizon Europe Research and Innovation Programme under grant agreement No. 101113002 & co-funding from project partners

Partners:

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

Contact:

Irini Angelidaki, iria@kt.dtu.dk

Timeline:

2023 - 2027

TRL:

→8

Tags

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

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:

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Timeline:

2022 - 2026

TRL:

4 → 8

Tags

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

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:

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

Partners:

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

Contact:

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Timeline:

2022 - 2026

TRL:

4 → 7

Tags

Environment | Forest | Biogenic CO_2 | Nature | Biological storage

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:

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

Partners:

HedeDanmark, Aarhus University, Stiesdal & University of Copenhagen

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Timeline:

2022 - 2026

TRL:

5 → 9

Tags

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

NATURE-BASED SOLUTIONS

RESTORE

Biochar addition during peatland rewetting to restore soil carbon and mitigate greenhouse gas emissions and nutrient leaching

Objective and hypothesis

Drained peatlands are major sources of greenhouse gas emissions. Rewetting is a key climate measure, and Denmark aims to restore 1,000 km² of peatlands by 2030 to reduce emissions by 2.6 million tonnes of CO_2 equivalents per year.

However, rewetting can also increase methane emissions and may raise CO_2 and nitrous oxide emissions due to changes in water levels and organic matter input. Phosphorus leaching may also threaten water quality, creating challenges for large-scale rewetting.

RESTORE explores biochar as a potential solution to reduce emissions and nutrient loss in rewetted peat soils. The project investigates biochar's effects on emissions, soil microbiology, and nutrient dynamics. Key hypotheses focus on whether biochar can reduce emissions, how its sorption and redox properties contribute, and whether results can be scaled to real-world conditions as part of a sustainable rewetting strategy.

Approach

RESTORE will test these hypotheses across three research activities:

1. Lab experiments will assess how biochar affects greenhouse gas emissions, carbon and nutrient dynamics in peat soils under Danish soil and climate conditions.
2. Microbiome studies will examine how biochar influences microbial communities, especially those involved in emissions and nutrient cycling, and how these changes relate to the lab results.
3. Outdoor experiments will verify lab findings in a year-long field experiment under real environmental conditions and different management strategies.

Expected impact/output

RESTORE will generate the first detailed insights into how biochar affects greenhouse gas emissions, nutrient cycles, and microbial communities in rewetted peat soils. The project aims to demonstrate that biochar can reduce emissions, prevent nutrient loss, and enhance carbon storage - helping Denmark reach its peatland rewetting goals for 2030.
If successful, RESTORE could pave the way for full-scale field implementation and inspire broader adoption internationally.

Budget:

DKK 3,168,000

Funded by:

Independent Research Fund Denmark

Partners:

GFZ Helmholtz Centre for Geosciences, SEGES, Stiesdal & University of Copenhagen

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Timeline:

2025 - 2028

Tags

Agriculture | Biochar | Biological storage | Environment | Microbiology

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:

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

Contact:

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Timeline:

2022 - 2025

TRL:

6 → 8

Tags

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

NATURE-BASED SOLUTIONS

TIMBERHAUS

Climate-smart, circular, and sustainable solutions for use of wood in the construction sector

Objective and hypothesis

To support the implementation of the EU Forest strategy and enhance the contribution of the forest-based sector to climate change mitigation, TIMBERHAUS pursues the following overarching objectives:

- Catalyse the green transition of the construction sector by making it more renewable and circular.
- To create a stronger link between the European forest sector and construction sector by matching the needs of the construction sector with available biomass in the forests.
- Create new value chains for currently underused wood types and species to maximise the climate mitigation potential of the forest sector.
- Identify and address barriers to scaling up wood construction in Europe.

Approach

Novel wood processing technologies based on machine learning will be developed and used to prototype innovative wood construction products incorporating currently underutilised wood resources. Circular wood building blueprints for multi-story buildings incorporating local cultural tradtions and design languages as well as human health and well-being aspects will be demonstrated as digital pilots together with European cities and their stakeholders. New knowledge on the quantitative limits and opportunities of wood as a resource will be generated to give valuable input to forest and climate policy development. A robust and cost-efficient methodology to quantify the carbon removal benefits of wood construction products and other building materials will be developed. Localised and EU-level decarbonisation strategies for buildings will be developed along with roadmaps for mainstreaming multi-story wood buildings. Based on project learnings, policy recommendations will be provided.

Expected impact/output

The construction sector is responsible for 40% of carbon emissions, 50% of extracted materials, and 35% of waste. EU policies highlight wood and renewable materials as key to decarbonising the sector. Despite their climate benefits, wood materials are still underused. TIMBERHAUS aims to boost wood use in construction by developing sustainable value chains and business models for under-utilised wood species and recycled biomass. This will support European competitiveness, sustainability, and self-sufficiency. By encouraging better forest management, TIMBERHAUS can enhance forest protection, attract investment in wood processing, and create rural jobs.

Budget:

DKK 65,000,000

Funded by:

Horizon Europe Research and Innovation Programme and the Swiss State Secretariat for Education, Research and Innovation (SERI)

Partners:

Bauhaus der Erde, Built by Nature, City of Baia Mare, City of Berlin, City of Siena, Climate-KIC, Danish Technological Institute, Demos Helsinki, EMPA, ETH Zürich, F. Junkers Industrier A/S, Icons, Maderas Gamiz, Metabolic Institute, Pfeifer Holding GmbH, Tegel Projekt, University of Copenhagen, Urbasofia & Waugh Thistleton Architects

Contact:

Anders Kjellow, awk@dti.dk

Timeline:

2024 - 2028

TRL:

3 → 6

Biological storage | Forest | International collaboration | Machine learning

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:

Horizon Europe Research and Innovation Programme under grant agreement No. 101082184 & co-funding from project partners

Partners:

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

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Timeline:

2023 - 2027

TRL:

2 → 6

Tags

Biogenic CO_2 | Biological storage | International collaboration | Material science

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

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:

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

Partners:

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

Contact:

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Timeline:

2022 - 2026

TRL:

5 → 7

Tags

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

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:

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

Partners:

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

Contact:

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Timeline:

2022 - 2026

TRL:

4 → 6

Tags

Geological storage | Monitoring | Infrastructure | Material science

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, Schneider Electric, Svanehøj, TGE Gas Engineering & Wartsila

Contact:

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Timeline:

2024 - 2030

TRL:

→9

Tags

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

STORAGE

C•ASH

CO_2 mineralisation by volcanic ASH

Objective and hypothesis

The project aims to demonstrate that volcanic ash layers in the Danish subsurface can be used to permanently remove CO_2 from the atmosphere through natural mineralisation processes. This approach builds on well-known geochemical reactions where CO_2, when dissolved in water, reacts with silicate-rich minerals to form stable carbonate minerals. The hypothesis is that volcanic ash layers - rich in calcium, iron, and magnesium - can bind large amounts of CO_2 when exposed to CO_2-saturated water, offering a safe, low-cost alternative to conventional CO_2 storage.

Approach

Researchers will establish Denmark's first pilot plant for CO_2 mineralisation, in collaboration with a local biogas facility. CO_2 separated from the biogas production will be dissolved in water from the geological formation, creating a concentrated "sparkling water" solution. This will be injected into 200–300 metre-deep boreholes containing volcanic ash layers formed 56 million years ago. The ash, composed of microscopic particles with a high surface area and the right chemical composition, is expected to rapidly react with the CO_2 to form solid minerals. The site will include several wells for continuous monitoring of water chemistry and carbonate formation.

Expected impact/output

If successful, the project will validate a CO_2 storage method that is permanent, safe, and locally deployable. Mineralisation requires no pressurised CO_2 or deep storage infrastructure, and the approach has the potential to scale through multiple small plants with minimal land footprint. In Denmark alone, the ash deposits may be able to mineralise the equivalent of 40–50 years of national CO_2 emissions. Globally, the potential is even greater, with large volumes of volcanic material available. This project lays the groundwork for broader use of CO_2 mineralisation as part of Denmark's and the world's negative emissions strategy.

Budget:

DKK7,151,000

Funded by:

Independent Research Fund Denmark, Novo Nordisk Foundation and more.

Partners:

Aarhus University, Geological Survey of Denmark and Greenland (GEUS), Klimafonden Skive, Morsø Municipality, Skive Municipality, Thisted Municipality, Sunstones ApS, Rybjerg Biogas

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Timeline:

2023 - 2027

TRL:

3 → 7

Tags

Biogenic CO_2 | Geological formations | Geological storage | Nature

STORAGE

CERBERUS

The CO_2 gate-keeper for intelligent and automated monitoring of geological CO_2 storage sites

Objective and hypothesis

The Cerberus project focuses on the intelligent monitoring of CO_2 stored in deep geological formations. It is an interdisciplinary initiative aimed at developing a cost-effective, fit-for-purpose, automated digital tool for continuous monitoring of containment and field-specific surveillance strategies. The project seeks to advance and validate THMC (Thermal-Hydrological-Mechanical-Chemical) simulation tools for CO_2 storage, improve petroelastic models, and develop a machine learning solution for monitoring CO_2 containment.

Approach

Cerberus aims to replace computation-intensive high-fidelity models with more efficient reduced order models (ROMs) using machine learning. These ROMs will address data and computation challenges, enabling real-time modelling of the subsurface while maintaining consistency with the original high-fidelity models and scenarios calibrated against real-world observations.

Expected impact/output

If successful, the developed toolkit will be integrated into future monitoring plans for large-scale CCS projects by field operators. It will address the critical need for a high-definition multiphysics model spanning from reservoir to surface, offering strong prediction capabilities and enabling low-cost analysis of monitoring datasets.

Budget:

DKK 14,000,000

Funded by:

Innovation Fund Denmark

Partners:

Nordsøfonden, TotalEnergies Exploration and Production Denmark & TotalEnergies Upstream Denmark

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Timeline:

2024 - 2029

TRL:

5 → 7

Tags

Geological storage | Machine learning | Modelling | Monitoring | Off-shore storage | Simulation technology

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

Funded by:

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

Partners:

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

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Timeline:

2022 - 2025

TRL:

2 → 3

Tags

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

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:

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

Partners:

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

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Timeline:

2023 - 2026

TRL:

3 → 5

Tags

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

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:

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

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Timeline:

2023 - 2027

TRL:

2 → 4

Tags

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

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 decisi-on-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:

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

Partners:

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

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Timeline:

2022 - 2025

TRL:

3 → 5

Tags

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

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:

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

Partners:

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

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Timeline:

2023 - 2027

TRL:

2 → 5

Tags

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

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:

The Energy Technology Development and Demonstration Programme (EUDP) & The Clean Energy Transition Partnership

Partners:

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

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Timeline:

2023 - 2025

TRL:

5 → 6

Tags

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

STORAGE

FOS

Fiberoptic chemical sensing

Objective and hypothesis

The project aims to develop a seabed surveillance system for detecting CO_2 leaks using fiber optics. The goal is to identify and build robust chemical sensors based on fiber optic technology. Fiber optics offer the advantage of combining optical sensing with robust telemetry.

Sensing can occur either through optical changes in the fiber's environment or through strain applied to the fiber. The project will explore the right combination of fiber types and sensing materials that produce detectable changes in response to CO_2 concentrations in the surrounding environment.

Approach

Fiber optics can be used as specific chemical sensors, where a material with specific interactions with a given chemical is placed on the fiber. This can be used as passive surveillance if placed close to potential leak paths such as abandoned wells or faults. Robust sensing and longevity of the active sensing points are very important factors in providing a successfully deployable technology.

