CLIMIT

2016 the year in review

NORWAY'S NATIONAL PROGRAMME FOR RESEARCH,
DEVELOPMENT AND DEMONSTRATION OF CCS TECHNOLOGY.

www.climit.no/en

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Ever closer to the target

After more than 10 years of research, a considerable base of knowledge on the capture, transport and storage of CO_2 has been built up in Norwegian research communities. While other countries have floundered somewhat, Norway has kept up the pressure throughout the years.

Now we can benefit from this persistence. Both the International Energy Agency (IEA) and the IPCC state in clear text that the world cannot achieve the two-degree target unless we implement technology to capture, transport and store CO_2 on a large scale. During the climate summit in Paris in 2015, 195 countries agreed to cut emissions, but few countries thought that the agreement would enter into force before 2020. Surprisingly, enough countries ratified the agreement so that it could already enter into force in November 2016.

Therefore, the interest in CCS is increasing. Several international research projects have started up, and thanks to our long-term strategy, Norway and CLIMIT are suitable partners in many contexts. In 2016, CLIMIT researchers entered into cooperation with research communities in both the USA and Australia. In addition, there was the start-up of the joint European research programme ACT – Accelerating CCS Technologies – in which Norway will contribute funds through CLIMIT. Several Norwegian actors are well-represented in the joint European projects proposals, which are now in the process of receiving funds from ACT.

The year 2016 has also been a year for planning the road ahead. Work on a new programme plan for the coming five years has been one of the main tasks for the CLIMIT Board for the year that passed. While the focus was previously on basic research and the development of technology, we are now focusing on demonstrating the entire value chain of full-scale capture, transport and storage of CO_2. CLIMIT shall contribute to ensuring that CCS receives the necessary attention nationally and internationally through cooperation between research and industry.

A number of Norwegian research institutes and industrial companies are in a position to contribute to the realisation of a full-scale project. Without CLIMIT, this would not have been possible. The pieces are starting to fall into place – thanks to long-term political will and long-term and systematic research efforts for more than 10 years.

Hans Roar Sørheim
Chair of CLIMIT's programme board

New programme plan 2017–2022

The aim of CLIMIT is to contribute to developing technology and solutions for the capture, transport and storage of CO_2. The outlook for how this technology will be implemented has changed since the programme was established 11 years ago. This is reflected in the programme plan for the next five years.

There is broad agreement among both researchers and politicians that CCS is a necessary means of achieving the two-degree target. For Norwegian authorities, CLIMIT is an important instrument for the development of technology and solutions for CCS, as well as for the reduction of costs and risk associated with the implementation of such technology. The ambition is also to contribute to broad international use of the CCS technology. CO_2 emissions are a global problem and carbon capture, transport and storage are part of the solution. Norway has good prerequisites for successful implementation. We have both broad political support, good research and technology communities and a great capacity for storage on the Norwegian continental shelf.

CHANGE IN FOCUS

When CLIMIT was established, it was based on the idea that CO_2 capture was suitable for reducing greenhouse gas emissions from gas-fired power plants, such as the plant at Mongstad. Today, the programme has shifted to focus more on capture from industry sources, such as industrial emissions. This change is implemented in the new programme plan for CLIMIT for the period 2017–2022.

The programme plan emphasises three main focus areas up to the year 2022:

- Early full-scale CO_2 value chains in Europe

HANS JØRGEN VINJE
Leader for CLIMIT

+ NORWAY IS A WORLD LEADER IN CCS AND WELL-EQUIPPED FOR IMMINENT REALISATION A FULL-SCALE PROJECT. +

- Large-scale storage of CO_2 on the Norwegian continental shelf in the North Sea
- Future solutions for CCS

FULL-SCALE PROJECTS IMPORTANT

The technology for carrying out capture, transport and storage of CO_2 is available today. Nonetheless, there are few enterprises that have implemented this technology. This is because the technology is costly and there are few incentives for implementing it. Nevertheless, it is important to get started. Therefore, a group of countries, including Norway, is leading the way through the development of early full-scale projects for CCS. CLIMIT will continue to support such activities to promote innovation, the spread of technology and a focused development of technology. Experience from full-scale projects will be when new requirements are introduced for business models and technology in the wake of the Paris Agreement.

LARGE-SCALE STORAGE

If CCS is to become a reality, storage is a key factor. While underground storage below populated areas has met a lot of resistance, there is a great potential for offshore storage of CO_2 on the Norwegian continental shelf. Norwegian centres of expertise are world leaders in offshore technology and operations, and the development of a CO_2 store on the Norwegian continental shelf may be important in order to promote the spread of CCS in Europe.

It will be important to strengthen the knowledge base concerning large-scale storage solutions in connection with assessments of capacity, integration and flexibility. Analyses from the operation and maintenance of storage facilities, including wells and fixed and floating installations, are equally important. Knowledge will contribute to reducing future risk and providing the necessary expertise for the development of government requirements, standards, commercial models and practical solutions.

NEW SOLUTIONS

To ensure that CCS becomes part of the climate solution of the future, new concepts must be developed. CLIMIT covers the entire development chain from research to demo, and the entire value chain for CCS. During the coming programme period, there is a prerequisite that the projects that are supported contribute to reduced costs and risks for CCS, and that the captured CO_2 be stored on a long-term basis.

