CLIMIT SUMMARY

2017

THE NATIONAL PROGRAMME for research, development and demonstration of CO_2 Capture and Storage (CCS)

CLIMIT

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Photo cover: Helge Hansen/TCM

CLIMIT'S PRIMARY OBJECTIVE is to contribute to the development of technology and solutions for CO_2 capture and storage (CCS) by supporting the development of knowledge, expertise, technology and solutions that can make important contributions to cost reductions and broad international propagation of CCS, as well the exploitation of national advantages and the development of new technology and service concepts with commercial and international potential. The programme is a collaborative partnership between Gassnova and the Research Council of Norway. CLIMIT encompasses the Research Council of Norway's support scheme for research and development (the R&D part) and Gassnova's support for development and demonstration (the Demo part). Gassnova has the overall responsibility and manages the programme secretariat.

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PREFACE

THE WORLD NEEDS LOW-CARBON TECHNOLOGIES

Hans Roar Sørheim
CLIMIT's Programme Chair

Hans Jørgen Vinje
Head of CLIMIT

DURING ITS FIRST TEN YEARS, the primary focus of CLIMIT was on basic research and the development of technology to improve the methods for carbon capture and storage (CCS). This production of knowledge was necessary to realise technology that is essential if we are to achieve the global climate targets.

The programme plan for 2017–2022 marks a new phase for CLIMIT. We are getting close to the realisation of a complete value chain for the full-scale capture, transport and storage of CO_2.

New research will still be conducted and new technology will be developed, but the practical application of the knowledge will be more important in our continuing work.

One year into the new programme period, increasing interest from industry is perhaps the most striking element. The Paris Agreement stresses that the green transition requires the use of CCS, especially because emissions from industry and other sources cannot be managed otherwise. Therefore, more and more enterprises, both in Norway and abroad, are looking at how they can utilise the planned infrastructure in the full-scale project and make use of capture technology. The interest in and the requirements for the various capture methods will be more specific, then. A solution that functions in a platform or in a power plant is not necessarily suitable in the process industry. Various emission sources require different capture technologies and adaptations. The challenges create exciting encounters between industry and research communities.

The world will have an increasing need for clean renewable energy in the coming years. Hydrogen is therefore an interesting alternative to oil and gas. The production of hydrogen from natural gas is the only feasible solution to obtaining adequate volumes of hydrogen for the production of energy or as fuel for vessels. Even though hydrogen in itself is a clean source of energy, production from natural gas results in large volumes of CO_2 as a by-product, and therein lies the challenge.

This means that if Norway and Statoil want to leave the oil boom for a new sustainable hydrogen boom, we must achieve full-scale carbon storage. There is no alternative.

INTERNATIONAL COOPERATION

SOLID INTERNATIONAL COOPERATION

International cooperation is required in order to make the capture, transport and storage of CO_2 an efficient climate measure. CLIMIT greatly contributes to this.

CLIMIT'S PROGRAMME BOARD **1.** Hans Roar Sørheim **2.** Per Reidar Ørke **3.** Hans Jørgen Vinje **4.** Eva Halland **5.** Per Aagaard **6.** Mette Vågenes Eriksen **7.** Eystein Leren **8.** Karen Lyng Anthonsen **9.** Marie Bysveen **10.** Sveinung Hagen **11.** Espen Bernhard Kjærgård.

Photo: Sverre Christian Jarlid

THROUGHOUT THE LAST 12 years, the CLIMIT initiative has given Norway a leading position internationally in the capture, transport and storage of CO_2. CLIMIT is now going in new directions to strengthen international cooperation. One example of this is the Research Council of Norway, which coordinates a European initiative in which ten countries cooperate on sharing knowledge and joint calls. This cooperation is called ACT – Accelerating CCS Technologies. In addition, the Research Council of Norway manages a secretariat for bilateral R&D cooperation with the USA.

All of this has led to increased international R&D cooperation that raises the quality of the research.

The Research Council of Norway also holds leading roles in strategically important international forums (IEA, GHG and CSLF – Carbon Sequestration Leadership Forum). This contributes to a coordinated international focus on CCS. As a result, all of the countries interested in CCS are pulling in the same direction.

The Norwegian plans for full-scale infrastructure for the transport and storage of CO_2 will undoubtedly contribute to strengthening Norway's position in CCS. Industry actors in both Norway and abroad are anticipating the start of the full-scale Norwegian project, which will eventually allow the storage of CO_2 from their own emission sources.

NORWEGIAN BENEFITS

For the Government, it is of course important that the full-scale project will benefit Norway. In addition, this may establish the foundation for increased international cooperation. CLIMIT can contribute by supporting further development of technology based on learning from the project. New research projects will benefit greatly from experience from the full-scale project, which will accelerate the development of technology. For Norway as a nation, it is also reasonable to expect that locations with a CO_2 infrastructure will be more attractive for the establishment of new industry. Some of CLIMIT's projects linked to the demonstration project will be related to an evaluation of the technical solutions and the additional costs associated with connecting a plant to the potential infrastructure in the full-scale project.

INCREASING INTEREST FROM INDUSTRY

In 2017, CLIMIT R&D experienced rising interest and more applications from industry than in many years. The Norwegian process industry's increasing interest in CCS will probably result in even more applications for CLIMIT Demo in 2018. In addition, there is interest from abroad in the opportunities that future full-scale Norwegian infrastructure will provide. SINTEF Energy and Chalmers University will be looking at the opportunities to test CO_2 capture technology at Preem's refineries in Lysekil and Gothenburg. Another example is CDI Global and its project partners SINTEF Tel-Tek, Elkem and Polchar, which will be evaluating the opportunities to move parts of Polchar's production of char (coke) to Norway with CO_2 capture and a connection to the future CCS infrastructure.

CO_2 TRANSPORT

The development of the full-scale Norwegian project has resulted in the oil companies becoming more active partners in projects that are supported by CLIMIT. The projects in this area can possibly contribute to reducing the risk and costs of the full-scale Norwegian project and other earlier CCS projects.

Statoil will conduct experiments with CO_2 transport in pipelines, among other things. Experimental data from the project will be used to validate software for the simulation of CO_2 flow ("flow assurance"). Another project, led by IFE with Shell and Statoil as partners, is studying corrosion in CO_2 injection wells to identify how various impurities in the CO_2 flow affect the corrosion rates for various pipe materials.

A cooperation project between DNVGL and the Australian research institution Energy Pipelines CRC is examining how pipelines should be dimensioned to avoid running fractures. The project conducted a test of running fractures in a pipeline in September 2017.

CO_2 STORAGE

The full-scale Norwegian project has increased the industry's interest in participating in the development of CO_2 storage. Several new projects, motivated by the needs associated with the development of the Smeaheia storage site, have been under development in 2017 and will be submitted for resolution in 2018. Companies such as Norsar, Octio Geophysical and the Norwegian Geotechnical Institute are developing technologies for monitoring CO_2 storage sites. In addition, the oil companies are increasingly participating in competence-building projects and basic research led by research institutions and universities.