Expected impact/output

This will provide a system that can be placed either as single sensing points or preferably as a grid in risk zones. As a passive monitoring system, the changes in CO_2 concentration will be reported spatially. The signal will provide accurate CO_2 concentrations in the environment around the fiber, and may also provide information on seasonal variations and changes in water chemistry.

Budget:

DKK 6,000,000

Funded by:

The Energy Technology Development and Demonstration Programme (EUDP) & project partners

Partners:

The Danish Underground Consortium (BlueNord Energy Denmark A/S, Nordsøenheden, TotalEnergies EP Danmark A/S), Technical University of Denmark

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Timeline:

2022 - 2025

TRL:

1→4

Tags

Monitoring | Off-shore storage | Storage de-risking

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:

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

Partners:

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

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Timeline:

2023 - 2027

TRL:

3 → 6-7

Tags

Geological storage

On-shore storage

Storage de-risking

Geological formations

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:

Danish Offshore Technology Center, Technical University of Denmark & TotalEnergies

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Timeline:

2024 - 2028

TRL:

2 → 5

Tags

Environment | Monitoring | Geological storage | Off-shore storage

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:

INNO-CCUS - Innovation Fund Denmark, NextGeneration EU & co-funding from project partners

Partners:

Aarhus University, Danish Gas Technology Centre, Explicit, Gas Storage Denmark

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Timeline:

2022 - 2025

TRL:

4 → 6-7

Tags

Geological storage | Monitoring | Storage de-risking

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.

Budget:

DKK 438,000,000

Funded by:

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

Partners:

Aker Carbon Capture, Blue Water Shipping, Dan-unity CO2, Danish Hydraulic Institute, Danish Technological Institute, Energy Cluster Denmark, Esvagt, Geelmuyden Kiese, Geological Survey of Denmark and Greenland (GEUS), INEOS Energy, INEOS Oxide, National Oceanography Centre, Noble, Rambøll, Resen Waves, Semco Maritime, Spotlight, Technical University of Denmark, TGS, University of Southampton, Welltec, Wind Power Lab & Wintershall Dea

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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

STORAGE

SEAL

Seabed Environmental Analyzer for CO_2 and CH4 Leakage

Objective and hypothesis

All CO_2 storage projects require monitoring to ensure containment in accordance with regulations. Notably, there is currently a lack of sensors capable of detecting CO_2 and CH_2 leaks in the water column in a cost-effective and reliable manner. Existing solutions are either too expensive or unsuitable for periodic deep-sea assessments. This project builds on the Danish Offshore Technology Centre's validated carbon dioxide and methane sensor to develop an autonomous, field-ready prototype capable of real-time data collection at up to 10 bar hydrostatic pressure. By integrating it with a seabed monitoring system, the project aims to enable efficient, periodic carbon dioxide and methane monitoring. The ability to measure CO_2 gives the sensor strong potential for future carbon storage site monitoring.

Approach

The project consists of four work packages:

1. Sensor manufacturing
2. Hardware prototype design
3. Software/data processing
4. Offshore demonstration.

The sensor will integrate with an ROV system, incorporating a single-board computer, quartz crystal microbalance electronics, and a pressure-rated enclosure. A fluidics system will ensure controlled water flow and a rapid response time. Initial testing will occur in a lab, followed by offshore pilot demonstrations to assess signal stability, the impact of seabed turbulence, and sensor integration with location, pressure, and temperature data.

Expected impact/output

The project will deliver a carbon dioxide and methane sensor system tested under offshore conditions and ready for market deployment. It will support cost-effective, periodic monitoring of decommissioned oil and gas fields, aligning with EU regulations. By enabling routine carbon dioxide and methane leak detection, the sensor developed in the project contributes to environmental protection and regulatory compliance. Additionally, by extending its application to carbon storage monitoring, the project positions its partners at the forefront of subsea gas monitoring technology.

Budget:

DKK 8,200,000

Funded by:

Energy Technology Development and Demonstration Programme (EUDP)

Partners:

Danish Technological Institute, PoreSense I/S, Technical University of Denmark (Danish Offshore Technology Center, DTU EngTech), The Danish Underground Consortium (BlueNord Energy Denmark A/S, Nordsøenheden, TotalEnergies EP Danmark A/S)

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Timeline:

2025 - 2027

TRL:

→7

Tags

Geological storage

Monitoring

Off-shore storage

Storage de-risking

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:

INNO-CCUS - Innovation Fund Denmark, NextGeneration EU & co-funding from project partners

Partners:

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

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Timeline:

2023 - 2025

TRL:

3 → 5

Tags

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

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

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 CO_2 Research Center at Aarhus University (CORC) & Bill & Melinda Gates Foundation

Partners:

Novozymes, Aarhus University, Topsoe & Washington University St Louis

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Timeline:

2023 - 2025

TRL:

→6

Tags

Microbiology | Utilisation | Process technology

UTILISATION

APPLAUSE

Apple • Aarhus University • Sustainable Energy

Objective and hypothesis

The project's aim is to develop technologies that enable a stable green power supply, even in scenarios dominated by power production from fluctuating renewables. To this end, the objective of the APPLAUSE project is to conduct research and technology development across multiple disciplines, combining specific aims within biogas, power-to-X, and energy system modelling, thereby coupling value streams of energy and carbon.

Approach

The APPLAUSE project is an interdisciplinary research initiative focused on the development of solutions that can supply renewable energy through the dynamic coupling of bioenergy and fluctuating renewable electricity. The overall aim of the project will be achieved through research leading to enhanced biogas yield from lignocellulosic biomasses, development and upscaling of biomethanation technology, development of novel carbon capture and utilisation technology, and the development of energy system models.

Expected impact/output

Through its interdisciplinary and multifaceted approach, the APPLAUSE project has led to the development of novel technology platforms and system modelling that couple value streams of carbon and energy. This includes the enhanced valorisation of biogenic carbon in anaerobic digestion through optimised biomass post-treatment, and the exploration of how biological methanation technology can be used for both the capture and conversion of CO_2 from flue gas and biogas.

Budget:

DKK 21,500,000

Funded by:

Apple Inc.

Partners:

Aarhus University & Apple Inc.

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Timeline:

2016 - 2025

Tags

Biogas | Biogenic CO_2 | Fuels | International collaboration | Point source capture | PtX | Utilisation

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:

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

Contact:

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Timeline:

2020 - 2025

TRL:

6 → 7

Tags

PtX | Biogenic CO_2 | Process technology | Utilisation | Biogas

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 Fonden

Partners:

Technical University of Denmark

Contact:

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Timeline:

2023 - 2025

TRL:

→1

Tags

Point source capture | Utilisation | Process technology | Value chain

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:

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Timeline:

2022 - 2027

TRL:

1→4

Tags

Utilisation | Process technology | Agriculture | Capacity building

UTILISATION

$CAPCO_2$ – Algae

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

Contact:

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Timeline:

2023 - 2026

TRL:

4 → 8

Tags

Utilisation | Process technology | Value chain | Biogas

UTILISATION

$CapCO_2$ – Electrolysis

Capturing CO_2 for simultaneous chlorine and ethanol production using sea water and sustainable electricity

Objective and hypothesis

CO_2 electrolysis enables CO_2 utilisation, but the techno-economics of commercialisation remain challenging. In conventional systems, the anodic reaction typically produces low-value oxygen, while the chloro-alkali industry generates low-value hydrogen at the cathode. This project aims to develop a dual electrolyser that combines both processes, generating higher-value products at each electrode. Specifically, it focuses on converting CO_2 to ethanol or propanol at the cathode—both cleaning agents—and potassium chloride to chlorine (also a cleaning agent) and potassium hydroxide at the anode.

Approach

The project is a joint Denmark–China collaboration. The Chinese partners focused on CO_2 capture and CO_2-to-CO electrolysis. From Denmark, Spectro Inlets contributed a gas product analysis device and developed an add-on for detecting liquid products. The Technical University of Denmark validated the system and designed catalysts and electrodes for CO-to-ethanol conversion. Chinese chloro-alkali company HADA tested these electrodes in a combined setup, and Danish company HybridGreentech carried out the techno-economic analysis.

Expected impact/output

Integrating CO_2 electrolysis with the chloro-alkali process has the potential to significantly improve the overall techno-economics of CO_2 utilisation. This project aims to demonstrate the technical feasibility of this dual-electrolysis approach, identify key challenges, and provide a comparative techno-economic analysis focused on Denmark and China to assess commercial potential.

Budget:

DKK 3,700,000

Funded by:

Innovation Fund Denmark, Ministry of Science and Technology of the People's Republic of China (MOST)-Bilateral Agreement project

Partners:

China University of Geosciences, Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences, HADA Electrolyzers, HybridGreen Tech, Spectro Inlets & Technical University of Denmark

Contact:

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Timeline:

2022 - 2025

TRL:

2 → 4

Tags

International collaboration | Process technology | Utilisation

UTILISATION

CAPeX

The Pioneer Center for Accelerating P2X Materials Discovery (Aviation and Maritime X-Trail)

Objective and hypothesis

Electrofuels based on CO_2 and renewable electricity are essential to decarbonise hard-to-electrify sectors like shipping and aviation. This center aims to contribute by using CO_2 electrolysis to produce long-chain carbon compounds suitable for use in these sectors. CO_2 electrolysis typically yields a narrow distribution of short-chain products, while high-temperature Fischer–Tropsch synthesis generates longer chains but with broader distribution. The goal is to perform CO_2 electrolysis at high temperatures to achieve both chain length and product selectivity tailored to fuel applications.

Approach

The center brings together a broad range of expertise to achieve its goals. Computational chemists at DTU Physics will design the catalysts, while nanoparticle synthesis specialists at the University of Copenhagen will produce them. Electrode testing will also be conducted at DTU Physics. Pulsing and varying the potential is expected to be key to achieving stable, efficient conversion, and experts from Aalborg University will optimise the power electronics.

Expected impact/output

By merging CO_2 electrolysis and Fischer-Tropsch, the project expects to develop new catalysts and create new product distributions. As this is a low-TRL, project, the primary impact will be understanding the science of the merging of these two fields. The goal will be to create electrolyzers that can then be uptaken by start-up incubators such as Villum P2X.

Budget:

DKK 300,000,000

Funded by:

Carlsberg Foundation, Danish National Research Foundation, Lundbeck Foundation, Ministry of Higher Education and Science in Denmark, Novo Nordisk Foundation, Villum Fonden

Partners:

Aalborg University, Aarhus University, Stanford University, Technical University of Denmark, University of Copenhagen, University of Southern Denmark & Utrecht University

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Tejs Vegge (CAPeX leader), teve@dtu.dk

Timeline:

2023 - 2036

TRL:

1→4

Tags

Energy systems | Fuels | Material science | Process technology | PtX | Utilisation

UTILISATION

Carbonive

Bacterial CO_2 Capture To Produce Mineral Carbonates For Industrial Use

Objective and hypothesis

The project is developing an innovative bio-based technology specifically designed for point-source CO_2 capture in high-emission industries, offering a practical and efficient solution for reducing carbon emissions directly at their source. The overarching goal of this project is not only to significantly reduce CO_2 emissions but also to produce industrially relevant minerals (such as calcium carbonate) during the capture process that can be reintegrated into industrial applications, contributing to a circular economy and further enhancing the sustainability of the industries involved. This dual approach of emission reduction and resource recovery makes the technology a promising tool for a more sustainable future.