New technology concepts for CCS must enable significant cost reductions. There are several technologies with a low technical maturity level that can contribute to reducing the costs of CCS, either by lower energy needs, utilisation of surplus heat, process simplification or process integration. For technology that is approaching introduction to the market, support will be awarded depending on whether the applicant can demonstrate the technical and commercial potential of the technology.

DISSEMINATION OF KNOWLEDGE

The programme will have a proactive work method for the coming programme period. This should ensure that projects receiving support contribute to achieving the performance targets that have been defined for the focus areas. It is expected that the projects that CLIMIT supports actively contribute to disseminating the knowledge and the results that are achieved. This will strengthen the reputation of CCS and increase the chances that CCS will be implemented as a climate measure. ●

CLIMIT'S PROGRAMME BOARD: Front, from the left: Karen Lyng, Marie Bysveen, Mette Vågnes Eriksen og Hans Roar Sørheim. Rear, from the left: Eva Halland, Hans Jørgen Vinje (Leader CLIMIT secretariat), Anita Utseth, Per Reidar Ørke, Jostein Dahl Karlsen, Cato Christiansen and Sveinung Hagen. Not present when the photo was taken: Per Aagaard.

CO_2 CAPTURE

Reinertsen's palladium pilot in operation

Reinertsen's membrane technology for the production of hydrogen from natural gas has come one step closer to commercialisation. The company recently started the operation of an industrial scale pilot plant at Statoil's methanol plant at Tjeldbergodden.

Imagine a future when natural gas from the North Sea is converted to pure hydrogen – and the CO_2 gas that remains is pumped back into the reservoir. This is made possible by allowing the natural gas pass through an extremely thin membrane of palladium. Reinertsen in Trondheim is in the process of turning SINTEF's patented membrane technology into a commercial product.

PALLADIUM MAGIC

This shiny metal can be confused with aluminium, but palladium is a far more rare and costly element with very unique properties.

Palladium allows hydrogen atoms to pass through, while CO_2 and other gases are held back. When the film is placed over a porous pipe that gas is sent through, hydrogen will be extracted through the membrane. The technology can thereby be used to produce hydrogen without releasing CO_2. Even if this is known technology, thanks to cooperation with researchers at SINTEF, Reinertsen has developed the thinnest and most effective palladium membrane on the market.

– The membranes that previously existed were too thick for practical use on a large scale, says Project Manager Frode Roness at Reinertsen. – The challenge has been to make adequately thin membranes over a sufficiently large area, and we have managed to do so thanks to a top notch team of SINTEF researchers and support from CLIMIT.

PILOT PLANT

The palladium membrane has previously shown promising results in the laboratory, but it is now being tested on an industrial scale at Statoil's plant at Tjeldbergodden. If the results from this test are as expected, Roness believes that they can launch it on the market by the end of 2017.

– A lot of the testing is now about surveying the life of the membrane, and of fine adjustment of the production plant, says Roness.

– We expect that the membrane will have a life of approximately five years before it will have to be replaced. The pilot will tell us whether our life

Reinertsen has started a pilot at Statoil's plant at Tjeldbergodden.

FACTS

PROSJEKT: CO_2 capture and hydrogen production with the use of palladium membranes
PROSJEKTEIER: Reinertsen
PROSJEKTPERIODE: 2014–2017
FINANSIERING: NOK 90 million
PARTNERE: SINTEF MK

FRODE RONESS
Project manager

time predictions are correctly. This is important, because it will be both demanding and costly to have to replace the membrane often.

COMMERCIALISATION

Thus far around NOK 100 million has been invested in the development of the membrane technology. CLIMIT has contributed NOK 70 million, and Reinertsen itself has contributed around NOK 30 million. Further financing by private investors is needed to launch the technology on the market, but Frode Roness at Reinertsen is optimistic.

– We are a couple years ahead on our competitors, and we believe that this will be good business too, he says.
– The world needs more clean energy, and hydrogen is a strong candidate to replace oil and gas as an energy carrier.

The challenge today is the fact that hydrogen production is both energy intensive and costly, so that it is neither competitive nor environmentally friendly enough. With Reinertsen's membrane technology, the production of hydrogen will be significantly less expensive than both traditional production from electrolysis and other separation technologies. In addition, the technology can make natural gas a good, green alternative.

– In the future, we envision that hydrogen can be produced in large quantities from Norwegian natural gas, while at the same time CO_2 is injected back into stores under the ocean floor in the North Sea. This hydrogen can thus be used for environmentally friendly energy production, transport, and the like, says Roness.

– Then we will have "low-carbon" gas operations that are also sustainable in a low-emission society. ●

What technology is best?

Many competing technologies are being developed for the capture and storage of CO_2. Which of them should we invest in? The EDDiCCUT project has developed methods and tools precisely to answer this question.

EDDiCCUT is an abbreviation for "Environmental Due Diligence of CO_2 Capture and Utilisation Technologies".

– This primarily involves decision support for finding the technology that provides the greatest environmental benefits, says the head of EDDiCCUT, Anders Hammer Strømman, Professor of Industrial Ecology at the Department of Energy and Process Engineering, NTNU.

– Ongoing economic and technological assessments are made on the basis of cost-benefit analysis. What we have introduced in addition is an assessment of which technologies will provide the greatest climate impact in the form of reduced CO_2 emissions. An overall assessment of the financial, technological and environmental factors will provide the best overall basis for comparative evaluation of the various technologies.

EDDiCCUT is primarily a research project, but the project is based on 10 representative case studies in co-operation with industrial partners. The results from the project are published in international research journals, and the knowledge is freely available to anyone who needs it.