THE USA IS WITH US

Even though there is a great deal of interest in CCS in Europe, it is somewhat uncertain whether there is a political will to continue to focus on CCS. Norway has long enjoyed good bilateral research cooperation with the USA, and fortunately this cooperation has remained good throughout 2017. There are no indications that the USA will withdraw from international cooperation projects – not from Norway, nor from other countries. As a pleasant expression of this, the USA hosted a special workshop on CCS, together with Saudi Arabia, during the major international initiative Mission Innovation. This resulted in international consensus on future research priorities and investment in CCS. Norwegian research communities put a clear mark on the workshop that was arranged in Houston, Texas in September. The participating countries in Mission Innovation, 22 countries plus the EU, have ambitions to double their research efforts in clean energy.

INTERNATIONAL COOPERATION

ACT IS WELL UNDER WAY

ACT – Accelerating CCS Technologies – is a joint European programme for CCS research, which is financed by the European Commission and nine participating European countries. The first cooperative projects have already started.

ACT SUPPORTS BOTH industrial projects and researcher-driven projects. The researcher-driven projects are also designed to meet the needs defined by industry.

It is important that research communities and industrial enterprises cooperate on solving challenges related to a reduction in the emission of CO_2.

"We have granted support to eight transnational projects so far. Overall, this involves approximately EUR 36 million, or close to NOK 350 million. All the projects are well under way," says Ragnhild Rønneberg, special advisor to the Research Council of Norway and coordinator for ACT.

Rønneberg is optimistic about the results from the projects and expects that synergies can be created between the projects that have been initiated, so that the implementation of CCS can take place more rapidly.

"We invited all the coordinators for the respective projects to a joint workshop a couple of months ago, and it turned out that several of them saw opportunities for further cooperation and synergies that would benefit the CCS field.

This is a very fine and open approach, a sharing of ideas and knowledge that bodes well for the future. No country alone can solve the problem of CO_2 emissions. To succeed in the reduction of CO_2 emissions from power and industrial plants and establish secure storage of CO_2 requires cooperation across both professional and national boundaries.

Several researchers have openly stated that they would not have got started with transnational cooperation without ACT. The programme has motivated them to find partners in other countries, and it has opened up the possibility of new approaches to CCS based on the priorities and strengths of the respective countries with regard to R&D communities and industry.

"Norway, Germany, the Netherlands and the United Kingdom are the prominent countries in ACT. Switzerland, Romania, Spain, Greece and Turkey also participate. The Norwegian contribution is from the CLIMIT programme, and it encompasses both researcher-driven projects and the more industrially oriented projects.

Norway participates in seven out of eight projects, and this is very good for the Norwegian research communities, as well as for the Norwegian industry actors," says Rønneberg.

The European Commission, which supports ACT with approximately EUR 11 million, is also very enthusiastic about ACT and attaches a great deal of importance to the significance of this international cooperation to Europe's focus on CCS.

"There are great expectations that CCS will also be established in Europe. In the USA, this technology has been operational and of commercial interest for several years, especially in connection with enhanced oil recovery. With the ACT projects that have been established now, the hope is to throw light on the environmental aspects and the technological opportunities in various industries, as well as on the commercial and legal aspects that are required for successful CCS on a broad scale in Europe.

"ACT is seeking partners from additional countries. The USA, Canada, Australia and France have shown interest, but they have not commited their participation yet. However, they are more than welcome to join us when we publish our next call in June 2018," says Rønneberg.

"In Norway, we are most focused on capture, transport and storage. Other countries, such as France, the UK and Germany, over time have focused more on the utilisation of CO_2 instead of pure storage. We will possibly see a certain shift in the ACT portfolio in this direction in the future.

Rønneberg expects regardless that the projects that ACT supports will have a good, rapid effect on the implementation of CCS/CCUS technology.

"We will not meet the Paris targets for the reduction of greenhouse gas emissions without full-scale implementation of CCS technology," she says.

HYDROGEN PRODUCTION WITH CCS

THE PRODUCTION of hydrogen from natural gas may be a promising direction for meeting the demand for emission-free energy for heating, cooling, transport and industrial processes. However, it is dependent on a solution for the storage of CO_2.

ELEGANCY is a project in ACT, with a number of European partners from research and the business sector. Statoil, Aker Solutions, the University of Oslo and SINTEF are participating from Norway, and SINTEF is the coordinator for the project.

"The project will illustrate through case studies how we can combine the production of hydrogen with the storage of CO_2, and how we can store CO_2 from industrial sources in the most cost-effective manner," says Svend T. Munkejord of SINTEF.

"Getting large-scale capture and storage of CO_2 in Europe started has been a slow process. There is a great deal of interest in the industry, but the enterprises will not start until there are good storage solutions. Our goal is to find out how we can best store CO_2 on land and offshore, and meet an increasing demand for clean energy at the same time.

ELEGANCY is expected to produce knowledge, products and technologies that can be exported to the entire world. The partners in the project are all world leaders in their respective fields, and they include not only recognised research institutions and legal experts, but also technology providers and international energy and petrochemical companies as well.

FACTS

Project
ELEGANCY – Enabling a low-carbon economy via hydrogen

Project owner
SINTEF Energi AS

Project period
August 2017 – August 2020

Total budget
NOK 150 million

Support from CLIMIT
NOK 20.6 million

MONITORING OF CO_2 STORAGE SITES

THE GREATEST challenges for accelerating the deployment of CCS is storage capacity, cost and public confidence. The Pre-ACT project meets these challenges through improved strategies for the monitoring and control of pore pressure.

One of the most important challenges to accelerate CCS is access to reliable and cost-effective storage sites.

Pre-ACT will develop a cost-effective system for reservoir monitoring that helps the operator make the right decisions, so that secure and efficient use of the CO_2 storage capacity can be achieved.

Pre-ACT has secured access to a broad and relevant set of monitoring data from important demonstrations sites worldwide. This data will be used to calibrate, verify and demonstrate solutions for CO_2 storage.

The industry partners in Pre-ACT – Statoil, Total, Shell and TAQA – will help ensure the relevance and usability of the tools and methods that are developed in the project, and they will contribute their operational experience and perspectives.

Partners from five countries are participating in the project: Norway, Germany, the Netherlands, the United Kingdom and France. In addition, Pre-ACT will establish cooperation with the USA and Australia. SINTEF (the coordinator), NORSAR, Statoil and Total, all from Norway, are participating in the project.

FACTS

Project
Pre-ACT

Project owner
SINTEF Industri

Project period
September 2017 – August 2020

Total budget
NOK 50 million

Support from CLIMIT
NOK 23.9 million

CAPTURE

CREATING GOLD IN A GREEN PROCESS INDUSTRY

The vision of the process industry is to increase production, become climate neutral and maintain a leading position in the international market. The roadmap for the process industries outlines several methods for achieving this goal. The Char C project aims to help the process industry achieve its climate targets.