Approach

By mimicking coral reefs, which absorb CO_2 from seawater and combine it with calcium ions to form calcium carbonate used to build their skeletons, the project has developed a bacterial approach to capture industrial CO_2 emissions and convert them into stable mineral carbonates, suitable for use in industries such as cement production, steel manufacturing, and the paper and pulp industry. By capturing CO_2 and converting it to calcium carbonate using bacteria, the project provides a biosustainable way of not only utilising CO_2 as a waste gas but also connecting various waste streams of calcium ions to create calcium carbonate for reuse.

Expected impact/output

The goal of this project is to transition from a laboratory-scale process to a scalable platform capable of large-scale CO_2 precipitation, offering a tangible solution for significantly reducing industrial CO_2 emissions. By demonstrating the technology's effectiveness on a larger scale, we aim to demonstrate its viability for widespread industrial adoption. This progression is crucial to driving the broader implementation of the technology, enabling industries to make substantial strides toward sustainability and emissions reduction. Ultimately, this project seeks to lay the foundation for the large-scale application of this innovative solution, helping to mitigate the global impact of carbon emissions across various high-emission industries.

Budget:

DKK 4,800,000

Funded by:

Independent Research Fund Denmark, TotalEnergies

Partners:

Technical University of Denmark, TotalEnergies

Contact:

Colleen Varaidzo Manyumwa, covama@dtu.dk

Timeline:

2022 - 2027

Tags

Biological storage | Cement industry | Environment | Microbiology | Nature | Point source capture | Utilisation

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:

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

Contact:

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Timeline:

2022 - 2025

TRL:

4 → 6

Tags

Material science | Process technology | Utilisation

UTILISATION

CO_2Nylon

CO_2 Electrolysis Integrated Adipic Acid Synthesis for Sustainable Nylon

Objective and hypothesis

Adipic acid is a key ingredient in the production of nylon, a commonly used polyester. Today, it is made from KA oil and nitric acid, which releases nitrous oxide as a by-product—a potent greenhouse gas. The CO_2Nylon project aims to develop a more sustainable alternative by starting with butadiene (which can be made from biomass-based ethanol) and electrochemically reducing CO_2 onto it to produce adipic acid.

Approach

As CO_2 electrolysis is typically done in water, and butadiene is not soluble in water, we need to find the optimal solvent that will allow for both butadiene and CO_2 electrolysis to occur simultaneously. Additionally, we need to identify a catalyst that enables both butadiene and CO_2 intermediates to adsorb onto its surface, allowing them to react efficiently.

Expected impact/output

This should allow for a new method to produce adipic acid, which is produced at 2.5 million tonnes per year globally. The focus of this project will be to develop the catalyst for this reaction and identify the limiting parameters. From a broader perspective, this will help develop the knowledge base for electrifying the chemicals industry.

Budget:

DKK 3,100,000

Funded by:

Independent Research Fund Denmark

Partners:

Technical University of Denmark

Contact:

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Timeline:

2024 - 2027

TRL:

2 → 3

Tags

Process technology

PtX

Utilisation

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:

EU Horizon research and Innovation programme & co-funding from project partners

Partners:

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

Contact:

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Timeline:

2022 - 2026

Tags

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

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:

EU Horizon research and Innovation programme under grant agreement No. 101084405

Partners:

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

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Timeline:

2022 - 2026

TRL:

2 → 5

Tags

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

UTILISATION

ECOMO

Electrobiocatalytic cascade for bulk reduction of CO_2 to CO coupled to fermentative production of high value diamine monomers

Objective and hypothesis

ECOMO is driven by the need for sustainable solutions to meet global material demand. The use of renewable energy, greenhouse gas CO_2 and nitrogen as starting materials for smart biotransformation steps is expected to play a game-changing role for the chemical industry in the coming years. The role of the Technical University of Denmark is within Innovation Gate 2 – acetate switch, investigating acetogenic biological transformation of CO with acetic acid as the target primary product. The objective is that the acetate switch will operate with a high specificity of more than 95% in a trickle-bed reactor (TBR), combining full conversion efficiencies of both CO and CO_2 with high production rates.

Approach

The objective of Innovation Gate 2, led by the Technical University of Denmark, will be accomplished through development of specialised and highly tolerant to CO microbial consortia for acetic acid production from CO as well as process development to promote high acetic acid selectivity and productivity. We will work with development of CO-tolerant, mesophilic and thermophilic microbial enrichments that will be kineticall characterised and used for the start-up of the trickle bed reactor (TBR) while in-situ acids extraction will be applied to optimise the process.

Expected impact/output

The ECOMO innovation chain includes all and specifically new steps of CO_2 capture and utilisation/storage and thus addresses disruptive and close to market solutions. ECOMO assembles around established technologies, thus bears an intrinsic high degree for implementation. ECOMO unites the worlds of sustainable CO_2 valorisation with the production of green monomers for established and new markets with a decreased or even negative CO_2 footprint.

Budget:

DKK 28,140,000

Funded by:

Horizon Europe Research and Innovation Programme

Partners:

Centre National de la Recherche Scientifique, Eilenburger Elektrolyse und Umwelttechnik, Fraunhofer-Gesellschaft, Technical University of Denmark & Technical University of Munich

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Timeline:

2023 - 2026

TRL:

2 → 4

Tags

Modelling | Process technology | PtX | Utilisation

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:

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

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Erik Christensen, erchr@dtu.dk

Timeline:

2023 - 2026

TRL:

3 → 5

Tags

Utilisation | Fuels | Process technology | Energy efficiency

UTILISATION

EXCCEL

Extremely Cold CO_2 Electrolysis

Objective and hypothesis

Electrochemical conversion of CO_2 is a promising pathway for turning greenhouse gases into valuable chemicals and fuels. Yet, the fundamental mechanisms behind the reaction are still not fully understood—especially why different products form under seemingly similar conditions.

CO_2 electrolysis is typically performed at room temperature or slightly elevated temperatures. However, this offers only a narrow window for understanding the reaction. The EXCELL project will analyse CO_2 electrolysis at temperatures as low as –100 °C. By generating data under conditions far from standard operating environments, we aim to gain insight into why the reaction behaves as it does.

Approach

We will place our standard electrolyser in a cryogenic freezer. This presents several challenges, as pumps and even electronic components can struggle to operate at such low temperatures. While water is typically used in CO_2 electrolysis, we will use a water–alcohol mixture to ensure a liquid-phase reactor is maintained at cryogenic temperatures.

Expected impact/output

This low-temperature dataset will provide computational chemists, machine learning experts and AI researchers with valuable input for developing fundamental models of CO_2 electrolysis. Given that room temperature electrolysis can produce up to 12 different products, cooling the system may help us better understand why these different products form and what determines product selectivity.

Budget:

DKK 3,000,000

Funded by:

Novo Nordisk Foundation

Partners:

Technical University of Denmark

Contact:

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Timeline:

2024 - 2027

TRL:

2

Tags

Process technology

PtX

Utilisation

UTILISATION

Flue-to-Fuel

Biomediated Conversion of Flue gas CO_2 to Biomethane

Objective and hypothesis

Flue-to-Fuel tackles a key challenge in the green transition by developing a low-energy pathway for CO_2 capture and direct conversion into e-methane using green hydrogen – with the potential to reduce emissions and supply renewable drop-in fuels.

The Flue-to-Fuel (FtF) technology platform is based on a novel concept termed bio-integrated carbon capture and utilisation (BICCU), which allows CO_2 to be captured from low-concentration flue gases and then converted into biomethane. The goal of the project is to advance the FtF technology from lab scale to prototype test in a realistic environment, enabling capture and conversion of CO2 from raw flue gas into e-methane.

Approach

The Flue-to-Fuel technology utilises conventional carbon capture agents to capture CO_2 from dilute sources. However, in contrast to conventional capture technologies, where heat is used for liberating CO_2 from the capture agent, the FtF technology alleviates this energy penalty by using biotechnology for combined liberation and conversion of CO_2 to biomethane. This holds the potential to substantially reduce the energy penalty of carbon capture and utilisation compared to conventional routes. The electrons needed for release and conversion are added in the form of hydrogen, which can be produced from water-electrolysis using renewable energy.

Expected impact/output

The developed technology combines CCU and Power-to-X and will enable cost-efficient capture of flue gas CO_2 to hereby reduce emissions from large scale emitters - e.g. combined heat and power plants - while at the same time produce e-methane as green drop-in fuel. The mature technology will enable the production of e-methane which can substite a significant fraction of the Danish natural gas consumption from captured CO_2 and renewable hydrogen.

Budget:

DKK 4,475,800

Funded by:

Villum Fonden/VELUX Fonden

Partners:

Aarhus University

Contact:

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Timeline:

2023 - 2025

TRL:

3 → 5

Tags

Energy efficiency | Fuels | Microbiology | Point source capture | PtX | Utilisation

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:

Horizon Europe Research and Innovation Programme under the grant agreement No. 101069605

Partners:

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

Contact:

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Timeline:

2022 - 2025

TRL:

4 → 6

Tags

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

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:

Aarhus University, Sasol & Topsoe

Contact:

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Timeline:

2023 - 2026

TRL:

5 → 7

Tags

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

UTILISATION

Gate2GreenFuels

Demonstration and development of CO_2-based fuel technologies in a regional living lab setting

Objective and hypothesis

The Gate2GreenFuels project will further develop the test and demonstration platform CCU-Hub Aalborg at the Port of Aalborg, which in the long term will encompass the entire value chain for the use of CO_2 in the production of sustainable fuels (including methanol as a key component).
Through testing and demonstration activities on and around the Gate2GreenFuels site at the Port of Aalborg, the project aims to lay the foundation for decision-making tools and roadmaps for CCU technologies.
At the same time, the project will investigate how such technologies perform under local and regional conditions and within existing infrastructure. In this way, it will explore potential changes and connections to local communities, and how the technologies may create value for the actors involved.

Approach

Gate2GreenFuels will operate as a Living Lab, supporting industries that wish to demonstrate and test both existing and new technologies, while also serving as a platform for knowledge sharing and future competence building.
Using a range of technologies, the project will ensure physical demonstrations as well as scenario development, creating a basis for effectively optimising and selecting technologies at scale – from both environmental and local perspectives.

Expected impact/output

By 2026, and with the implementation of the planned activities, the project aims to make a significant contribution to the development and potential final investment decision (FID) for European Energy's e-methanol plant at the Port of Aalborg. If realised, this could lead to substantial capital investments in renewable energy and methanol production in Aalborg and the wider North Jutland region.
In addition, the project is expected to support continued testing and development related to methanol demonstration facilities at the site, as well as ongoing demonstration activities, commissioning, and the gradual establishment of methanol-related infrastructure.
Finally, the test platform will contribute to competence development among employees in collaboration with knowledge and educational institutions.

Budget:

DKK 7,901,735

Funded by:

CO2Vision - EU

Partners:

Aalborg CSP, Aalborg Portland, Aalborg University, Blue World Technologies, Circle K, European Energy, Heatflow ApS & Port of Aalborg (Research and Development)

Contact:

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Timeline:

2023 - 2026

Tags

Capacity building | PtX | Utilisation | Value chain

UTILISATION

HEC

Data-Driven Development of High-Entropy Catalysts for CO_2 Utilisation

Objective and hypothesis

Developing efficient ways to convert CO_2 into useful products is key to making carbon utilisation more sustainable and economically viable. This project focuses on high-entropy oxide catalysts for the reverse water-gas shift (RWGS) reaction, which transforms CO_2 and H_2 into materials that can be used in industry. The hypothesis is that high-entropy oxide catalysts—particularly those containing first-row transition metals—can significantly improve the efficiency and selectivity of the RWGS reaction due to their unique structural properties, such as increased oxygen vacancies and metal disorder.