– For example, the users may be the appropriating authorities who need to assess the value of developing a technology further, or they may be industrial actors who need to assess what type of technology they will invest in, says Strømman.

– Our task is to develop the tools. Now it is up to others to put them to use. ●

FACTS

PROJECT: EDDiCCUT – Environmental Due Diligence of CO_2 Capture and Utilisation Technologies"
PROJECT OWNER: NTNU
PROJECT PERIOD: 2013–2017
FINANCING: NOK 18.7 million
PARTNERS: Shell, Uniper, Bharat Petroleum, Siemens (portions of the project period), Utrecht University and Tel-Tek

CO_2 STORAGE

Improved knowledge provides safe storage

Statoil is preparing for a future in which they can use their offshore knowledge and experience to offer storage of CO_2 under the ocean floor. This presupposes that there are safe storage locations with great enough capacity.

Filling empty oil and gas fields in the North Sea with CO_2 sounds like a good idea, but if the idea is to have any merit, we must make sure that the greenhouse gas does not leak out due to porous rock types or cracks. Together with researchers at the Department of Geosciences at the University of Oslo, Statoil has therefore been searching for suitable locations for the storage of large amounts of CO_2.

– Statoil has ambitions to be a major actor in CO_2 storage. However, Statoil is also a commercial actor, so if we are to invest in CO_2 storage, we must know that the project is profitable. This means in turn that we must be able to offer sufficient storage volume and a proper sealing of the stores, explains Rudolf Maurer, geologist at Statoil and project manager for CO_2Seal.

SAFE STORAGE

A critical key factor for successful full-scale CCS is suitable storage locations. This concerns to a great extent the properties of the reservoir rock where the CO_2 is stored. Porous rocks are suitable for holding the gas, but to ensure that it will not leak out again, the store must have a cap of a more stable and denser type of rock.

– Good storage locations affect both the economy of the projects and people's confidence in this type of storage being safe and secure, says Maurer.

NEW CORE SAMPLES

CO_2Seal is financed 50/50 by CLIMIT Demo and Statoil, and there has been close cooperation between Statoil and researchers at the Department of Geosciences at the University of Oslo.

– The project started in 2010 and has been carried out in different phases. We began by mapping potential storage locations, then studying the composition and rock mechanical properties of the caprock formations, says Maurer.

– Statoil of course had many previous geological core samples, but they were old now and unreliable for our analysis. Therefore, obtaining new samples was necessary in order to ensure the quality of our analysis work. Thanks to the CO_2Seal project, we have been able to be much more thorough and

Statoil is planning to store CO_2 under the ocean floor in the North Sea.

have acquired significantly more knowledge than we would have had if we were to do this alone.

CO_2Seal has given us both knowledge and experience that will be of benefit when assessing many future storage locations for CO_2.

– Among other things, we have surplus material available from our core samples, which we will make available to researchers who would like to use them in their analysis work, says Maurer.

FACTS

PROJECT: Evaluation of the long-term sealing capabilities in the southern Norwegian sector of the North Sea for CO_2 storage purposes
PROJECT OWNER: Statoil
PROJECT PERIOD: 2010–2016
FINANCING: NOK 16.6 million
PARTNERS: University of Oslo

CO_2 STORAGE

CO_2 injection for EOR reduces the carbon footprint

PER HELGE NØKLEBY
Head of EOR business development at Aker Solutions.

Aker Solutions has substantial expertise in offshore technology for the recovery of oil and gas. Now they will use their knowledge and subsea technologies to get more out of the fields by injecting CO_2 in the reservoirs.

CO_2-EOR – or Enhanced Oil Recovery by means of CO_2 – is a method that has been known and used for the recovery of oil for 40 years, but only onshore. Now Aker Solutions and Statoil have developed a technology concept that can realise offshore EOR with the aid of CO_2.

– What we will do is to inject CO_2 from a ship down into the reservoir, and at the same time manage the CO_2 that returns with the oil flow in a subsea installation, says Pål Helge Nøkleby, head of EOR business development at Aker Solutions. By using the reservoir for permanent storage for CO_2 after commercial oil production, the extra oil produced will have a negative carbon footprint.

HAVE THE EQUIPMENT

There are several advantages to the Aker Solutions concept for offshore EOR. They can use many of the equipment components that they already use for subsea oil and gas production, but assemble the elements in new ways to create a functioning production line.

– This will still be demanding. Therefore, we are working on further qualification of our technology, such that the method can hopefully be part of a full-scale process for CCS in connection with the planned national CCS full-scale project, says Nøkleby.

GREAT VALUE

Great value can be realised if this technology is implemented.

– Calculations show that approx. 300 million cubic metres of extra oil can be recovered by means of CO_2 injection on the Norwegian continental shelf. This corresponds to around 10 per cent of what has already been recovered. There is perhaps three times as much on the British side, says Nøkleby.

– Best of all, nonetheless, is the fact that this method can create a great deal of value, at the same time as a reduced carbon footprint for the extra oil produced.

Norwegian continental shelf

300

MILLION cubic metres of extra oil can be recovered by means of CO_2 injection

THIS CORRESPONDS to around 10 per cent of what has already been recovered

FACTS

PROJECT: Concept study for the combination of full-scale capture of CO_2 with storage and use of EOR for North Sea oilfields
PROJECT OWNER: Aker Solutions
PROJECT PERIOD: 2013–2016
FINANCING: NOK 9.4 million
PARTNERS: Statoil

InflowControl has developed a fully automated valve for EOR recovery.