The process industry is completely dependent on carbon capture to become climate neutral. Capture methods adapted to various sources have been tested at SINTEF's laboratory at Tiller outside of Trondheim.

Photo: Thor Nielsen

Helene Mørne
Manager
CDI Global

PROJECT

Prosjekt
Project Char-C – Capture of CO_2 from the production of char with coal as the raw material

Project owner
CDI Global

Project period
2017

Total budget
NOK 3.6 million

Support from CLIMIT Demo
NOK 2.5 million

Partners
Elkem, PolChar, SINTEF, Air Products

– IT IS DIFFICULT to do anything about SOME OF THE EMISSIONS in the process industry. In the silicon industry, coal and coke are an essential part of the chemical process to make silicon products," says Helene Mørne, the CEO of CDI Global AS. She is managing a project that will be studying the opportunities for reducing the emissions from this industry.

GREEN PROCESS INDUSTRY

Silicon is an element that is available in almost unlimited quantities, but has to be processed so that it can be used in everything from electronics and solar cells to lipstick and implants. A carbonaceous reduction material is required for the process to extract silicon from quartz; the reduction material can be coke or coal, where coke, or char, gives the lowest emissions of CO_2, NOx and particles.

"Our idea, then, is to produce coke combined with carbon capture and storage. This is how industry can reduce its carbon footprint. In Norway alone, the process industry emits millions of tonnes of CO_2 annually. We think that it will be possible to reduce the emissions by half in parts of this industry, and to make the Norwegian process industry the world's greenest," says Mørne.

GREEN TRANSITION

The process industry is essentially a polluting industry with low margins and strong international competition. Mørne believes, however, that higher carbon taxes will make this industry greener over time. Enterprises that are prepared for the green transition and are able to produce in a more climate-friendly way will then have a competitive advantage.

"It is likely that this industry and others will encounter higher carbon taxes and increasing demands from consumers to produce in a more environmentally friendly way," says Mørne.

"In the long term, the industry will not be able to continue its activities without reducing CO_2 emissions. Therefore, the Norwegian process industry is engaging in extensive research to reduce emissions. There are several ways in which this can be accomplished, and we will contribute through delivering a CO_2-reduced reduction material," says Mørne.

WILL CREATE JOBS

The project is currently in a very early phase, but the goal for CDI Global is to build a Norwegian factory for the production of coke combined with the capture and storage of CO_2. The project is dependent on the full-scale project and the necessary infrastructure for transport and storage becoming a reality. Partners in the project include the Polish company Polchar (which delivers half of the coke the Norwegian silicon industry currently uses), SINTEF, Elkem and the American-owned company Air Products.

"Carbon capture is essential in order to achieve the climate targets in the Paris Agreement.

Norway currently has a leading position in carbon capture and has a unique opportunity now to position itself in capture technology and a green manufacturing industry," says Helene Mørne.

She finds that many envision that Norway will be big in the storage of CO_2 from the Continent, but we can also focus on moving the industry here.

"Imagine if we can move polluting industry to Western Norway, clean it up, capture the CO_2 and store it under the ocean floor in the North Sea. I think it must be possible to inspire industry to establish itself near the storage sites instead of transporting CO_2 in large volumes across thousands of kilometres," says Mørne.

"I am convinced that we can become a real pioneering country in the area of environmentally friendly industrial technology, and that an investment in connection with the full-scale project can secure many jobs in Norway.

STORAGE

COST-EFFECTIVE MONITORING OF CO_2 STORAGE SITES

When CO_2 is injected below the ocean floor, very small movements in the bedrock may arise. OCTIO in Bergen is attempting to find the most cost-effective method for the long-term monitoring of microseismic activity around the future CO_2 storage sites.

THE NORWEGIAN CONTINENTAL SHELF generally has very stable geology, but even in the most stable geological areas, very small movements may arise from time to time. Such microseismic movements often have natural causes, but they can also be triggered by human activity. OCTIO has lengthy experience with the microseismic measurement of acoustical sensors in connection with oil and gas activities. They bring with them this knowledge when they develop a solution for monitoring in connection with CO_2 injection.

"Like drilling for oil, the injection of CO_2 is a type of human activity that may trigger small movements in geological formations in and around the storage sites. Therefore, the storage sites should be monitored continuously during and after the injection of CO_2," says Tatiana Thiem, OCTIO's project manager.

CONTINUOUS MONITORING

There are several measurement methods, depending on whether the measurements are to be sporadic or permanent.

"At the planned CO_2 storage site at Smeaheia, it may be desirable to have continuous monitoring. With sensors on the ocean floor above the storage site and access to real time data, it will be possible to analyse developments continuously both during the injection of CO_2 and in subsequent periods," says Thiem.

The question is where the sensors should be placed and how many will be required for reliable measurement. The number of sensors is the one factor that has the greatest consequences for the costs associated with a monitoring solution. The goal of the project is to determine the most cost-effective monitoring solution, the solution that has the right balance between the required and the adequate number of sensors.

DEVELOPMENT OF A MODEL

To find the optimal solution, OCTIO has developed a geophysical model of expected microseismic activity in connection with CO_2 injection at Smeaheia. Based on this model, they are now working to find out how the sensors should be positioned in order to capture the signals in the best possible way.

As part of the monitoring solution, OCTIO is also developing software with a user-friendly interface. This will make it possible for operators without any special technical knowledge to monitor the microseismic activity. Measurements that are surprising or unexpected will immediately become visible on the monitor during injection.

FACTS

Project
CO_2 monitoring – Cost-effective monitoring and processing solutions for seabed caprock systems and microseismic surveillance

Project owner
OCTIO

Project period
2016–2018

Total budget
NOK 5.5 million

Support from CLIMIT Demo
NOK 2.7 million

OCTIO is attempting to find the most cost-effective method for monitoring the CO_2 storage sites.