Approach

The project will implement a data-driven, high-throughput screening approach to optimise the synthesis of high-entropy oxide catalysts. Using Bayesian optimization, the project will plan new experiments based on a probabilistic analysis of each incoming dataset, balancing exploration and exploitation to improve the catalyst composition and synthesis continuously. Additionally, thorough material characterization using techniques like XRD, XRF, XPS, and Raman spectroscopy will be conducted to understand the structure-activity relationship of the catalysts.

Expected impact/output

To support more sustainable and cost-effective CO_2 utilisation, the project will develop highly efficient and selective high-entropy oxide catalysts for the RWGS reaction. The project will also advance the field of heterogeneous catalysis by providing new insights into the structure-activity relationship of high-entropy oxides, and the data-driven methodology developed could be applied to other catalytic processes.

Budget:

DKK 3,167,604

Funded by:

Independent Research Fund Denmark

Partners:

Technical University of Denmark

Contact:

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Timeline

2025 -2028

TRL:

2 → 3

Tags

Machine learning

Material science

Utilisation

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:

Aarhus University, Landia & University of Queensland

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Timeline:

2021 - 2025

Tags

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

UTILISATION

MECOE

Mixed organic-aqueous Electrolytes for selective CO Electrolysis (ME-COE)

Objective and hypothesis

Reducing unwanted hydrogen formation is a key challenge in CO_2 and CO electrolysis, as it lowers efficiency and limits product yield. While water is needed to hydrogenate CO_2 /CO, excess water can easily lead to hydrogen evolution. This project looks to operate CO_2 /CO electrolysis in primarily non-aquoeous solvents to reduce hydrogen evolution

Approach

As the solid oxide electrolysis community is excellent at converting CO_2 to CO, our approach is to primarily focus on CO electrolysis. This has the added advantage that it eliminates carbonates, which can easily form salt deposits. Dimethyl sulfoxide, dimethyl formamide, and acetonitrile all will be tested to determine the best solvent. An additional aspect is that we will use hydrogen oxidation at the anode (instead of water oxidation) and a proton shuttle to allow us to mitigate the amount of water we need and save power when operating the device.

Expected impact/output

This should provide a new perspective on CO_2 and CO electrolysis by opening up the field of non-aqueous CO_2 electrolysis. Futhermore, with a different dielectric medium, this can potentially allow us to produce new organic chemicals to help support the organic chemicals industry.

Budget:

DKK 2,900,000

Funded by:

Independent Research Fund Denmark

Partners:

Technical University of Denmark

Contact:

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Timeline:

2023 - 2025

TRL:

2

Tags

Energy efficiency | Process technology | PtX | Utilisation

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

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Timeline:

2023 - 2025

TRL:

2 → 3

Tags

Utilisation | Microbiology | Modelling | Process technology

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 CO_2 Research Center at Aarhus University (CORC)

Partners:

Aarhus University

Contact:

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Timeline:

2022 - 2026

Tags

Fuels | Utilisation

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

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Timeline:

2023 - 2025

TRL:

4 → 5

Tags

Microbiology | Utilisation | Process technology

UTILISATION

Mobile CU Reactor

Mobile Carbon Utilization Reactor

Objective and hypothesis

With the globally increasing rate of production and the growing demand for transport, CO_2 emissions are also rising exponentially. This has measurable and significant climate-related consequences, which is why reducing global CO_2 emissions is high on the political agenda. For many companies, both now and in the future, the cost of CO_2 disposal must be factored in to meet mandatory climate targets (carbon neutrality).

Approach

The objectives of this project are to:

- Finalise the full-scale design of the Carbon Capture (CC) reactor
- Design and implement an effective power supply system
- Develop and integrate a control system and data management platform for process optimisation
- Assemble all physical components
- Monitor, measure, and optimise the efficiency of the CC reactor

The design phase builds on Algicel's previous project (Q2 2022 – Q2 2023), which produced a scale model partly developed and manufactured by Roblight. The current aim is to complete the detailed technical package required for constructing the CC reactor, develop the control and 1 MW power supply systems, and deliver a full-scale demonstration unit.

Expected impact/output

Using a biological photosynthesis process driven by artificial light and CO_2, the Carbon Utilisation Reactor (CCU) – a so-called photobioreactor – produces algae-based oils and proteins, along with pure oxygen, while consuming significant amounts of CO_2. Surplus heat is the only by-product, and it can be fully utilised.

The end products are high-value compounds, such as omega-3 oils and/or protein-rich biomass. This supports resource efficiency by enabling circular use of natural resources. The CU reactor is designed as a plug-and-play system that can be delivered in 40" containers for on-site deployment, with remote monitoring from central service centres in collaboration with local partners. This CO_2 capture and utilisation technology will enhance national competitiveness and position North Jutland as a hub for sustainable CO_2 solutions.

Budget:

4,600,000

Funded by:

CO2Vision - EU

Partners:

Aalborg University, Algiecel, Danish Technological Institute & Roblight

Contact:

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Timeline:

2023 - 2026

Tags

Biological storage

Process technology

Utilisation

UTILISATION

PowerLBG

Development of power-to-gas technology for production of liquefied biogas for the transport sector

Objective and hypothesis

To support the decarbonisation of heavy transport and maximise the climate benefits of biogas, PowerLBG aims to develop a complete process chain for producing liquefied methane (e-LBG) from biogas and electricity-derived methane (e-methane).
The project builds on the further development and industrial maturation of the InjectMe in situ biomethanation technology, which enables the biological conversion of CO_2 directly within biogas reactors, before the biogas leaves the system.

Approach

The project will develop a full process chain for producing liquefied biomethane and e-methane from biogas, by adding hydrogen produced through electrolysis. This includes research and development of in situ methanation at both pilot scale (30 m³) and full scale (10,000 m³), process modelling, and the development and testing of advanced sensor technology. PowerLBG builds on existing infrastructure at Aarhus University (Campus Viborg) and ongoing developments at GrønGas Hjørring.

Expected impact/output

The project will enable the following:

1. Production of green drop-in fuel for heavy transport sectors.
2. Direct production of LBG from biogas without need for prior separation, infrastructure, or transport of CO_2
3. Design and evaluation of process chain for localised production of LBG at biogas plants without connection to the natural gas grid.

Budget:

DKK 11,501,881

Funded by:

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

Partners:

Aarhus University, GrønGas Hjørring, Landia, NxPAS, University of Queensland & Wärtsilä

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Timeline:

2024 - 2027

TRL:

5 → 7

Tags

Biogas · Biogenic CO_2 · Fuels · Infrastructure · International collaboration · Point source capture · PtX · Simulation technology · Utilisation

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:

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

Contact:

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Timeline:

2023 - 2027

TRL:

3 → 7

Tags

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

UTILISATION

PyroCO$_2$

Demonstrating sustainable value creation from industrial CO_2 by its thermophilic microbial conversion into acetone

Objective and hypothesis

The PYROCO2 project will demonstrate the scalability and economic viability of carbon capture and utilisation (CCU) to make climate-positive acetone, a platform chemical for many other chemicals, fuel additives, and materials.

Approach

The aim is to produce climate-positive acetone from industrial CO_2 and hydrogen derived from renewable electricity, as a platform for manufacturing chemicals and materials with a negative carbon footprint. The core of the technology is an energy-efficient thermophilic microbial bioprocess. The acetone produced by the PYROCO2 process will be demonstrated as a platform for the catalytic synthesis of a range of chemicals, synthetic fuels, and recyclable polymer materials derived from CO_2.

Expected impact/output

The project aims to demonstrate the large-scale industrial feasibility of thermophilic microbial gas fermentation to produce acetone from CO_2 and renewable electricity as a platform for further chemo-catalytic upgrading into a range of other commodity chemicals and materials. The PYROCO2 demonstrator plant will be located at an industrial cluster in Norway. From here, the PYROCO2 project will represent a key driver for the emergence of CCU hubs across Europe. Besides the large-scale demonstration and full financial, regulatory, and environmental assessment of the PYROCO2 technology, the project will explore public acceptance and market exploitation to further encourage the development of the CCU market.

Budget:

DKK 332,000,000

Funded by:

Horizon Europe Research and Innovation Programme

Partners:

Again ApS, Arkema France SA, Axelera, Bioprocess Technology AB, CiaoTech Srl, Chalmers University of Technology, Ecoinnovazione Srl, Firmenich SA, Herøya Industrial Park, Johnson Matthey Plc, Karlsruhe Institute of Technology, National Centre for Scientific Research, NextChem SpA, Norce Norwegian Research Centre AS, Norner Research AS, Ranido S.R.O., SCG Chemicals, SINTEF AS, Technical University of Denmark & Vestfold and Telemark County Council

Contact:

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Timeline:

2021 - 2027

TRL:

4 → 7

Tags

International collaboration | Microbiology | Process technology | PtX | Utilisation | Value chain

UTILISATION

Reformable

Biogas to Syngas

Objective and hypothesis

Reformable produces sustainable fuels and chemicals from biogas. One of the main technical challenges is to convert methane (CH4) and carbon dioxide (CO_2), the two main components of biogas, into syngas (CO and H_2) without forming coke, which deactivates the catalyst. Reformable's solution is a new, patented technology that effectively removes the coke from the catalyst's surface, which results in high catalytic activity and stability.

Approach

The project will allow Reformable to optimise the catalytic process using a new dedicated and automated 16-parallel reactor setup equipped with state-of-the-art process control technology and online sample analysis. Furthermore, the project will focus on designing a future pilot plant.

Expected impact/output

In the short term, the project will allow Reformable to optimise and upscale a first pre-commercial prototype catalyst, which is needed for future pilot-scale testing using authentic biogas in the field. In the long term, Reformable aims to commercialize their technology, providing the catalysts and core process design needed to produce higher-value fuels and chemicals, such as methanol, ethanol, or sustainable aviation fuels from biogas.

Budget:

DKK 4,600,000

Funded by:

Villum Fonden/VELUX Fonden

Partners:

Technical University of Denmark

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Timeline:

2025 - 2027

TRL:

4 → 5

Tags

Biogas | Biogenic CO_2 | Fuels | Process technology | Utilisation

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

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Timeline:

2023 - 2030

TRL:

2 → 4

Tags

Microbiology | Fuels | Process technology | Utilisation

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:

Horizon Europe Research and Innovation Programme under grant agreement No. 101084297

Partners:

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

Contact:

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Timeline:

2022 - 2026

TRL:

→7

Tags

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

UTILISATION

SimCO$_2$CFuel

Simultaneous CO_2 Capture and Renewable Fuel Production by 4D Self-Electro-Promoted Catalyst Concept

Objective and hypothesis

SimCO2CFuel aims to develop a compact and energy-efficient method for producing renewable methanol from CO_2, using only water and flue gas or atmospheric CO_2 as input. To achieve this, the project will develop a novel 4D self-electro-promoted catalyst concept that captures CO_2 from flue gas or ambient air and converts it into renewable methanol using water as a raw material in a compact, low-pressure process. This hybrid catalyst is designed to split water, filter and purify hydrogen, adsorb CO_2, and self-promote the hydrogenation reaction by increasing the catalyst's Fermi level using semiconductor materials.