VIDAR MATHIESEN
CEO and founder of the company InflowControl.

Norwegian-designed valve prevents CO_2 leakage

For enhanced oil recovery with CO_2 (EOR), the breakthrough of CO_2 to the production well may be a challenge. A Norwegian-designed self-regulating valve may solve the problem.

The valve is a further development of a valve that the company InflowControl in Porsgrunn has designed for conventional enhanced oil recovery by water injection. The water is forced into the field through an injection well and takes the oil with it towards a production well. The water chooses the path of least resistance towards the production well, such as fractures in the oil field that have a lower flow resistance than the surrounding formations. If a large portion of the water follows such a shortcut to the production well, which is called a breakthrough, then the production of oil becomes less effective. The valve that InflowControl has designed closes off areas in production wells where a breakthrough has occurred. Thus the shortcut is closed off, and the water must travel farther over a larger area and thus takes more oil with it.

With support from CLIMIT Demo, InflowControl has developed a version of the valve that can be used for enhanced oil recovery with CO_2, which has been tested in a CO_2 EOR oilfield in Canada. From a CCUS perspective, the valve is interesting because it can contribute to an oilfield storing a larger volume of CO_2 when oil production ends than if the oil production ends earlier due to the breakthrough of CO_2.

– The results were very encouraging, says Vidar Mathiesen, CEO and founder of the company InflowControl in Porsgrunn. The valve is self-regulating and does not require signals or energy from the surface to work. The various fluids that run through the valve have differing viscosities, and it is the differences in this property that determine whether the valve opens or closes.

– This means that it can let the oil through in EOR production, but prevent large amounts of CO_2 from flowing back in together with the oil. The experiment shows that the valve works as intended. It identifies undesirable fluids automatically, and closes and opens when it should, says Mathiesen.

The valve, which has been called an Autonomous Inflow Control Valve (AICV), can contribute to quadrupling oil production compared with competing technologies.

FACTS

PROJECT: Autonomous valves for enhanced recovery of oil reservoirs with increased storage of CO_2 at the same time
PROJECT OWNER: InflowControl Porsgrunn
PROJECT PERIOD: 2015–2016
FINANCING: NOK 4.3 million
PARTNERS: Apache

CO_2 TRANSPORT

Cooperation for safer and less costly pipelines for CO_2 transport

Carbon capture and storage (CCS) requires transport of large volumes of CO_2 in pipelines. Norwegian and Australian experts have joined forces on a test programme for pipelines to determine important safety limits.

Pipelines will probably become the predominant way of transporting CO_2. Pipelines have to be strong enough to withstand the pressure of the CO_2 in case of an accidental crack to avoid a running fracture, which may damage a considerable length of pipe The key question addressed by this project is to predict how strong the pipes have to be to avoid a running fracture.

NORWEGIAN-AUSTRALIAN COOPERATION

DNV GL in Norway and the Australian cooperative research centre Energy Pipelines CRC (EPCRC) entered into cooperation in the summer of 2016, the goal of which is to further develop models to calculate the strength of pipes to ensure fracture arrest and dispersion of CO_2 in case of a pipe rupture. The project is supported 50/50 by CLIMIT and the Australian Department of Industry, for a total of NOK 40 million. A large share of the funds goes to performing large-scale tests of pipelines at the DNV GL test centre at Spadeadam in the United Kingdom.

– This is quite a unique cooperation project, says Project Manager Bente Helen Leinum at DNV GL. – Both because it is the only cooperation project of its kind in the field of CO_2 transport, and because through the agreement we act as a single project.

CREATING NEW MODELS

The main goal of the project is to further develop models for the design of pipelines. There's a lack of verified guidelines and models for determining wall thickness and material properties for fracture arrest. In practice, this means building pipelines so solid that it is completely certain that they are solid enough. A crack in a pipeline can have serious consequences.

– We primarily have experience from the transport of natural gas, and CO_2 does not behave in the same way as natural gas. A leak at one location in a pipeline can, in the worst case scenario, result in the pipeline cracking along its entire length – over many kilometres, says Leinum. Pipelines are typically built with pipe in lengths of 12 metres that are welded together. If a crack can be limited to a single length of pipe, the amount of damage will be limited significantly.

– It is also costly to build long pipelines, so if we can develop knowledge that can contribute to the dimensioning of CO_2 pipelines with margins smaller than the current practice. This will result in major cost reductions, says Leinum.

FRACTURE ARREST TESTS AND SIMULATIONS

Two full-scale fracture arrest tests at the Spadeadam test centre will be carried out in the project. In these tests, we will not only gain knowledge of how the pipelines act, but also how the CO_2 spreads in the event of a leak.

– The knowledge we gain from the tests will subsequently be used to update standards and models for the design and operation of CO_2 pipelines. We are testing both materials and dimensions, and even if this is a project that is carried out jointly by Australia and Norway, the knowledge and models will benefit everyone who is engaged in CO_2 capture, says Leinum. – The goal is to ensure that the transport of CO_2 can be done as safely and economically as possible.