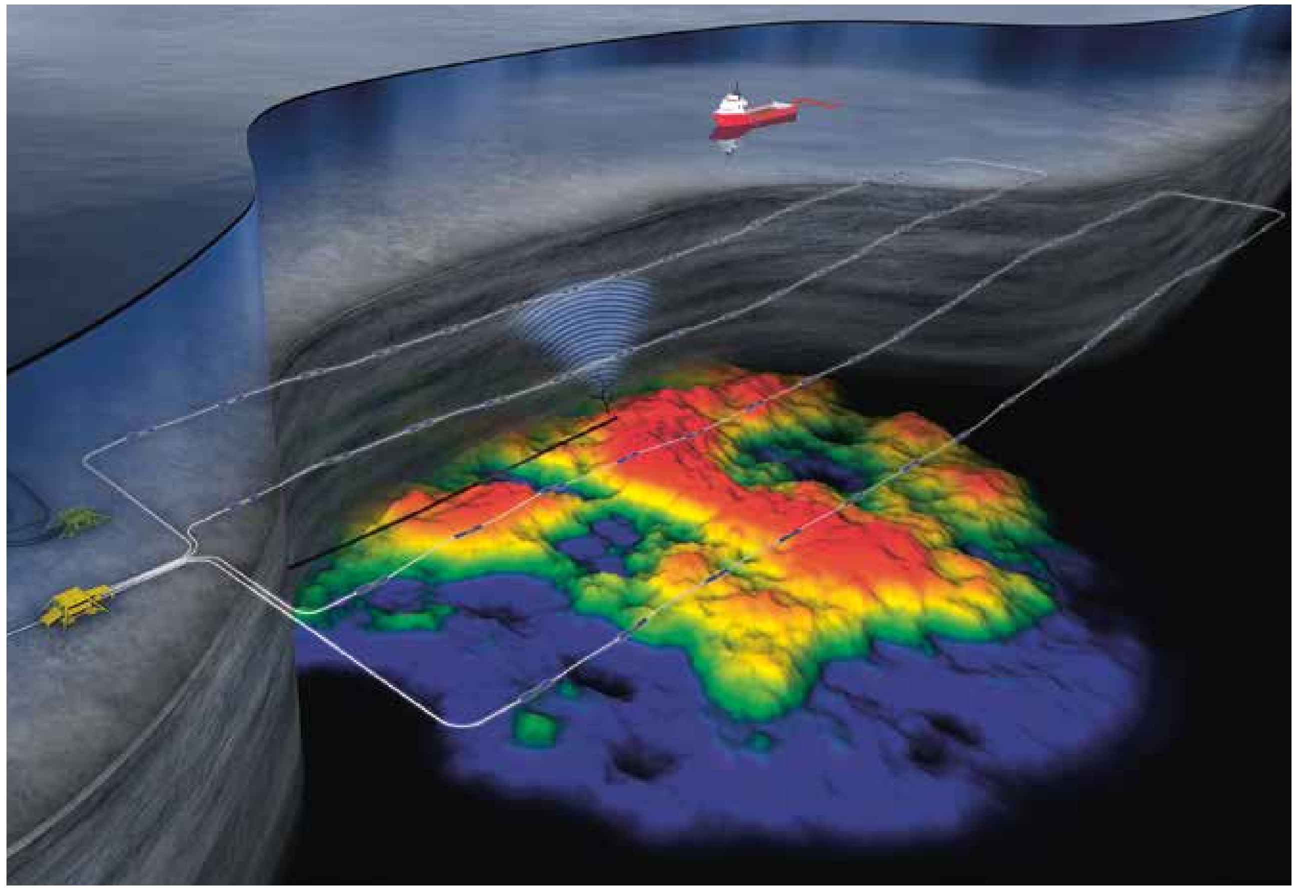


Illustration: OCTIO

Tatiana Thiem
Project manager at OCTIO

THE GOAL OF THE PROJECT IS TO DETERMINE THE MOST COST-EFFECTIVE MONITORING SOLUTION.

CAPTURE

Oil refineries are constrained by both limited space and emissions from many different sources. This represents a challenge for cost-effective CO_2 capture.

Photo: Shutterstock

MORE REASONABLE CO_2 CAPTURE FROM REFINERIES IS POSSIBLE

Worldwide, oil refineries are responsible for approximately four per cent of the fabricated CO_2 emissions. The emissions can be reduced by carbon capture, but the costs and limited space are a challenge.

Kristin Jordal
Research leader at SINTEF and the project manager for ReCap

FACTS

Project
Understanding the Cost of Retrofitting CO_2 Capture in an Integrated Oil Refinery (ReCap)

Project owner
SINTEF Energi

Project period
2014–2017

Total budget
NOK 10.0 million

Support from CLIMIT Demo
NOK 5.7 million

Partners
CONCAWE, IEAGHG

– **IN ALL PROBABILITY** there will probably not be many new oil refineries constructed in the world in the coming years. Therefore, it is important to find good carbon capture solutions that can be adapted to the existing refineries," says Kristin Jordal, a research leader at SINTEF and the project manager for ReCap. The project's main objective was to evaluate post-combustion carbon capture with amines at existing refineries, in order to determine what the costs would be.

LACK OF SPACE

"There are a number of challenges associated with just finding space for a capture plant at an existing refinery. Amine plants typically take up a lot of space, and space may be in short supply at an oil refinery," says Jordal.

"In addition, refineries are characterised by not having just one, but many emission sources that release varying amounts of CO_2 in different concentrations. The points of emission are dispersed throughout the refinery. In practice, this means that a high degree of carbon capture will require multiple capture plants.

ENERGY INTENSIVE

Moreover, carbon capture is energy intensive, and the costs rise if you cannot use the surplus heat, but must produce steam from a separate heat source.

"In our models, we have assumed the use of a natural gas-fired heating plant, without any CO_2 capture. Even if the capture degree is 90 per cent from the actual refinery, the emissions from the power plant will reduce the effective capture degree to 60 per cent," says Jordal.

"The production of energy is also the greatest single cost.

In addition, there will be some CO_2 sources that have a high sulphur content, and this will result in additional costs in the form of desulphurisation.

POSSIBLE, BUT CHALLENGING

The ReCap project shows that it is technically feasible to implement CO_2 capture in modern oil refineries, but the space requirements, complexity of the plant and the energy requirements can drive up the costs and reduce the level of efficiency.

"We think that one should avoid using a separate power and heating plant for the production of steam and power. This increases the costs considerably and reduces the CO_2 capture degree. Refineries often have spare capacity for power and heat production, and one recommendation is to continue to study this spare capacity, and with more modern and energy-efficient amines and amine-based processes reduce the CO_2 capture costs," says Jordal.

Four different generic oil refineries of varying complexity were defined in the project, and a total of 16 different cases with a 90 per cent CO_2 capture degree from 1–5 exhaust flows were examined. The cost of avoiding CO_2 emissions from refineries were estimated to be USD 161–210/tonne of CO_2.

"These costs are far too high to make CO_2 capture in refineries attractive today, but we think there are good opportunities for cutting costs through the use of new and more energy-efficient amines and amine-based processes and the use of waste heat," says Jordal.

THE RECAP PROJECT SHOWS THAT CARBON CAPTURE IS TECHNICALLY FEASIBLE IN MODERN OIL REFINERIES.

CAPTURE

DEVELOPING SPECIAL MATERIALS THAT CAN CAPTURE CO_2

The most common technology used to capture CO_2 from flue gas is the use of amines. However, this is an energy intensive process. SINTEF develops materials that can capture CO_2 by adsorption.

A 3D-printed mould in stainless steel to create MOF monoliths. The material inside is UTSA-16 (cobalt-based MOF).