Approach

The SimCO2CFuel strategy focuses on the development of a hybrid 4D catalyst material that integrates thermoelectric and pyroelectric properties, facilitating the concurrent capture of CO_2 and the production of renewable methanol. A thermoelectric core, when exposed to temperature gradients, facilitates electron transfer, whereas a photoelectrochemical layer decomposes water into hydrogen and oxygen.

Expected impact/output

The successful development of the 4D catalyst will facilitate efficient, low-pressure CO_2 capture and conversion, leading to a reduction in energy consumption and costs compared to conventional methods. The technology offers the potential for scalable application across various CO_2 emitters, contributing to sustainability in line with the European Green Deal. The anticipated results will include a validated catalyst prototype, theoretical models, and experimental correlations, which will enhance catalyst design and establish a basis for future compact renewable fuel systems.

Budget:

DKK 1,991,625

Funded by:

Villum Fonden/VELUX Fonden

Partners:

Aalborg University

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Timeline:

2023 - 2026

TRL:

1→3

Tags

Fuels | Modelling | Utilisation

UTILISATION

SUSTEPS

Sustainable, Secure, and Competitive Energy Through Scaling Up Advanced Biofuel Generation

Objective and hypothesis

SUSTEPS aims to enhance the sustainable production of algae-based biofuels by addressing challenges and leveraging opportunities in the value chain. The project focuses on developing a cost-effective and eco-friendly bio-refinery concept. It efficiently produces biofuel from non-food microalgae by utilising CO_2 emissions from high-pollution sources and nutrients from wastewater. The goal is to minimise production costs, promote large-scale production, and contribute to a more sustainable biofuel industry.

Approach

Innovative customised biofuels targeting market standards will be produced using leading-edge catalysts while minimizing waste streams and impurities. The production of biofuels using microalgae as a raw material and CO_2 as a feedstock holds significant potential for positive environmental impact. This process contributes to carbon capture by utilising flue gas, reducing greenhouse gas levels in the atmosphere. Microalgae's rapid growth and high lipid content make them an efficient biofuel feedstock, offering a renewable alternative to traditional fossil fuels. This can reduce overall carbon footprints, enhance energy security, and pave the way for a more sustainable and environmentally friendly energy future.

Expected impact/output

1. Disruptive renewable energy and renewable fuel technologies and systems to accelerate the replacement of fossil-based energy technologies.
2. Reduced costs and improved efficiency of renewable energy and fuel technologies, their value chains and net zero greenhouse gas emissions by 2050.
3. Better integration of renewable energy and renewable fuel-based solutions in energy consuming sectors.
4. Strengthened European research and export opportunities
5. Enhanced sustainability of renewable energy and renewable fuels value chains in line with the European Green Deal priorities.
6. More effective market uptake of renewable energy and fuel technologies.
7. Faster development of of CCUS as a CO_2 emissions mitigation option in industrial applications.

Budget:

DKK 22,380,000

Funded by:

Horizon Research and Innovation Programme under grant Agreement No. 101122363

Partners:

ArditEC Association, Boğaziçi University, ErinN Innovation Limited, Federal University of Itajubá, Forschungszentrum Jülich GmbH, Institut de Recherches en Énergie Solaire et en Énergies Nouvelles, Ketjen Netherlands BV, Paul Scherrer Institute, Scientific and Technological Research Council of Turkey, University of Calgary & University of Southern Denmark

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Timeline:

2023 - 2026

TRL:

3 → 5

Tags

Fuels | International collaboration | Microbiology | Process technology | Utilisation | Value chain

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:

Horizon Europe Research and Innovation Programme under grant Agreement No. 101112345

Partners:

Bergene Holm AS, DECHEMA, Gesellschaft für Chemische Technik und Biotechnologie e.V., Nofima AS, Norwegian Institute for Sustainability Research (NORSUS), RISE Research Institutes of Sweden, SINTEF, Skretting Aquaculture Research Centre AS, Technical University of Denmark & WAI Environmental Solutions AS

Contact:

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Timeline:

2023 - 2028

TRL:

4 → 6

Tags

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

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:

INNO-CCUS - Innovation Fund Denmark, NextGeneration EU & co-funding from project partners

Partners:

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

Contact:

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Timeline:

2023 - 2025

TRL:

3 → 5-6

Tags

DAC | Utilisation | Microbiology | Process technology | Value chain

UTILISATION

VALORGAS

Engineering a novel reactor system for enhanced valorization of syngas and CO_2 to chemicals and fuels

Objective and hypothesis

As industry seeks to convert CO_2 and syngas into fuels and valuable chemicals using renewable electricity, new reactor technologies are needed to make the process more efficient and scalable.

VALORGAS focuses on developing:

- A novel, compact reactor system that eliminates the need for an external water electrolysis unit while still securing enhanced mass transfer rates and productivities
- A model tailored to simulate the novel reactor type, which can be used for design purposes—i.e. to predict the optimal reactor size and dimensions for a given industrial scale of gas valorisation, as well as the best operating conditions for maximising productivity and carbon utilisation.

Approach

We will work on reactor design and construction, while simultaneously developing electroactive microbial enrichments to initiate the reactor process. The next step will be to measure the kinetics of the enriched microbial consortia and develop a model for the biological reactions in the novel reactor. This approach targets proof-of-concept for the reactor and the creation of a modelling tool that can be used to scale up the process.

Expected impact/output

Successful implementation of VALORGAS will pave the way for more cost-effective CO_2 valorisation using renewable electricity. The novel reactor and the methodology for electroactive microbial enrichment can also be applied to syngas valorisation, and the system could accommodate electroactive strains and defined co-cultures. Similarly, the model will be tunable and adjustable for specific applications. This adaptability maximises the potential impact of VALORGAS.

Budget:

DKK 3,000,000

Funded by:

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

Partners:

Technical University of Denmark

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Timeline:

2024 - 2027

TRL:

2 → 4

Tags

Fuels | Process technology | PtX | Utilisation

UTILISATION

Value4Farm

Sustainable renewable energy value chains for answering farmers' needs

Objective and hypothesis

The aim of Value4Farm is to increase on-farm renewable energy and bio/e-fuel production while preserving food production, soil health, soil carbon accumulation, and biodiversity, as well as reducing water and fertiliser use. The project focuses on several innovations to support more sustainable farming. These include developing better-adapted cropping systems for integrated, wind-sheltering agrivoltaics and combining food and bioenergy production through green biorefineries. It also aims to advance the concept of in situ power-to-methane and create a decision support tool to help farmers produce food, energy, and materials more sustainably.

Approach

The Danish platform of Value4Farm combines agrophotovoltaics, green biorefineries, anaerobic digestion, and biomethanation. Its aim is to maximise production of electricity, food, and feed, while ensuring an optimal supply of carbon for the production of bio- and electricity-based methane in a fully circular system. The project includes demonstration sites in Belgium, Italy and Denmark.

Expected impact/output

The continued deployment of renewable energy facilities based on wind and solar power will ultimately compete with access to arable land for food production. Value4Farm will explore how best to combine technologies for the production of green crops with electricity and bio/e-fuels through biogas-based Power-to-X. To this end, the project will develop new knowledge, technologies, and decision-support tools.

Budget:

DKK 58,033,089

Funded by:

Horizon Europe Research and Innovation Programme

Partners:

Aarhus University, Energy Institute Hrvoje Požar, Euroquality SARL, Helmholtz Centre for Environmental Research – UFZ, Inagro, Institute of Soil Science and Plant Cultivation – State Research Institute (IUNG-PIB), Italian Biogas and Gasification Consortium (CIB), Mitis, Orkidea samstarfsverkefni, REM Tec Srl, Università Cattolica del Sacro Cuore, University of Reading, Wageningen University and Research & World Biogas Association

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Timeline:

2023 - 2027

Tags

Agriculture | Biogas | Biogenic CO_2 | Energy systems | Environment | International collaboration | Modelling | PtX | Value chain

UTILISATION

VINGEGAARD

The advanced electrochemlcal based carbon capture and green gas to methanol process demonstration

Objective and hypothesis

The project aims to demonstrate an innovative Power-to-X process that integrates electrochemical carbon capture with CO_2-based methanol synthesis at a wastewater treatment plant. The project will develop and validate a cost-effective and energy-efficient pathway for converting CO_2 emissions into green methanol. We expect that combining ESTECH's carbon capture technology, Elplatek's methanol synthesis expertise, and DTU's scientific support will enable a scalable and decentralized Power-to-X solution.

Approach

The project integrates electrochemical carbon capture with a modular methanol synthesis unit to create a cost-effective Power-to-X solution. ESTECH's advanced technology efficiently captures CO_2 from wastewater treatment plant flue gas, while Elplatek's containerised reactor converts CO_2 and H_2 into green methanol. DTU provides scientific and operational support to enhance efficiency, scalability, and automation, ensuring higher safety and reduced operational risks. Our approach focuses on a decentralised, containerised system that minimises energy consumption and operational costs.

Expected impact/output

The VINGEGAARD project will demonstrate that wastewater-derived CO_2 can be effectively utilised, reducing greenhouse gas emissions, while contributing to Denmark's green fuel transition. This will advance Power-to-X technology, enhancing Denmark's leadership in sustainable fuel solutions, and contributing to climate goals. The project will create a scalable, modular system for decentralised green methanol production, fostering industrial collaboration and knowledge transfer. End-user IKEA will evaluate the produced methanol for its applications, promoting sustainable supply chains and reducing fossil fuel dependence.

Budget:

DKK 26,113,701

Funded by:

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

Partners:

Technical University of Denmark (Chemical Engineering), Elplatek, ESTECH, VandCenter Syd & IKEA

Contact:

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Timeline:

2025 - 2027

TRL:

5 → 7

Tags

Fuels | Point source capture | Process technology | PtX | Utilisation | Value chain

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 CO2 Research Center at Aarhus University (CORC)

Partners:

Aarhus University

Contact:

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Timeline:

2023 - 2026

TRL:

1→4

Tags

Utilisation | Process technology

UTILISATION

Wavefuels I

Wavefuels - A novel Power-to-X technology pathway

Objective and hypothesis

The project aims to design, test, optimise, and prepare for the demonstration of a novel technology – microwave cracking – at industrial scale. The goal is to advance the technology from TRL 6 to TRL 8 by converting biomass into biofuels and carbon storage products. Organic Fuel Technology's patented system enables a new Power-to-X pathway, where electricity is transformed into biofuels and stable carbon by generating a uniform electromagnetic field of a scale and intensity not previously achieved.

Approach

Building on Organic Fuel Technology's previous work—including computer simulations, lab-scale designs and experiments, and pilot plant construction and optimisation—a full-scale demonstration plant for microwave cracking is being developed and optimised. The plant will convert dewatered wastewater sludge into bio-oil and biochar and will include an integrated system for biomass reception and handling, drying, microwave cracking in specially designed reactors, condensation of gas-oil into oil, and storage of the resulting biochar. In parallel, the end products (oil and char) will be analysed, and methods for optimising post-treatment of the oil will be identified.

Expected impact/output

Over the project's 18 months implementation period aim is to achieve the following success criteria:

1. A detailed design for a full-scale microwave processing unit will be optimised and finalised.
2. A detailed plant design for microwave cracking of sewage sludge will be completed and optimised, including interfaces with the demonstration site, sludge drying, and facilities for intake, processing, and storage
3. The construction plan for the first full-scale plant at GreenLab Skive will be finalised, with all required permits in place.
4. The full value chain for bio-oil and biochar will be tested, demonstrated, and validated, with short- and medium-term off-taker agreements secured.