The project started up in the summer of 2016, and the first tests will be carried out in the summer of 2017. These tests will provide new knowledge that can be used to calibrate subsequent tests that are scheduled for December 2017. ●

+ THE KNOWLEDGE WE GAIN FROM THE TESTS WILL SUBSEQUENTLY BE USED TO UPDATE STANDARDS AND MODELS FOR THE DESIGN AND OPERATION OF CO_2 PIPELINES. +

FACTS

PROJECT: CO_2SafeArrest
PROJECT OWNER: DNV GL
PROJECT PERIOD: 2016–2019
FINANCING: NOK 40 million
PARTNERS: Energy Pipelines CRC

——— CO_2 cloud after controlled leakage from a pipe at DNV GL's plant at Spadeadam in the UK.

INTERNATIONAL

ACT is accelerating the technology

The European Commission is donating EUR 13 million, and nine cooperating countries are donating a total of EUR 29 million for a joint European project ACT – Accelerating CCS Technologies. The funds will be distributed in the summer of 2017.

AAGE STANGELAND
Adviser in The Research Council of Norway

+ A COMMON APPLICATION SYSTEM FOR ALL THE PARTICIPATING COUNTRIES IS GOOD NEWS, WHICH SIMPLIFIES THE PROCESS FOR APPLICANTS AND INCREASES. +

– A total pot of EUR 43 million in fresh capital is very good news for both international CCS research and for the research communities in Norway, says Research Council of Norway adviser Aage Stangeland. Together with his colleague Ragnhild Rønneberg, he will be responsible for coordination of the project. The funds have now been advertised, and applications will be processed up towards distribution in the summer of 2017.

– We are now requesting applications for industrial projects, i.e. pilot projects in cooperation with research communities and industry, says Stangeland. – Funds will not be granted for basic research this time.

In addition to having an industrial partner, applicants must also find research partners from at least two of the other countries. Applications for financial support will be accepted for all types of projects, both in capture, transport and storage – and EOR.

– Of course I cannot say anything more detailed about the applicants other than that we have received some very exciting applications, says Stangeland. In the pile of applications from Norway, there will of course be many actors who have already received support through CLIMIT.

We will focus on pilots that focus on industrial activities, we do not want basic research. We want to link research and industry, and there must also be partners from two other countries.

– We will distribute all the funds this summer. Most of it will be allocated to large projects, but also some to smaller projects. We also have ambitions to award a new pot of funds in 2018 and an additional one in 2020, says Stangeland. Norway is contributing EUR 6 million to the common pot, but Stangeland thinks there is reason to believe that Norwegian projects will receive support that exceeds what we are contributing.

– Norway, especially thanks to CLIMIT, has seen a high level of activity in this research field for more than 10 years. In several other countries, the level activity has tapered off or completely disappeared. What is perhaps the most gratifying with this focus is that we are now managing to mobilise both countries that have not been so active, and countries that have previously been very active, says Stangeland.

– This means that these countries will use a lot more funds on this research than they would have otherwise. ACT is creating momentum that we really need now. A common application system for all the participating countries is also good news, which simplifies the process for applicants and increases the chances that the projects will be carried out. ●

FACTS

THE COUNTRIES PARTICIPATING IN ACT ARE CONTRIBUTING EUR 29 million. The Commission has adopted support for ACT of EUR 12.9 million, and the total budget is thus close to EUR 43 million.

THE FOLLOWING COUNTRIES ARE PARTICIPATING IN ACT: Norway, Germany, UK, Netherlands, Switzerland, Turkey, Romania, Spain and Greece.

NORWAY AND GERMANY HAVE LED THE WORK on the application, and the Research Council of Norway represented by Ragnhild Rønneberg and Aage Stangeland, will be responsible for the coordination of ACT.

THE NORWEGIAN CONTRIBUTION TO ACT of EUR 6 million comes from CLIMIT.

FACTS

PROJECT: Solvent Sensor for Online Process Monitoring (S-SENCE)
PROJECT OWNER: SINTEF
PROJECT PERIOD: 2015–2017
FINANCING: NOK 4.87 million
PARTNERS: ION Engineering

Rewarding Norwegian-American cooperation

More than 10 years of research efforts through CLIMIT have made Norway an attractive partner for foreign researchers. Both the technical expertise and the unique Technology Centre at Mongstad are drawing cards.

In 2016, the American company ION Engineering established a branch office in Norway in order to take advantage of the opportunity to cooperate with researchers at SINTEF and have access to the Technology Centre at Mongstad (TCM).

– It is very interesting that ION is now establishing itself in Norway to cooperate further with us, says Solrun H. Vevelstad at SINTEF Materials and Chemistry.

– This shows that Norway has become an important international partner for research in CCS. Both the research expertise we possess and the testing opportunities at TCM are compelling incentives.

SPECIALISTS

ION Engineering was established in 2008 and has, for example, specialised in the development of solvents for CO_2 capture that require far less energy than other solvents. Operating costs will thus be reduced. In laboratory tests, the solvent has captured 95–96 per cent of the CO_2 from flue gas. In one case, it captured as much as 99 per cent. They have tested the technology at home in the USA at the National Carbon Capture Center, but they lacked the methods and instruments to optimise their products. They found these at SINTEF in Trondheim, which had developed a concept for the online analysis of solvents. In 2015, SINTEF and ION entered into cooperation to develop this further.

– We had the idea for the analysis tool, but thanks to research cooperation with ION Engineering, we received the resources to develop this further to a functioning prototype that can provide faster and more cost-effective sampling and analysis than the manual system we have had until now, says Vevelstad. The instrument makes it possible to have continuous measurement of the components of mixtures that previously could have only been accomplished by manual analysis.