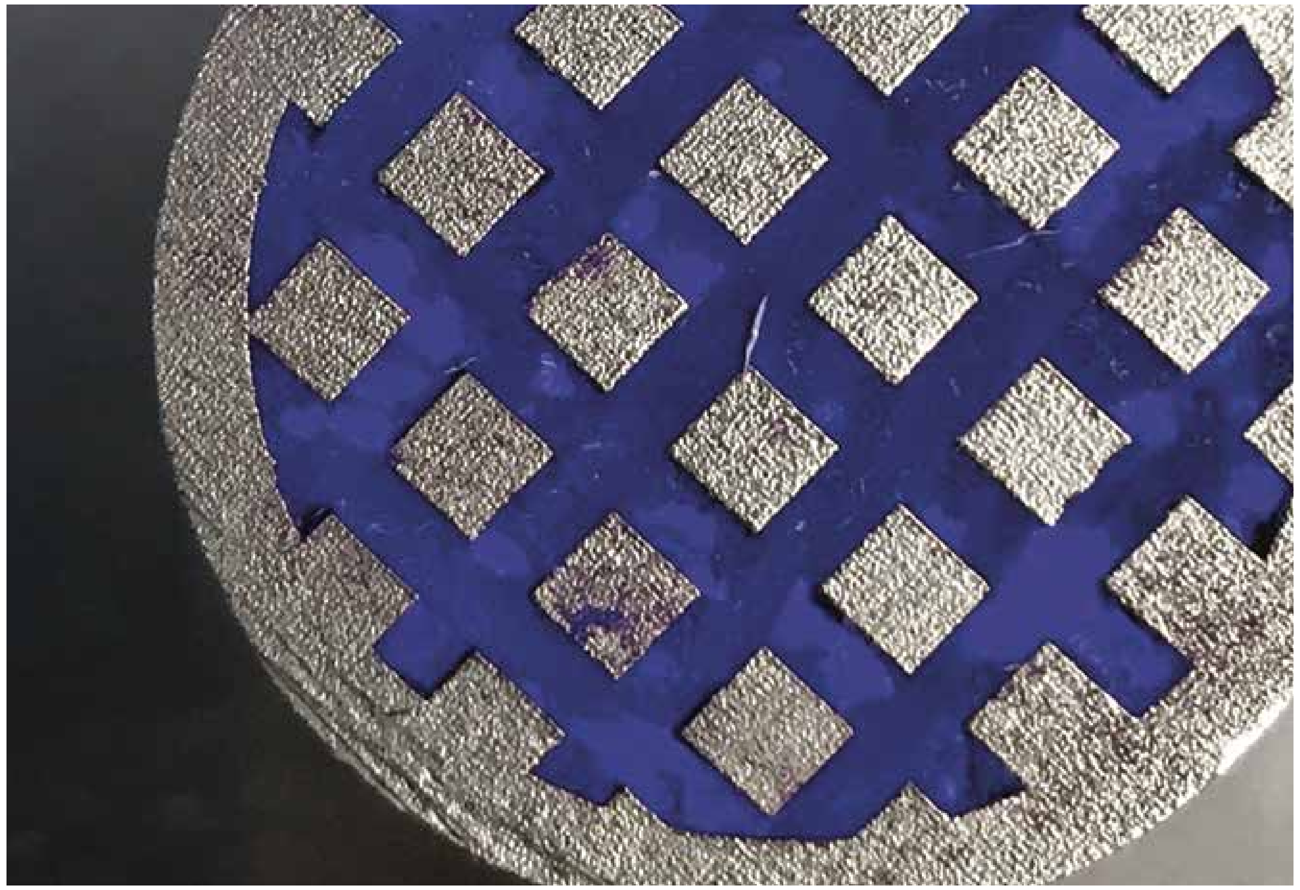


Foto: SINTEF

Carlos Grande
Project leader and senior researcher at SINTEF

FACTS

Project
Shaping of advanced materials for CO_2 capture processes

Project owner
SINTEF

Project period
2014–2018

Total budget
NOK 9.0 million

Support from CLIMIT R&D
NOK 7.2 million

Partners
SINTEF Industri & SINTEF Energi, Statoil, Gassco, GDF Suez E&P Norge, Total E&P Norge, Shell Techn. Norge and Conoco Phillips Skandinavia through the BIGCCS centre.

EVERYONE KNOWS WHAT absorption is, but perhaps not adsorption. This is a process where gas binds to the surface of a solid. This is a process that takes place in nature all the time, which is also used for industrial purposes and in catalytic converters in cars. A distinction is made between pressure swing adsorption (PSA) and temperature swing adsorption (TSA), depending on whether pressure differences or temperature differences bind and release the gasses. Researchers at SINTEF are developing methods to use this technique to capture CO_2 in a cost-effective manner.

"The adsorbents that are being developed contain special hybrid materials (MOF) that are formed into monolithic structures, or "columns" with very small corridors that the gas can flow through," says Carlos Grande, project manager and senior researcher at SINTEF. The monoliths are produced by means of 3D printers.

"The goal is to create as large a surface area as possible to bind the CO_2.

For now, the monoliths are just small models of what Grande envisions for the future.

"At present the materials are very costly to produce, and they cannot be produced in the volumes or dimensions that will be necessary for practical use," says Grande.

So far, the researchers have produced and tested 200 grams of an MOF material that called UTSA-16.

"This is the best MOF we know about at present, and we are looking into how it can be used for the simultaneous production of H_2 and CO_2 from natural gas," says Grande.

He stresses that his research has a 10-year perspective for commercialisation.

"We are far from a finished product, but the method is very promising for future hydrogen scrubbing and CO_2 capture.

WE ARE NOW LOOKING AT HOW THE METHOD CAN BE USED FOR THE SIMULTANEOUS PRODUCTION OF H_2 AND CO_2 FROM NATURAL GAS.

CAPTURE

TESTING WHETHER CAPROCK CAN WITHSTAND THE PRESSURE

CO_2 storage sites under the ocean floor in the North Sea consist of porous rock types with a harder and denser caprock type above it. THE PROTECT project is studying the ability of the caprock type to withstand pressurised CO_2.

The CO_2 storage sites under the ocean floor consist of porous rock types beneath a cap of denser and harder rock.