Budget:

DKK 10,060,000

Funded by:

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

Partners:

Aarhus University, Biological and Chemical Engineering, Energy Cluster Denmark, Euromilling A/S, Organic Fuel Technology A/S & Topsoe

Contact:

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Timeline:

2023 - 2025

TRL:

6 → 8

Tags

Biochar · Environment · Fuels · Process technology · PtX · Pyrolysis

UTILISATION

Wavefuels II

Wavefuels - A novel Power-to-X technology pathway

Objective and hypothesis

Building on the design and development work carried out in WaveFuels I, this project aims to demonstrate microwave cracking at full industrial scale. By constructing and operating a facility that converts dewatered wastewater sludge into bio-oil and biochar, the project will support the technology's progression towards TRL 8 and lay the groundwork for future commercial deployment.

Approach

WaveFuels II comprises the construction and demonstration of a full-scale plant for converting dewatered wastewater sludge into biooil and biochar. The plant will include an integrated system for biomass reception and handling, drying, microwave cracking in specially designed reactors, condensation of gas-oil into oil, and storage of the resulting biochar. In parallel, the end products (oil and char) will be analysed, and methods for optimising post-treatment of the oil will be identified.

Expected impact/output

1. The first full-scale microwave processing plant for sewage sludge will be commissioned by mid-2025
2. Industrial symbiosis solutions will enable the use of surplus heat from nearby green energy facilities.
3. The plant will be optimised and demonstrated, running 24/7 for 27 days per month, processing over 900 tons of sludge (240 tons dry matter) and producing at least 50 tons of bio-oil monthly.
4. The full value chain for handling, upgrading, and utilising bio-oil and biochar will be demonstrated and validated, with short- and medium-term off-taker agreements secured.
5. Upstream and downstream technologies will be verified to support serial production and commercial roll-out.

Budget:

DKK 52,320,000

Funded by:

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

Partners:

Aarhus University (Biological and Chemical Engineering), Energy Cluster Denmark, Euromilling A/S, Organic Fuel Technology A/S & Topsoe

Contact:

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Timeline:

2024 - 2029

TRL:

6 → 8

Tags

Biochar | Environment | Fuels | Process technology | PtX | Pyrolysis

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

CarbonChains

Emerging Carbon Value Chains in Denmark and the North Sea

Objective and hypothesis

The CarbonChains project aims to examine how emerging carbon management value chains—encompassing capture, transport, utilisation, and storage—are taking shape in Denmark and the broader North Sea region. The core hypothesis is that combining technological innovation with supportive socio-institutional frameworks can significantly accelerate the scale-up of CCS, CCU, and CDR solutions. By focusing on the interplay among sectors such as heavy industry, energy, and agriculture, the project posits that well-coordinated policy and governance efforts are essential to resolving 'chicken-and-egg' challenges—where supply and demand fail to align—and to establishing robust infrastructure for carbon management at scale.

Approach

Using socio-technical transition studies and innovation systems methodologies, the research team investigates cross-sector alliances, policy experiments, and market mechanisms that could spur carbon management innovation. This includes mapping actor networks, analysing mission-oriented climate initiatives across heavy industry and agriculture, and examining how different carbon value chains interact—whether by sharing infrastructure or overlapping actors. By spotlighting potential synergies and conflicts, the project sheds light on the 'chicken-and-egg' issues that arise when multiple sectors converge, such as misaligned supply and demand or uncertain investment flows.

Expected impact/output

CarbonChains ultimately seeks to provide actionable insights for policymakers, industry stakeholders, and researchers aiming to broaden the adoption of carbon management solutions in line with urgent climate goals. The project will produce policy recommendations, stakeholder guidance, and frameworks for creating viable business models. In doing so, it underscores the pivotal role of cross-sector coordination and governance in overcoming barriers such as infrastructure bottlenecks, regulatory uncertainties, and market mismatches.

Budget:

DKK 4,000,000

Funded by:

Novo Nordisk Foundation

Partners:

University of Copenhagen

Contact:

Allan Dahl Andersen, ada@ifro.ku.dk

Timeline:

2024 - 2028

Tags

Biological storage | Cement industry | DAC | Infrastructure | Public acceptance | Regulation | Society | Value chain

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:

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

Partners:

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

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Timeline:

2023 - 2026

Tags

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

SOCIETAL COUPLING

CC and PtX

Optimal utilisation of surplus heat from Carbon Capture and PtX

Objective and hypothesis

This concept- and development-based project aims to investigate, map, model, develop, and analyse resource flows and synergies across the energy value chain related to Carbon Capture (CC) and Power-to-X (PtX).
In particular, it explores how surplus heat from CC and PtX plants can be utilised in the most efficient way within the energy system, to maximise overall benefits – including the phase-out of fossil fuels and reduced resource consumption in energy production.

Approach

Surplus heat is expected to play a significant role in future energy systems, but its integration requires computational development, local collaboration, practical experience, and targeted solutions.
Locally, Aalborg Utility is undergoing a major production transition due to the planned closure of the North Jutland Power Station in 2028, which currently provides approximately 60% of Aalborg's heat supply.
Meanwhile, CIP plans to establish a new PtX facility for the production of green fuels. To support the PtX process, a new CC plant will be established at Nordværk in collaboration with CIP. Both the CC and PtX plants are expected to generate substantial amounts of surplus heat.
The project will map and model the above processes and develop concept and system designs, as well as calculation models, to support the development of new technical solutions and improve competitiveness.

Expected impact/output

The project will explore how to integrate as much surplus heat as possible from CC and PtX into the energy system in the most effective way. Digital twins of the processes and their integration into the system will be developed.
Calculation methods, models, and technology concepts (and/or configurations) for production and thermal storage will also be developed and tested in a real-life case at Aalborg Utility.
These outcomes will support the development of new technical solutions that can later be commercialised and delivered by Aalborg CSP, and implemented in connection with CC, PtX, and energy supply systems.

Budget:

DKK 2,670,185

Funded by:

CO2Vision - EU

Partners:

Aalborg CSP & Aalborg forsyning A/S

Contact:

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Timeline:

2023 - 2026

Tags

Energy systems | Modelling | Process technology | PtX | Utilisation

SOCIETAL COUPLING

CCUS-INFRASTRUCTURES

Strategic Planning of CCUS Infrastructure

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:

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

Partners:

Aalborg University, TotalEnergies & Ørsted

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Timeline:

2023 - 2027

TRL:

3 → 7

Tags

Infrastructure | Energy systems | Value chain | Economy

SOCIETAL COUPLING

CO_2QMON

Developing a standardised system for CO_2 monitoring and quality assurance

Objective and hypothesis

The purpose of the project is to define and build a system for monitoring, quality assurance, management, and reporting of CO_2 produced for a shared pipeline infrastructure. The methodology is exemplified using CO_2 gas produced at a carbon capture plant, with a particular focus on quantities and quality. The goal is to develop a practical solution that can serve as a de facto standard and be demonstrated and documented throughout the project.

Approach

The project includes a review and description of the requirement specifications for CO_2 gas produced at individual carbon capture plants, along with the quality standards likely to be required for supplying a national infrastructure. Based on these specifications, suitable methods for analysing and monitoring impurities in the CO_2 gas will be recommended.

In collaboration with Olicem, Thisted CHP Plant (KVVT), and FORCE Technology, the project will demonstrate practical solutions for a monitoring system (metering skid) capable of determining the quantity and quality of the CO_2 produced. Identification of appropriate test facilities is also part of the project.

Expected impact/output

The project will develop and demonstrate a practical solution for automatic reporting of measurement data, including systems for ensuring data quality in accordance with applicable requirements. The intention is to create a system that can be used as a de facto standard. Testing and demonstration will be carried out using data from practical trials, followed by data comparison and preparation of the final project report and documentation.

The project partners estimate that CO_2 data management and quality assurance could have a market potential of over DKK 200 million in Denmark alone. In addition, ongoing handling and auditing requirements are expected.

Budget:

DKK 1,586,558

Funded by:

CO2Vision - EU

Partners:

Aalborg Portland, FORCE Technology, Kraftvarmeværk Thisted & Olicem A/S

Contact:

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Timeline:

2023 - 2026

Tags

Monitoring | Process technology | Regulation | Value chain

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:

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

Partners:

Aalborg University, En2Save & Greenport North

Contact:

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Timeline:

2022 - 2026

Tags

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

SOCIETAL COUPLING

MARVIC

Developing and testing a framework for the design of harmonized, context-specific Monitoring, Reporting and Verification systems for soil Carbon and greenhouse gas balances by Agricultural activities

Objective and hypothesis

MARVIC aims to support climate action in agriculture by creating a reliable monitoring, reporting and verification (MRV) framework for measuring how farming practices affect carbon storage and greenhouse gas emissions in soil and woody vegetation. The project will develop and test a harmonised, context-specific MRV system to assess changes in carbon stocks and emissions from agricultural soils and woody biomass.

The main ambition is to offer scheme developers across Europe a standard approach for designing robust monitoring systems that:

1. Comply with upcoming European rules for certifying carbon removal
2. Balance accuracy with cost-effectiveness
3. Consider risks related to carbon loss due to changing land use or natural events such as extreme weather or climate shifts

Approach

The framework will be developed for four key land-use types:

4. Arable land with mineral soils
5. Permanent grasslands with mineral soils
6. Managed peatlands
7. Areas with woody crops or agroforestry systems

Expected impact/output

The framework will support different levels of detail and precision depending on the purpose of the climate initiative—whether related to agricultural policy or the voluntary carbon market. It will be flexible enough to adapt to local conditions, data availability and infrastructure, while also being manageable for landowners in terms of cost and paperwork.

An important feature of the MARVIC framework is that it will be open and freely available. This allows researchers and practitioners across Europe to update and improve the system over time as new evidence emerges - from field trials, scientific studies, or advances in data technology and automation.

Budget:

DKK 6,819,549

Funded by:

Horizon Europe Research and Innovation Programme, Mission Soil

Agroscope, Agrosolutions, Aarhus University, CSIC – Spanish National Research Council, Czech University of Life Sciences Prague, Eesti University of Life Sciences, Finnish Meteorological Institute, Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), INRAE – French National Research Institute for Agriculture, Food and Environment, SAE Innova, Teagasc – Agriculture and Food Development Authority, Università Cattolica del Sacro Cuore, Universität Freiburg, University of Copenhagen, University of Teramo & Wageningen University and Research

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Timeline:

2023 - 2027

Tags

Agriculture | Biological storage | International collaboration | Modelling | Monitoring | Regulation | Society

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 Research and Innovation Programme

Partners:

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

Contact:

Wei Yan, weya@kemi.dtu.dk

Timeline:

2024 - 2028

Tags

Point source capture | Geological storage | Material science | Capacity building | Infrastructure

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:

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

Partners:

Aalborg University, Copenhagen Business School & Technical University of Denmark

Contact:

Manuel Llorca, mll.eco@cbs.dk

Timeline:

2023 - 2025

Tags

Public acceptance | Society

SOCIETAL COUPLING

REFOREST

Agroforestry at the forefront of farming sustainability in multifunctional landscapes in Europe

Objective and hypothesis

The primary mission of the project is to foster innovation, knowledge exchange and provide novel solutions to empower farmers in Europe and associated countries to deliver to multiple objectives: food production, carbon capture, and biodiversity.