ONLINE TOOL

Online fluid analysis is important in order to minimise energy consumption in the capture process under varying conditions. Such fluid analysis will also increase our knowledge of the degradation and environmental emissions with the use of solvents, and reduce the need for costly laboratory analysis.

– For ION Engineering of course this is also interesting, says Solrun J. Vevelstad. – They develop solvents for the capture of CO_2 from waste gasses that they can now test at TCM.

The cooperation project between ION Engineering and SINTEF has received financial support from both the US Department of Energy (DOE) and from CLIMIT.

– The fact that they have now established a company in Norway shows that they value our cooperation and that they intend to continue to use the facilities at Mongstad and Norwegian research expertise, says Vevelstad.

COMMERCIALISATION

SINTEF and ION have each built their own mobile analyser. ION Engineering will use theirs to test their technology at TCM during the first half of 2017. SINTEF's analyser can be used for other projects.

ION Engineering and SINTEF are working on plans for commercialisation of the concept and further development of the analyser as a compact industrial measuring system with custom components. The measuring principle can also be used for fluid analysis in other types of industrial processes. ●

SOLRUN JOHANNE VEVELSTAD
Scientist

Microseismic research cooperation

Efficient CCS is ultimately dependent on safe, permanent storage underground or under the ocean floor in the North Sea. How safe will such storage be? Norwegian and American researches are cooperating to find the answer.

– In order to store CO_2 safely underground or under the ocean floor, we must have full control of how CO_2 behaves during injection and of where it could possibly leak out, says Volker Oye, researcher and department head for microseismic monitoring at NORSAR in Kjeller. NORSAR are seismic measurement specialists, and are leading a Norwegian–American research project on the microseismic monitoring of CO_2 stores.

DISTURBING FINDINGS

– The background for the project were findings we made in a CO_2 store in Illinois, where many thousands of microseismic events occurred during the injection of CO_2, Oye explains.

– The findings were surprising, because the injection was under very low pressure. We had not expected that such events could happen.

Microseismic events are tiny earthquakes, often triggered by manmade activities that change the pressure and tension underground. They can occur in mines and in connection with oil and gas recovery, but they have not been regarded as any great risk for CO_2 storage.

– In this case, it involved very small movements that no one can feel, but this caused a certain degree of unease because of the unexpected number of microseismic events, says Oye. Surveying microseismic events underground can also contribute to increased understanding of how CO_2 penetrates and fills up a "store" and thus contribute to better monitoring of the stores.

The Illinois State Geological Survey wanted to include NORSAR in subsequent studies, and applied for financing from the US Department of Energy (DOE). Since the project is also highly relevant to planned Norwegian CO_2 storage under the ocean floor in the North Sea, NORSAR joined forces with SINTEF and applied for financial support from CLIMIT Demo for the Norwegian participation. – This is the first time we have had such research cooperation for CO_2 storage, which is exciting in itself, says Volker Oye.

START-UP PHASE

The CLIMIT-financed project is just in the start phase, so Volker Oye does not have many results to offer yet. However, the goal of the project is clear.

– The hope is that we can find out under what conditions, where, and in what layers and rock types these events occur, he says. Volker Oye believes that the relevant Norwegian storage places are good candidates for future CO_2 storage, but the findings of microseismic events in Illinois show how important it is to be observant.

– There are examples of manmade activities that have triggered earthquakes, so it is important to be cautious. In my opinion it is always wise to take some time and resources for surveying and research before storing millions of tonnes of CO_2 somewhere. It is a small price to pay for long-term safety. ●

VOLKER OYE
Researcher and department head for microseismic monitoring at NORSAR

FACTS

PROJECT: Monitoring of CO_2 Storage Using Microseismicity and 4D Seismic Modelling
PROJECT MANAGER: NORSAR
PROJECT PERIOD: 2016–2018
FINANCING: NOK 13.63 million
PARTNERS: SINTEF and the Illinois State Geological Survey

COMMERCIALISATION

American company buys Norwegian membrane

A group of researchers at NTNU have developed a membrane that imitates the manner in which our lungs filter out CO_2. Now the American company Air Products Inc. has entered into a licence agreement with NTNU for use of this technology.

The air we breathe consists primarily of nitrogen and oxygen. Through respiration, our bodies absorb oxygen and filter out carbon dioxide (CO_2). May-Britt Hägg and a group of researchers at NTNU have developed a membrane that imitates the manner in which our lungs filter out CO_2.

– In our lungs, we have an enzyme that "captures" and transports away CO_2 when we breathe, and the membrane we have developed also contains such a chemical compound with approximately the same properties, says May-Britt Hägg. The membrane represents a very environmentally friendly and cost-effective method of filtering out CO_2 from flue gas.

ENVIRONMENTALLY FRIENDLY AND REASONABLE

– The membrane technology requires significantly less energy than other methods, and no chemicals to treat the waste gases either, Hägg explains. The membranes consist of a plastic substance (polyvinyl amine) in which the amine group in the plastic acts as a carrier of CO_2.

– This amine acts as a transport molecule for CO_2 through the membrane when moisture is present, Hägg explains.

– The process can be compared to what happens in our lungs when we breathe.

The technology was recently tested at both Norcem's cement factory in Brevik, and at SINTEF's CO_2 lab in Tiller outside of Trondheim; earlier also at a coal-fired power plant in Portugal. It has been shown to be particularly effective for the treatment of flue gases when the CO_2 content is 10% or higher, for example from a coal-fired power plant. According to Hägg, the membrane can eliminate close to 90 per cent of the CO_2.