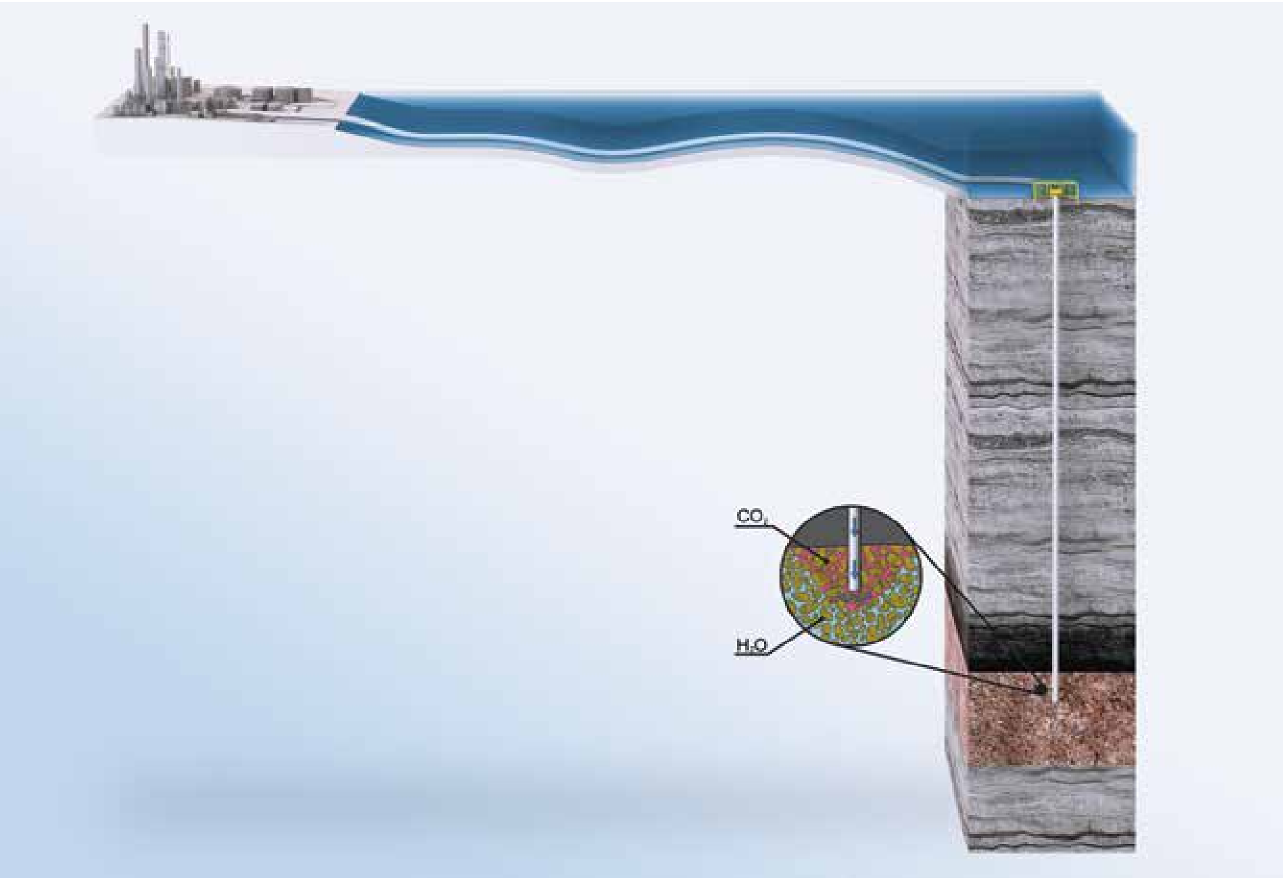


Illustration: Gassnova

Sarah Gasda
Project manager at Uni Research CIPR

– THIS IS A typical interdisciplinary research project in which we attempt to find out what happens during the injection of large volumes of CO_2 into a storage site," says Sarah Gasda, project manager at Uni Research CIPR in Bergen.

"We have been joined by mathematicians, geochemists, geologists and other experts, and have conducted laboratory studies, modelling and simulations. Even if we have previous experience from CO_2 storage in the North Sea, from Sleipner, for example, what we are talking about now is of a completely different magnitude," says Gasda.

GREAT POTENTIAL

The storage potential in the North Sea is enormous. Probably several tens of billions of tonnes of CO_2 – enough to meet the needs of all of Europe for many, many years to come.

"The challenge is the fact that the continuous injection of large volumes of CO_2 will change the pressure in the reservoir, and then we must know how the pressure will be distributed and what will happen with the cap rock," says Gasda.

There is no other way of finding this out than by conducting research, collecting as much data as possible on all conceivable parameters, and then building simulation models based on that data. This is precisely what PROTECT is about. The project has received core samples of caprock from Statoil and studies the rock's ability to withstand various types of stress. Analyses of what happens on a small-scale basis – from a metre down to centimetres – are scaled up to create a model of what can occur in an entire reservoir.

SECURE STORAGE

"All types of rock are subject to natural movements, cracks and faults that may be affected by pressure. Chemical and thermal processes can also affect the caprock. The purpose of the project is to understand how pressure changes can affect the storage complex. This knowledge is important for good reservoir management and secure storage," says Gasda.

Sarah Gasda stresses that any leaks from the CO_2 storage sites will not be harmful to humans or nature.

"CO_2 is neither toxic nor explosive, and there are already substantial natural 'leaks' of CO_2 from the ocean floor.

Secure CO_2 storage is primarily about efficiency and economics.

If we are paid to store a million tonnes of CO_2 and 10 per cent leaks out again, it is not good for business," she says.

FULL SCALE NEEDED

PROTECT has already conducted full-scale simulations of what will happen during 25 years of injection into the Utsira formation. The results show that the formation has a substantial capacity for the secure storage of CO_2. However, models are just models.

"That is why the full-scale project at Smeaheia is so important. We can not go all the way through simulations and models. In the final analysis, we need data from real projects order to determine with certainty how this will work in practice," says Gasda.

THE STORAGE POTENTIAL IN THE NORTH SEA IS ENORMOUS. PROBABLY SEVERAL TENS OF BILLIONS OF TONNES OF CO_2 – ENOUGH TO MEET THE NEEDS OF ALL OF EUROPE FOR MANY, MANY YEARS TO COME.

FACTS

Project
Protection of Caprock Integrity for Large-Scale CO_2 Storage

Project owner
Uni Research CIPR, Bergen

Project period
2014–2018

Total budget
NOK 16.3 million

Support from CLIMIT R&D
NOK 13.0 million

Partners
UiB, NGI, UiO, IFE

CAPTURE

The Fjell Technology Group has created a carbon capture plant that is significantly more compact than a traditional plant.

Illustration: Fjell Technology Group

CUTTING COSTS WITH COMPACT CAPTURE PLANTS

If carbon capture is to be implemented on a large scale, the solutions must be financially sustainable. A group of actors led by the Fjell Technology Group in Bergen has enhanced the efficiency of a well-proven method.

Asbjørn Strand
CTO of Fjell

Dag A. Eimer
SINTEF Tel-Tek consultant and professor at the University College of Southeast Norway

FACTS

Project
Integrated 3C Pilot

Project owner
Fjell Technology Group

Project period
June 2017 – December 2018

Total budget
NOK 36.5 million

Support from CLIMIT Demo
NOK 23.2 million

Partners
Statoil ASA, SINTEF Industri and CMR Prototech

– THE CAPTURE OF CO_2 with solvents has been carried out for many years, but the method is based on technology developed in the 1930s," says SINTEF Tel-Tek consultant and professor at the University College of Southeast Norway, Dag A. Eimer. Fjell, SINTEF Tel-Tek and CMR Prototech have worked together with Statoil over the last 10 years to develop a more efficient capture plant that requires less space.

HIGH PIPES TAKE UP SPACE

"The use of solvents is about giving the chemicals enough time and contact with the flue gas to bind the CO_2," Fjell CTO Asbjørn Strand explains.