To achieve this, the project focuses on agroforestry – an integrated land use system that combines trees and agriculture. Agroforestry enables continued food production while improving environmental sustainability and supporting a range of ecosystem services. The project addresses key barriers to wider adoption of agroforestry, such as limited knowledge, uncertainty around economic impacts for farms, and unclear policy frameworks.

Approach

Reforest will employ a cocreation and multi-actor approach as our fundamental research method to place agroforestry systems in the right balance of farm productivity, socio-economic viability and sustainability. The project will make use of existing knowledge and data, apply agroforestry living labs based on previous projects, and establish a stakeholder and actor engagement platform to enable knowledge transfer, training and innovation.

Expected impact/output

This project will prioritise enhancing knowledge exchange and transfer, enabling the integration of carbon and biodiversity finance in farm business models, and by proposing targeted policy interventions to overcome barriers to agroforestry expansion.

DKK 24,873,387

Funded by:

Horizon Europe Research and Innovation Programme, grant agreement No. 101060635

Partners:

Czech University of Life Sciences Prague, Euro-Mediterranean Economists Association, Europroject Ltd., FarmTree BV, German Association for Agroforestry (DEFAF), INAGRO, Philipps University of Marburg, Polish National Agroforestry Association, Progressive Farming Trust Ltd LBG, Trakia University, University of Bonn, University of Copenhagen, University of Reading & University of Sopron

Contact:

Bhim Bahadur Ghaley, bbg@plen.ku.dk

Timeline:

2022 - 2026

Tags

Agriculture | Biological storage | Capacity building | Environment | Forest | International collaboration | Modelling | Regulation

SOCIETAL COUPLING

RenByLand

Demonstrating circular bioeconomy through integrated biomass processing on Mors

Objective and hypothesis

The vision of the RenByLand project is to establish a combination of technologies that can collectively handle and create value from local waste and residual biomass on the island of Mors.
RenByLand is a demonstration project in circular bioeconomy. Technologically, the project is built around a drying technology based on superheated steam.
This technology offers a clear energy and, consequently, economic advantage compared to traditional hot-air drying, as 85% of the energy used can be recycled for process or district heating.

Approach

The aim of the mini-lighthouse is to carry out a feasibility study to assess the technological viability of the RenByLand vision and circular bioeconomy, by exploiting sector coupling and synergy effects within the overall project.
The long-term goal is to establish an integrated drying and pyrolysis plant capable of processing various types of waste and residual biomass, including sewage sludge, organic household waste, and slurry fibres from biogas plants. The process will generate surplus heat from drying, as well as oil, gas and biochar from pyrolysis. Additionally, a scrubber will be installed to purify ammonium sulphate from the drying water, which can, for example, be used to increase the fertiliser value of the biochar before it is applied to agricultural land.

Expected impact/output

In addition to enabling CO_2 storage, the project contributes to emission reductions in the energy and agricultural sectors through:

- Displacement of fossil fuels
- Reduction of methane and nitrous oxide emissions from slurry
- Conversion to grass production by establishing a market outlet for clover grass for feed products

Budget:

DKK 2,250,625

Funded by:

CO2Vision - EU

Partners:

Burhøjgaard ApS, Filtenborg, GRAINAS A/S, Morsø Municipality, Morsø Spildevand A/S, Nordendahl Landbrug v. Niels Holger Nordendal Nielsen, Sdr. Herreds Kraftvarmeværk & Danish Technological Institute

Contact:

Alex Søgaard Moreno, asm@aalborg.dk

Timeline:

2023 - 2026

Biochar | Biogenic CO_2 | Biological storage | Energy efficiency | Pyrolysis

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 tothe following climate goals:

- INNO-CCUS climate targets: Contribute to a reduction of 0.2 m. ton CO2e per year in 2025 and 2-4 m. ton CO2e per year in 2030.
- Achieve 2 m. tonnes of CO2e 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:

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

Partners:

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

Contact:

Tobias Pape Thomsen, tpapet@ruc.dk

Timeline:

2023 - 2026

Tags

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

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:

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

Partners:

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

Contact:

Karl Sperling, karl@plan.aau.dk

Timeline:

2022 - 2025

Tags

Value chain | Society | Energy systems | Economy

ARCHIVE

Completed projects

CAPTURE

Aalborg I - Carbon capture from Aalborg Portland

The project was the first step in realising Aalborg Portland's vision of creating a flagship for CCUS in the industry. The project's objective was to analyse and model two different CO2 capture technologies, with the aim of providing a decision-making basis for selecting the most cost-effective CO2 capture technology for Aalborg Portland.

Budget: DKK 3,070,000
Funded by: Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners
Partners: Aalborg CSP, Aalborg Portland & Aalborg University
Contact: Maria Kristiansen, mak@energycluster.dk
Timeline: 2022 - 2023
TRL: 3 → 4-5

$BioCO_2$ - Biogas upgrading for high-purity CO_2 and natural gas distribution

The objective of this project was to develop and demonstrate a new, more energy-efficient way of upgrading biogas for the combined production of biomethane and $bioCO_2$. The aim was 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.

Budget: DKK 13,800,000
Funded by: The Energy Technology Development and Demonstration Programme (EUDP) & co-funding from project partners
Partners: Danish Gas Technology Centre, Pentair Union Engineering & Technical University of Denmark (DTU Chemical Engineering)
Contact: Sebastian Nis Bay Villadsen, snbvi@kt.dtu.dk
Timeline: 2022 - 2023
TRL: 4 → 6

CCCH2 - Combined carbon capture and hydrogen production

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

Budget: DKK 33,640,000
Funded by: REACT-EU (Regional Development Fund)
Partners: Danish Gas Technology Centre, ESTECH, PureteQ, Technical University of Denmark & VandCenter Syd
Contact: Søren Gert Larsen, sgl@estech.dk
Timeline: 2016 - 2023
TRL: → 8

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

The objective of this project was 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.

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

Net Zero Arc - Net zero energy carbon capture at ARC

The objective of the project was 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, aimed to construct, commission and operate a cost-effective demonstration-scale Carbon Capture (CC) unit at ARC.

Budget: DKK 62,600,000
Funded by: The Energy Technology Development and Demonstration Programme (EUDP) & co-funding from project partners
Partners: ARC (Amager Resource Center), Pentair Union Engineering, Rambøll & Technical University of Denmark
Contact: Jannik Kappel, jkap@a-r-c.dk
Timeline: 2020 - 2024

NATURE-BASED SOLUTIONS

Flash pyrolysis - Development of a system for gas-borne flash pyrolysis

The project's purpose was 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.

Budget: DKK 30,605,000
Funded by: The Danish Energy Agency's Pyrolysis Pool & co-funding from project partners
Partners: Frichs Pyrolysis, Lisbjerregaard, Lykkesmeden, Springkilde Bio & University of Southern Denmark
Contact: Søren Bruun, sbr@frichs.com
Timeline: 2022 - 2024
TRL: 5 → 8

Future forests - Trees for the future forests

This project addressed 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 studied how to select, improve or prepare the trees for the future forests.

Budget: DKK 5,900,000
Funded by: Villum Fonden
Partners: University of Copenhagen
Contact: Erik Dahl Kjær, edk@ign.ku.dk

PETREA - Oaks in green transition

This project examined 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.

Budget: DKK 2,875,000
Funded by: Independent Research Fund Denmark
Partners: University of Copenhagen
Contact: Erik Dahl Kjær, edk@ign.ku.dk

Vesthimmerland - Agricultural innovation, CO_2 storage, and utilisation

This project aimed 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 was already undergoing testing. However, crucial knowledge was lacking regarding value creation in the preceding process leading up to the actual pyrolysis process.

Budget: DKK 1,639,000
Funded by: REACT-EU (Regional Development Fund)
Partners: Lundsby Biogas, Vesthimmerland Biogas & Vesthimmerland Municipality
Contact: Maria Kristiansen, mak@energycluster.dk
Timeline: 2022 - 2023
TRL: 7 → 8

SkyClean 2MW - Combining biofuel production with CO_2 capture and storage

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

Budget: DKK 36,440,000
Funded by: The Energy Technology Development and Demonstration Programme (EUDP) & co-funding from project partners
Partners: Danish Gas Technology Centre, Energy Cluster Denmark, Stiesdal SkyClean, Technical University of Denmark, Topsoe & Ørsted Bioenergy & Thermal Power
Contact: Jesper Ahrenfeldt, jah@stiesdal.com
Timeline: 2021 -2024
TRL: 3 → 7

STORAGE

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

The project combined 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 aimed 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?

Budget: DKK 2,300,000
Funded by: Danish Offshore Technology Center
Partners: Danish Offshore Technology Center, Geological Survey of Denmark and Greenland (GEUS), Technical University of Denmark
Contact: Hamid Nick, hamid@dtu.dk & Charlotte N. Larsen, clarsen@dtu.dk
Timeline: 2022 - 2024
TRL: 2 → 4

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

When injecting CO_2 in an existing oil and gas reservoir the legacy wells are the main risks for potential future leakage. It is 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 looked into the potential degradation of the cement/metal interface under CO_2 storage conditions. In addition, a data driven machine learning (ML) based model was built for CO_2 storage related corrosion prediction, based on empirical data (incl data from the CO_2 Corr project).

Budget: DKK 5,200,000
Funded by: Danish Offshore Technology Center
Partners: Aarhus University, Danish Offshore Technology Center, Technical University of Denmark
Contact: Rajan Ambat, ram@mek.dtu.dk
Timeline: 2022 - 2024
TRL: 3 → 6

Cement durability - Experimental and numerical studies of microstructure and durability for cement

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 was, 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.

Budget: DKK 4,700,000
Funded by: Danish Offshore Technology Center
Partners: Aarhus University, Danish Offshore Technology Center & Technical University of Denmark
Contact: Wolfgang Kunther, wolku@dtu.dk & Charlotte N. Larsen, clarsen@dtu.dk
Timeline: 2021 - 2024
TRL: 3 → 4

CO_2 Corr - Investigation of corrosion issues and developing empirical prediction model

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 was to investigate these issues specifically in connection with the purpose of CO_2 injection and storage. Meanwhile the project developed an empirical model for predicting the corrosion level based on sequence of operational parameters.

Budget: DKK 3,500,000
Funded by: Danish Offshore Technology Center
Partners: Danish Offshore Technology Center, IKM Ocean Team & Technical University of Denmark
Contact: Rajan Ambat, ram@mek.dtu.dk
Timeline: 2021 - 2024
TRL: 2 → 5

CO_2 injection in chalk - De-risking CO_2 injection and storage in chalk

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 was to understand the impact of CO_2 injection on the flow and geomechanical behaviour of chalk.

Budget: DKK 2,000,000
Funded by: Danish Offshore Technology Center
Partners: Danish Offshore Technology Center
Contact: Hamid Nick, hamid@dtu.dk & Charlotte N. Larsen, clarsen@dtu.dk
Timeline: 2022 - 2024
TRL: 2 → 4

CO_2 Seal Integrity - Shale as a barrier

The CO_2 Seal Integrity project aimed at securing long-term well barrier seal integrity for CO_2 storage sites in North Sea Oilfields. The project investigated 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.