TO BE LAUNCHED ON THE MARKET

After many years of research, and with support from CLIMIT among others, the membrane is ready for the market. Hägg and NTNU have entered into an agreement with the American company Air Products Inc., who clearly see the commercial potential of the membrane technology.

– This is very gratifying for us. We are researchers, but we are also concerned that what we develop can be beneficial. Therefore, it is a good thing that someone can utilise our knowledge to create value for society, says Hägg.

WORKPLACES

Air Products has more than 16,000 employees in 50 countries, and is a major supplier of natural gas process technology and equipment. The company also has a branch office in Kristiansand, and this is where it is envisioned that the membrane systems will be produced.

– Air Products will be the ones responsible for further development, and there is reason to believe that this membrane technology can contribute to creating many new workplaces in the Kristiansand area, says Hägg.

The licence agreement is good news for NTNU, which will receive royalties for every new Air Products customer that puts the method to use, in addition to a significant seven-figure amount upon the signing of the agreement.

+ THERE IS REASON TO BELIEVE THAT THIS MEMBRANE TECHNOLOGY CAN CONTRIBUTE TO CREATING MANY NEW WORKPLACES. +

MAY-BRITT HÄGG
Scientist

PHD SEMINAR

Experts of the future will increase the pace of CCS

The PhD students who attended CLIMIT's PhD seminar have go-ahead spirit, enthusiasm and lots of good ideas for how CCS can contribute to solving climate challenges.

This year's seminar was held in Hamar from 20 to 21 October 2016, in cooperation with FME SUCCESS. Approximately 30 PhD students participated.

– One important goal of CLIMIT is to educate PhD students so that in the coming years there will be growth in the number of experts who are to implement CCS on a large scale, says Aage Stangeland, project coordinator at CLIMIT R&D.

The CLIMIT programme arranges an annual seminar for all PhD students who work with CCS. This year's seminar showed that recruitment of the experts of the future is very promising. At the PhD seminar, the students were given an opportunity to show their work with presentations and posters. A broad range of presentations were shown: Everything from CO_2 capture combined with hydrogen production, to corrosion in oil pipelines, and new models for the storage of CO_2.

– With a lot of passion and good projects, we are convinced that the young researchers have what it takes to implement new solutions for the capture, transport and storage of CO_2, says Stangeland.

Nonetheless, Stangeland would like to point out two students who each walked off with an award. Odd Andersen from the University of Bergen / SINTEF received an award for the best lecture on the modelling of CO_2 storage.

– He has used advanced mathematics to predict how CO_2 flows and reacts in a store. This is something that industry needs, says Stangeland.

Bjørn Morland from IFE received an award for the best poster.

– He has done solid work on CO_2 transport and thermodynamics and showed how CO_2 can be transported in a pipeline in a safe manner, says Stangeland.

The PhD students come primarily from the major universities in Norway, such as the University of Oslo, University of Bergen and the Norwegian University of Science and Technology (NTNU) in Trondheim. ●

+ ONE IMPORTANT GOAL OF CLIMIT IS TO EDUCATE PHD STUDENTS SO THAT IN THE COMING YEARS THERE WILL BE GROWTH IN THE NUMBER OF EXPERTS WHO ARE TO IMPLEMENT CCS ON A LARGE SCALE. +

Key figures 2016

There has been a great deal of interest in CLIMIT's support programme in 2016. Altogether 38 new projects have received grants with a total budget of NOK 254 million. The increase in the number of applications received in 2016 has been gratifying. We see that more of the projects are on a positive path towards advancing the projects in the course of development.

The CLIMIT programme experienced an increasing volume of applications in 2016, and we see that several of the R&D projects are progressing to the Demo section. The SOLVit project was concluded in 2016, and this is one of the largest projects that has been in CLIMIT's portfolio. This is also a good example of interaction between the R&D and Demo sections.

In addition, the secretariat has been strongly involved in ACT (Accelerating CCS Technologies). The number of applications to ACT indicates that the coming years will be exciting with a strong international cooperation. CLIMIT has contributed significant use of its own resources to assist the ACT secretariat with the establishment of the project, support for project evaluation and general professional assistance in all the fields of expertise associated with CCS. We see the same thing in the ECCSEL initiative, where several CLIMIT projects are using infrastructure built under the ECCSEL scheme

RESEARCH PROJECTS

At the end of 2016, CLIMIT R&D had 68 active projects with a combined support budget of NOK 478 million. The greatest number and the largest disbursements are for CO_2 capture and storage. In December 2016, 14 new projects with a combined budget of NOK 104 million were approved and will start their work in 2017. In addition, the R&D section had 30 PhD candidates and 18 PostDoc candidates in its portfolio.