Traditional capture is carried out by releasing the waste gases through a high pipe. On their way up, the flue gas encounters CO_2 binding chemicals – so-called solvents – which are sprayed down from the top and sides and absorb CO_2. Then the solvent is transferred to a desorber, where CO_2 released from the solvent.

"The absorption method can require a pipe that is several tens of metres high. This means that you will have a capture plant that requires a great deal of space, which both limits the areas of application and results in substantial investment costs," says Strand.

While many projects in CLIMIT have contributed to the development of more efficient and less costly solvents, the Fjell Technology Group has looked at the opportunities to improve the actual capture plant.

ROTATING GASKETS

"Simply explained, we have developed a compact plant that increases the surface area of the amine by means of rotating technology. This reduces the time that the flue gas must be in the capture unit, which also reduces the size of the plant," Strand explains. The method also makes it possible to use concentrated and viscous solvents that absorb CO_2 more efficiently. It is of no consequence what types of solvent are used. The technology is solvent neutral.

The Fjell Technology Group's cooperation with Statoil, SINTEF Tel-Tek and CMR Prototech began already in 2007. That is when the group, under the management of Statoil, developed a compact "stripper" or desorber that separates the CO_2 from solvents after carbon capture. This is the same group that is responsible for the new pilot for the absorber component of the capture plant, which is being tested now under the direction of SINTEF Tel-Tek at the University College of Southeast Norway in Porsgrunn.

"Work on the development of the absorber stopped in 2012, but upon agreement with Statoil, we took over the rights and resumed the work in 2015. We then had an idea about how we could solve the absorption process. We applied for and received support from CLIMIT, which has been decisive in getting us to where we are today," says Strand. Statoil has also contributed financing.

"The technology is still immature, but the goal is to be ready with a compact plant that has a broad area of application, both in industry and on the oil platforms by the end of 2020.

In addition to being space-saving, the concept will also be less costly than traditional capture plants.

"The investment costs will be significantly lower, and it also looks like the operating costs will be somewhat lower," says Strand.

STORAGE IS DECISIVE

If the carbon capture plant is to be interesting commercially, however, it is crucial that an infrastructure for transport and storage be put in place. Madsen anxiously awaits the start of the full-scale project for carbon capture, but he trusts that it will take place according to plan.

"Almost all scenarios for how we can reach the two-degree target from the Paris Agreement require the capture of CO_2 from power plants and industry. We do not have any alternative to parallel use of carbon capture," says Strand. "The earlier we get started, the better."

TRANSPORT

IMPURITIES CHALLENGING FOR CO_2 TRANSPORT

It is difficult to capture CO_2 from flue gas, for example, without capturing other gases or water at the same time. Even small amounts of the other gases can create major problems when CO_2 is to be transported to the storage site.

Three different steel samples are exposed to supercritical CO_2 with impurities.

Photo: IFE

Gaute Svenningsen
Institute for Energy Technology (IFE)

FACTS

Project
Corrosion and cross chemical reactions in pipelines that transport CO_2 with impurities

Project owner
Institute for Energy Technology (IFE)

Project period
2015–2018

Total budget
NOK 13.5 million

Support from CLIMIT R&D
NOK 10.0 million

Partners
UiO, OLI Systems, OCAS NV, Gassco, Shell, Total

“IF THE CO_2 GAS comes from a gas-fired power plant, coal-fired power plant or industry, it is almost never 100 per cent pure CO_2,” says Gaute Svenningsen of the Institute for Energy Technology at Kjeller outside of Oslo. “Depending on how well the CO_2 gas is purified, it will contain a greater or lesser degree of impurities in the form of particles, water, sulphur or nitrogen compounds.”

CO_2 IN VARIOUS MIXTURES

In the project that Svenningsen is managing, the goal is to determine what degree of impurities can be accepted. Many of the impurities can react and form products that can destroy the steel pipes that are to transport the CO_2.

“If we envision an infrastructure for CO_2 transport with many different sources, the CO_2 may contain various impurities that both separately and in mixture can result in destructive reactions,” says Svenningsen.

“CO_2 captured from a coal-fired power plant may, for example, contain small amounts of sulphuric gas. If this is exposed to water and oxygen, sulphuric acid can form and corrode the steel in a pipeline. CO_2 from other sources may contain other impurities that can result in other reaction products, including solid particles. Particles in the gas or detached particles from corrosion processes can also create problems, especially at the final station where the CO_2 is injected into the underground storage site.

LABORATORY EXPERIMENTS

All the experiments are conducted at a laboratory at Kjeller, where different types of impurities from separate sources are added to the CO_2 in very exact doses and at specific time intervals. Then the effect on steel corresponding to what is used in pipelines is measured over time.

“Corrosion and cross chemical reactions are studied in autoclave and flow labs in which all of the variables are under precise control,” Svenningsen explains. Spectrometers, laser light and infrared light are used to measure the content of impurities and reaction products. If impurities disappear from a gas mixture, it is an indication that a chemical reaction is taking place, which is generally not desirable.

SMALL VOLUMES, LARGE CONSEQUENCES

“What we have seen is what would normally be regarded as very small amounts of impurities, but which can have large consequences over time. CO_2 with sulphuric acid can eat through 40 mm steel pipe in just one year,” says Svenningsen.

“When there are plans to transport many millions of tonnes of CO_2 over many kilometres for many years to come, it is important that costly pipelines do not rust away in a short period of time. With knowledge of how much, and which, impurities the infrastructure can withstand over time, it is possible to stipulate precise requirements for the purification of CO_2 from different sources before transport and storage.

The project will establish a basis for recommended maximum concentrations for various types of impurities in CO_2 mixtures that are transported in pipelines. This knowledge will be of decisive importance to anyone who is responsible for the operation of pipelines and other plants that handle impure CO_2.

KEY FIGURES 2017

There was a great deal of interest in applying for funding from CLIMIT in 2017, and at the end of the year a total of 64 new projects had received NOK 221 million in support. A growing number of research projects are continuing as demonstration projects.

DEMONSTRATION PROJECTS

CLIMIT-Demo had 103 active projects with a total allocated support of NOK 564 million in 2017.

Seventeen new projects were awarded support. In addition, support was awarded to conceptual studies, smaller studies and information initiatives. Overall, conditional allocations totalled approximately NOK 82 million in 2017. A total of 39 projects were concluded in 2017.