Budget: DKK 2,400,000
Funded by: Danish Offshore Technology Center
Partners: Danish Offshore Technology Center, Technical University of Denmark
Contact: Irene Rocchi, ireroc@dtu.dk & Charlotte N. Larsen, clarsen@dtu.dk
Timeline: 2022 - 2024
TRL: 3 → 5

CO_2Impure - Effects of impurities on CO_2 storage in chalk reservoirs

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

Budget: DKK 3,400,000
Funded by: Danish Offshore Technology Center
Partners: Danish Offshore Technology Center
Contact: Hamid Nick, hamid@dtu.dk & Charlotte N. Larsen, clarsen@dtu.dk
Timeline: 2023 - 2024
TRL: 2 → 3

CORROPro - Corrosion protection for CO_2 storage facilities using nanofilament coatings

The project tested whether newly developed silica nanofilaments (SNF) could 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 aimed to help de-risk and reduce uncertainties with respect to the reuse of existing infrastructures for CO_2 storage.

Budget: DKK 1,918,000
Funded by: INNO-CCUS - Innovation Fund Denmark, NextGenerationEU & co-funding from project partners
Partners: Aarhus University, BlueNord, Nordsøfonden, Technical University of Denmark & TotalEnergies
Contact: Christian Husum Frederiksen, chfred@dtu.dk
Timeline: 2022 -2024
TRL: 2 → 3

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

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

Budget: DKK 2,500,000
Funded by: Aarhus University, Danish Offshore Technology Center, Unisense
Partners: Aarhus University, Danish Offshore Technology Center & Unisense
Contact: Mikkel Holmen Andersen, mha@unisense.com
Timeline: 2022 - 2024
TRL: 3 → 6

Effect of CO_2 injection - Effect of CO_2 injection on chalk properties - phase II

The project objective was 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 was designed to address uncertainties identified during Phase I with respect to suitability of CO_2 storage in Danish chalk reservoirs and potential showstoppers.

Budget: DKK 5,600,000
Funded by: Danish Offshore Technology Center
Partners: Danish Offshore Technology Center, Geological Survey of Denmark and Greenland (GEUS) & Technical University of Denmark
Contact: Frederik Ditlevsen, fpd@geo.dk
Timeline: 2022 - 2024
TRL: 3 → 4

Methane and CO_2 detection - Sensors for methane and CO2 detection in water column

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 aimed to develop sensors to fill this gap considering the complex interplay between CO_2, CH_4, and O_2 levels to reduce false positives.

Budget: DKK 4,000,000
Funded by: Danish Offshore Technology Center
Partners: Danish Offshore Technology Center
Contact: Jonas Sundberg, jonsun@dtu.dk & Charlotte N. Larsen, clarsen@dtu.dk
Timeline: 2021 - 2024
TRL: 1 → 6

Project Bifrost - Scalable CO_2 storage with potential to propel Denmark towards European CO_2 Hub

The aim of Project Bifrost was 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 leveraged 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 seeked to demonstrate the reusability of existing wells for CO_2 injection and storage, foster alternative CO_2 transportation options, and develop monitoring technologies.

Budget: DKK 157,000,000
Funded by: Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners
Partners: Technical University of Denmark, TotalEnergies EP Denmark A/S & Ørsted Sales & Service A/S
Contact: David Nevicato, david.nevicato@totalenergies.com
Timeline: 2022 - 2024
TRL: 4-5 → 7

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

The SEABAS project focued on understanding the offshore environmental baseline prior to initiating a CO_2 injection project. In another ongoing study (SEEP) a baseline was being created for Natural Hydrocarbon Seepage around offshore installations and the aim of SEABAS was to extent the SEEP study to potential leakage of CO_2. The hypothesis was 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.

Budget: DKK 10,000,000
Funded by: Danish Offshore Technology Center
Partners: Aarhus University, Geological Survey of Denmark and Greenland (GEUS), Technical University of Denmark
Contact: Charlotte N. Larsen, clarsen@dtu.dk
Timeline: 2021 - 2024
TRL: 1 → 5

SHARP Storage - Enhancing CO_2 storage safety and monitoring

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

Budget: DKK 5,500,000
Funded by: Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners
Partners: ASN Alcatel, bp, British Geological Survey, Equinor, Geological Survey of Denmark and Greenland (GEUS), Indian Institute of Technology Bombay, INEOS Oil & Gas Denmark, Norwegian Geotechnical Institute, Norwegian University of Science and Technology, NORSAR, Risktec, Rockfield, Shell, Technical University Delft, University of Oxford & Wintershall Dea
Contact: Marie Keiding, mke@geus.dk
Timeline: 2021 - 2024
TRL: 2-3 → 5

WellCS - A multiphysics informed risk assessment framework for CO_2 leakage through wells

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 was to develop an assessment tool capable of assessing containment risk through wells.

Budget: DKK 1,500,000
Funded by: Danish Offshore Technology Center
Partners: BetterWells & Danish Offshore Technology Center
Contact: Hamid Nick, hamid@dtu.dk, Charlotte N. Larsen, clarsen@dtu.dk
Timeline: 2023 - 2024
TRL: 3 → 5

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

The objective of this project was 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 was to collect CO_2 from Novozymes and utilize it in the ALGIECEL photobioreactor (PBR).

Budget: DKK 1,200,000
Funded by: Innovation Fund Denmark & co-funding from project partners
Partners: ALGIECEL, Knowledge Hub Zealand, Novozymes, P2CC (Power to Climate Change) & Technical University of Denmark
Contact: Henrik Busch-Larsen, hbl@algiecel.com
Timeline: 2021 - 2023
TRL: 1→3

Bio-hydrogen production - Decarbonisation of CO_2 storage platforms by bio-hydrogen production

The main objective of the project was to develop an efficient bio-hydrogen production system for a target field in the Danish North Sea. The project would 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.

Budget: DKK 2,300,000
Funded by: Danish Offshore Technology Center
Partners: Danish Offshore Technology Center, Technical University of Denmark
Contact: Hamid Nick, hamid@dtu.dk
Timeline: 2022 - 2024
TRL: 2→3

BioReFuel - Biogas upgrading for high-purity CO_2 and natural gas distribution

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 was to execute the second phase of the project, which included constructing and testing a biogas-to-methanol demonstration unit.

Budget: DKK 17,000,000
Funded by: Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners
Partners: Elplatek, Lemvig Biogas, Pentair Union Engineering, Technical University of Denmark (Energy Resources Engineering) & Unicat Catalyst Technologies
Contact: Philip Loldrup Fosbøl, plf@kt.dtu.dk
Timeline: 2020 - 2024

BioTechCCU - Biotechnology for converting CO_2 to platform chemicals

This project aimed to build on the biomethanation platform as CO_2 capture and integrate it with the utilisation pathways. This would be done by developing biological technologies to produce platform and value-added chemicals. The project had 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.

Budget: DKK 5,128,000
Funded by: INNO-CCUS - IInnovation Fund Denmark, NextGenerationEU & co-funding from project partners
Partners: Aarhus University, Danish Gas Technology Centre, Nature Energy & University of Southern Denmark
Contact: Muhammad Tahir Ashraf, muta@igt.sdu.dk
Timeline: 2022 - 2024
TRL: 3→4

CooCE - Harnessing potential of biological CO_2 capture for circular economy

The overall aim of the project was 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 aimed to develop and demonstrate a novel biotechnological platform in which CO_2 (from biogas or exhaust gasses) was 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.

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), Energy Technology Development and Demonstration Program (EUDP) & co-funding from project partners.
Partners: BTS Biogas, Euronewpack, Hellenic Agricultural Organisation – Demeter, Imperial College London, Lemvig Biogas, Pond, Qlab Analytical Laboratory, Technical University of Denmark & University of Padua
Contact: Irini Angelidaki, iria@kt.dtu.dk
Timeline: 2021 - 2024
TRL: → 6

Let-them-stick - Increasing Sporomusa ovata cell numbers on cathodes

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 hypothesised that the production rate of microbial electrosynthesis can be improved by increasing the number of cells on the cathode.

Budget: DKK 2,935,000
Funded by: Novo Nordisk Foundation
Partners: Aarhus University
Contact: Jo Philips, jo.philips@bce.au.dk & Klaus Koren, klaus.koren@bio.au.dk
Timeline: 2020 - 2024
TRL: 1 → 3

Marine Renewable Hub - Establishing production facilities for bunkering 100% green fuels from Hirtshals Havn

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 was 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 had the potential to become the crucial link between North Jutland producers of PTX fuels and maritime consumers.

Budget: DKK 76,220,000
Funded by: CO2Vision - REACT-EU (Regional Development Fund)
Partners: Aalborg University, Greenport North, Grøn Brint Hjørring & GrønGas Hjørring
Contact: Hanne Skovby, has@greenportnorth.dk
Timeline: 2022 - 2023
TRL: 3 → 7

METHARC - Wellbore hydrogen production with CCUS

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.

Budget: DKK 750,000
Funded by: Project partners
Partners: FORCE Technology
Contact: Stuart Gillick, info@metharc.com
Timeline: 2023 - 2024
TRL: 2 → 5

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

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 aimed to utilise biogas plants and, at the same time, benefit the environment by creating a simple plug-and-play technology that enabled the simultaneous production of biomethane and bio-succinic acid (BioSA).

Budget: DKK 18,220,000
Funded by: Horizon Europe & co-funding from project partners
Partners: AINIA & BiotechPRO, Aristotle University of Thessaloniki, Ingeniería Verificaciones Electromecánicas y Mantenimientos, Norvento Enerxía & Technical University of Denmark
Contact: Irini Angelidaki, iria@kt.dtu.dk
Timeline: 2020 - 2023
TRL: → 9

RD-BECCUS - Research and development platform for flexible BECCU/S

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 investigated, designed, and planed 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 modeled both a full scale and pilot plant.

Budget: DKK 7,742,000
Funded by: INNO-CCUS - Innovation Fund Denmark, NextGenerationEU & co-funding from project partners
Partners: Alexandra Institute, Ammongas, CO2Techn, Danish Technological Institute, Hafnium Labs, Technical University of Denmark & Verdo
Contact: Lars Schwarzer, lars@teknologisk.dk
Timeline: 2022 - 2024
TRL: 3 → 5

SOCIETAL COUPLING

COLLATE - IKUM CCUS test center

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 was to strengthen the upscaling, maturation, and commercialisation of CCUS on a global scale. Through partnerships and collaborations, IKM aimed to bridge technical knowledge gaps, educate and train needed personnel, conduct risk assessments and much more.

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: 2022 - 2023

CO2 Hub Hanstholm

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 aimed 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.

Budget: DKK 4,940,000
Funded by: REACT-EU (Regional Development Fund)
Partners: Evida, FORCE Technology, Port of Hanstholm, Thisted Cogeneration Plant, Thisted Heat Supply & Thisted Municipality
Contact: Maria Kristiansen, mak@energycluster.dk
Timeline: 2022 - 2023
TRL: 3 → 4

EnCO$_2$ age - A framework for energy and environmental assessment of a european carbon capture, transport, and storage network

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 aimed 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 considered the interplay between the boundaries and specification of the system, current technology, and geotechnical constraints to design a CCS network to minimise cost, energy demand, and environmental footprint

Budget: DKK 1,700,000
Funded by: Danish Offshore Technology Center
Partners: Danish Offshore Technology Center & Technical University of Denmark
Contact: Ali A. Eftekhari, aliak@dtu.dk & Charlotte N. Larsen, clarsen@dtu.dk
Timeline: 2023 - 2024
TRL: 2 → 4

Projects

Project title

Project partners

Partner

Partner

Project tags

Tag

Tag

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