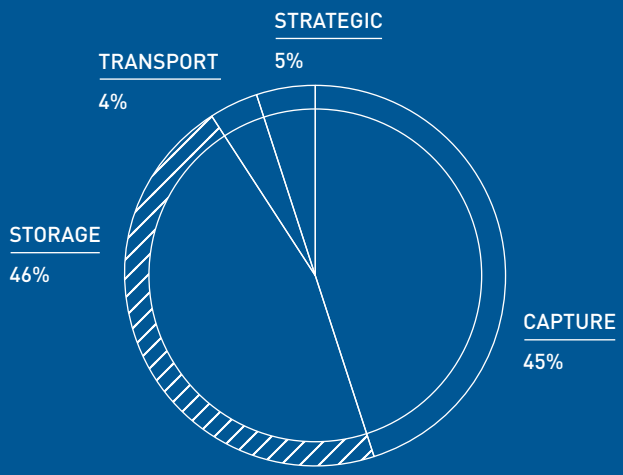
DEMO PROJECTS

CLIMIT Demo had 107 active projects with a combined allocated support budget of NOK 632 million in 2016. 24 projects were awarded support in 2016. In addition, support was awarded to conceptual studies, smaller studies, information initiatives. Overall, conditional allocations totalled approximately NOK 150 million in 2016. A total of 33 projects were concluded in 2016.

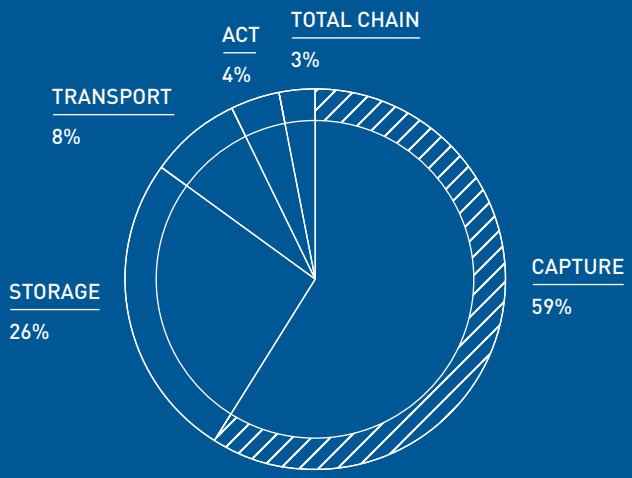
INTERNATIONAL PROJECTS

CLIMIT focuses on international cooperation. In the last few years, in several projects there has been bilateral cooperation between Norwegian actors and actors from the USA, Canada, the EU and Australia.

ALLOCATED PROJECTS

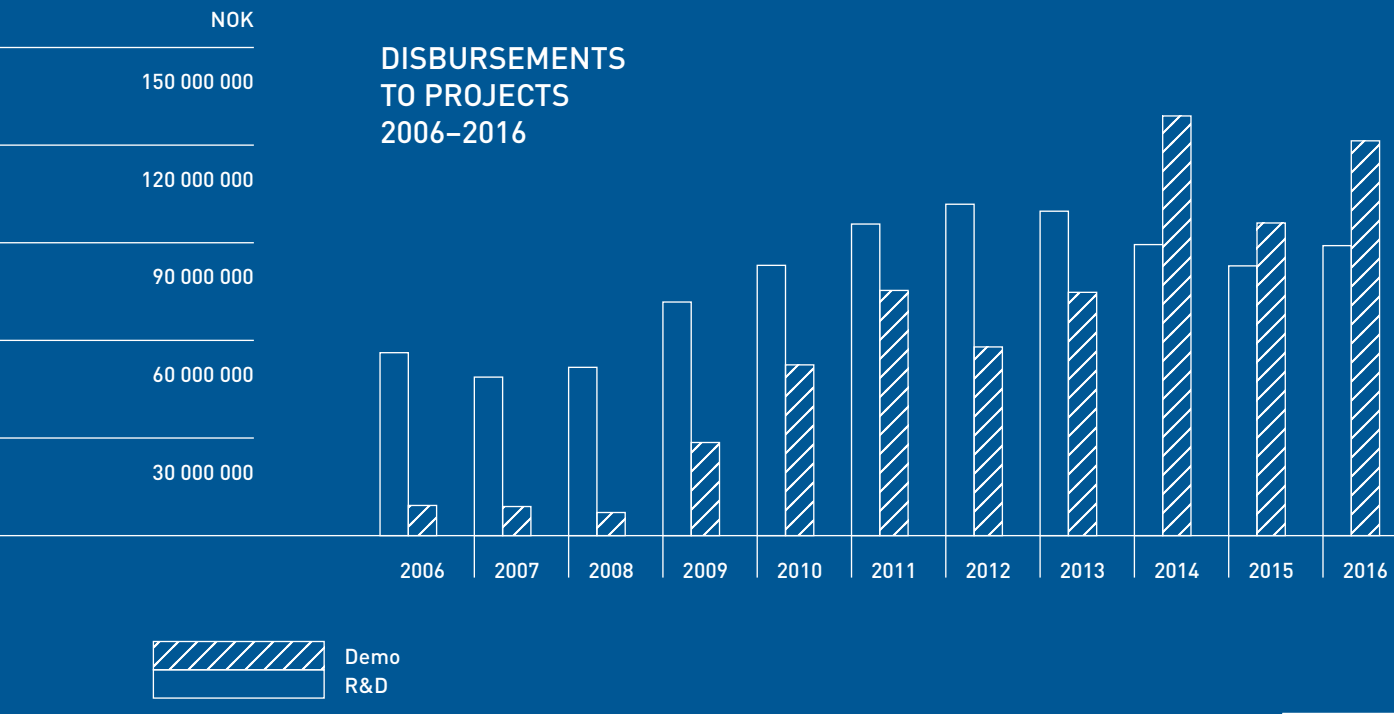


CLIMIT DEMO



CLIMIT R&D

DISBURSEMENTS TO PROJECTS 2006–2016



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