RESEARCH PROJECTS

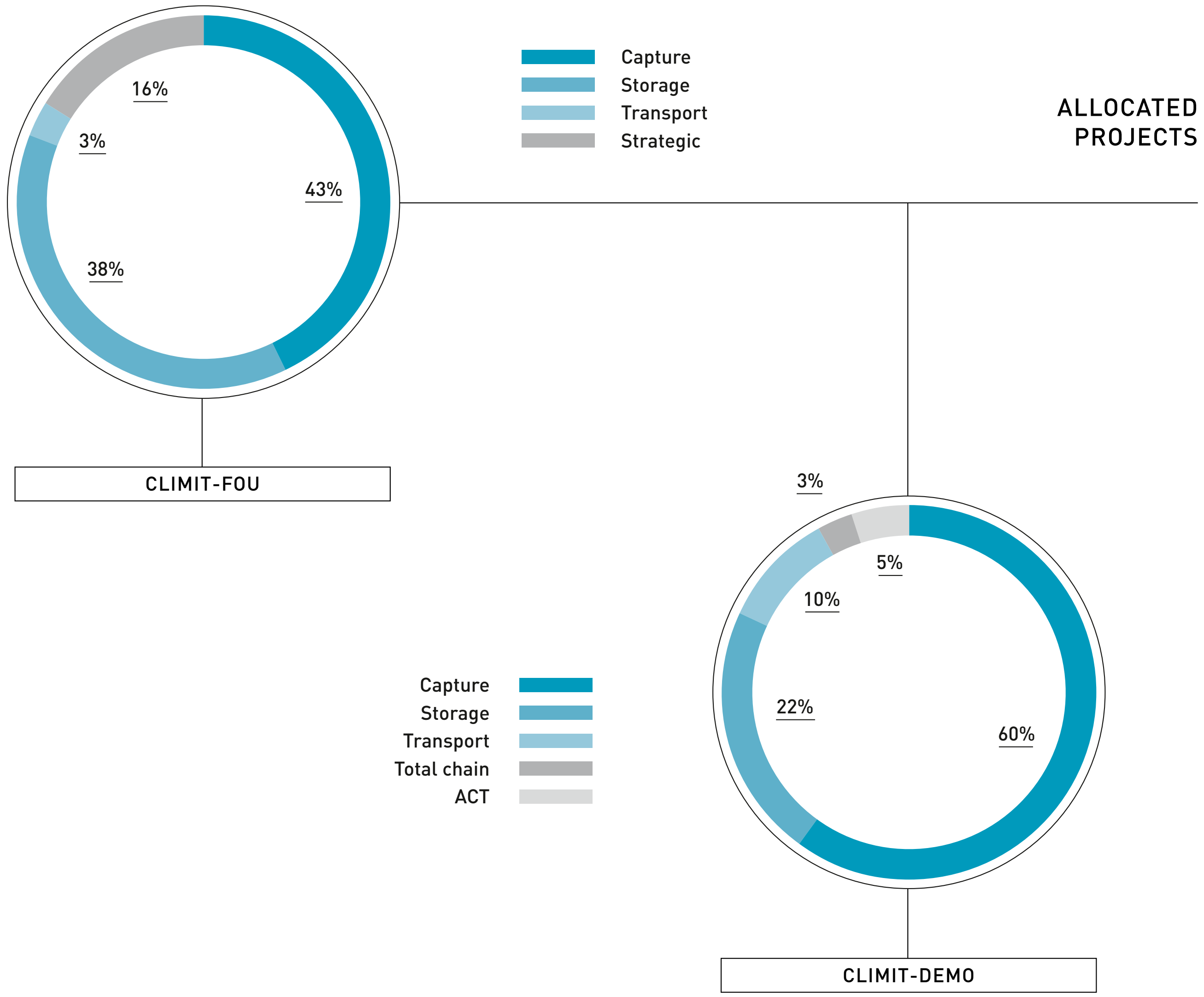
In 2017, CLIMIT R&D had 69 active projects that received a total of NOK 101 million in support during the year. A total of NOK 483 million in support has been budgeted for these projects over several years.

In 2017, support was awarded to 12 larger projects, of which four were research projects, three were competence-building projects for the business sector and five were innovation projects for the business sector.

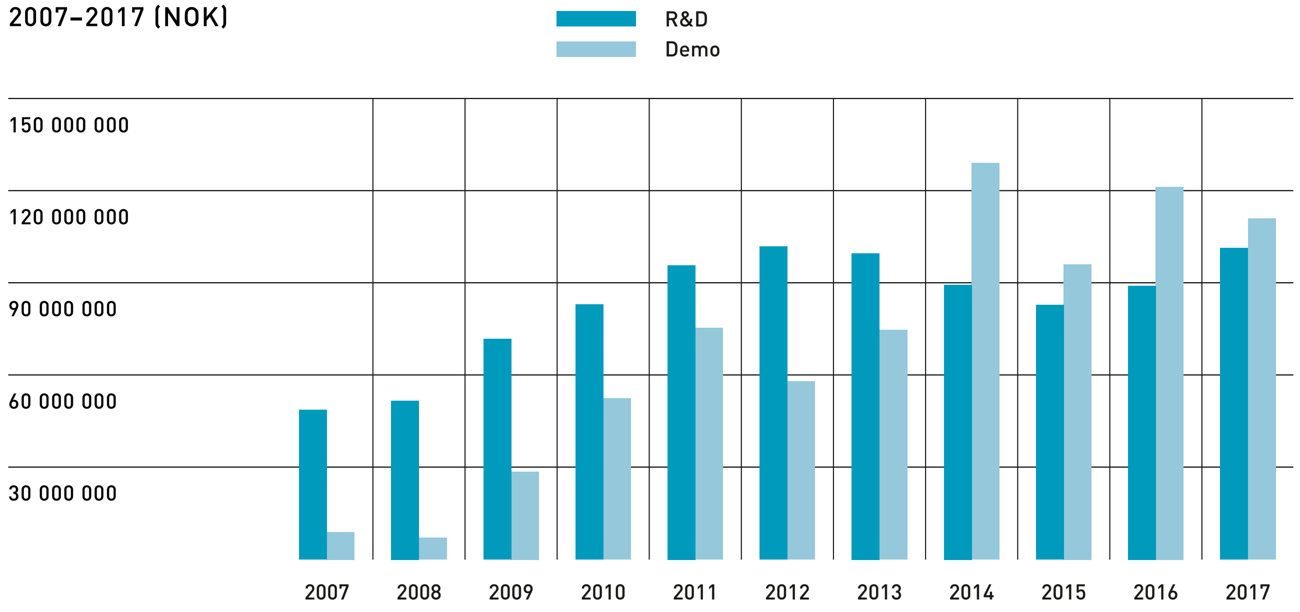
In addition, support has also been awarded to several small projects, including network projects, support for events and mobility grants. In 2017, NOK 139 million was allocated to new projects (including the Norwegian participation in ACT projects).

ACT

The Research Council of Norway is the coordinator for the European initiative ACT (Accelerating CCS Technologies), in which nine countries cooperate on sharing knowledge and releasing joint calls. In 2017, eight new ACT projects started up with a total of EUR 36 million in support from ACT. Seven of the projects have Norwegian partners, and the Norwegian partners are receiving a total of NOK 96 million in support from ACT. Funding to the Norwegian partners comes from CLIMIT R&D (NOK 37 million), CLIMIT Demo (NOK 28 million) and the European Commission (NOK 32 million).



PAYMENTS TO CLIMIT-PROJECTS 2007–2017 (NOK)



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