



GASSNOVA



THE NORWEGIAN STATE ENTERPRISE FOR CARBON CAPTURE AND STORAGE

CARBON CAPTURE AND
STORAGE FOR A BETTER
CLIMATE

2010 ANNUAL REPORT

CARBON CAPTURE AND STORAGE

—FROM TECHNOLOGY DEVELOPMENT
TO A FUNCTIONING MARKET

Well-functioning market

Deployment and internationalisation
of CCS technologies

Reduced costs and risks associated with CCS

Providing advice within framework conditions,
and decision making to enable the implementation of CCS

Increased understanding and acceptance of CCS among decision makers in society

Early implementation of full-scale CCS in Norway

New technologies developed and verified



GASSNOVA



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Gassnova SF

– the Norwegian state enterprise for carbon capture and storage
Norway aims to be a pioneer within carbon capture and storage

Images in this annual report:

Front cover, pages 10 and 11: TCM DA

Pages 4, 5, 6, 7 (lab), 8 and 14: Styrk Fjørtoft Trondsen

Pages 2, 7 and 15: Liv Lønne Dille

Others: iStockphoto.com

Gassnova's objectives and key tasks are to:

- » Manage the Norwegian state's interests related to carbon capture and storage (CCS) and carry out the projects decided by the general meeting
- » Advise the Ministry of Petroleum and Energy in issues concerning CCS
- » Contribute to technology and market development through CCS projects and execution of the CLIMIT programme



Working for a BETTER CLIMATE

The International Energy Agency (IEA) and other expert bodies are unanimous in their conclusion: carbon capture at major emission points is an essential part of the package of measures needed to address global climate issues in the period up to 2050.

The International Energy Agency (IEA) and other expert bodies are unanimous in their conclusion: carbon capture at major emission points is an essential part of the package of measures needed to address global climate issues in the period up to 2050. Insufficiently mature technology and the need for broad international application call for extensive and long-term public efforts in many countries. Close cooperation with the industry must be an ever-present factor in this development towards a future market-based application of carbon capture and storage (CCS) technologies.

The climate issue received a great deal of international media attention in 2009. In 2010, however, the world was no longer focused on the climate. This state of affairs may not last: 2010 turned out to be one of the warmest years since systematic measurements began, even though we

still enjoy good skiing winters at our own latitudes.

For us in Gassnova, 2010 became the year when our projects received the full attention of our politicians, as well as the rest of Norway. Gassnova is a driving force for technology development through financial support for R&D, by entering into partnerships with the industry and by creating a pioneering market through demonstration projects. We also emphasise the importance of government regulation and financial incentives to help create a market for CO₂ technology. The cost of CO₂ emissions needs to go up, and the cost of the technology must come down. Increasing the general public's understanding of the importance of CCS is also necessary, to ensure that the broader community supports the investments of major public resources.

Now in its third year of operation, Gassnova is well underway in addressing these tasks, and we have staked out the main direction for our activities and efforts. There may be some discussion regarding the rate of progress and the benefit of individual measures, but this will not shift our focus from our work on technology development, pilot plants and providing ongoing advice to the authorities on carbon issues.

The Government has informed Stortinget (the Norwegian Parliament) of a proposal in early 2011 concerning the first full-scale CO₂ project. This will focus on the environment and costs associated with a pioneer plant for carbon capture and storage – what is the right time and place to realise such demonstration plants, where do we find ourselves on the learning curve, and how mature is the technology?



"I feel certain that the authorities will listen to Gassnova's views, and that we will play an important role in the Government's further plans."

I feel certain that the authorities will listen to Gassnova's views, and that we will play an important role in the Government's further plans. Meanwhile, the technology centre at Mongstad (TCM) is aiming for start-up in early 2012. At the end of 2010 we allocated funds to Norcem/Heidelberg – our first project for carbon capture in the process industry. We have also conducted seismic surveys in the North Sea, looking for a suitable site for CO₂ storage.

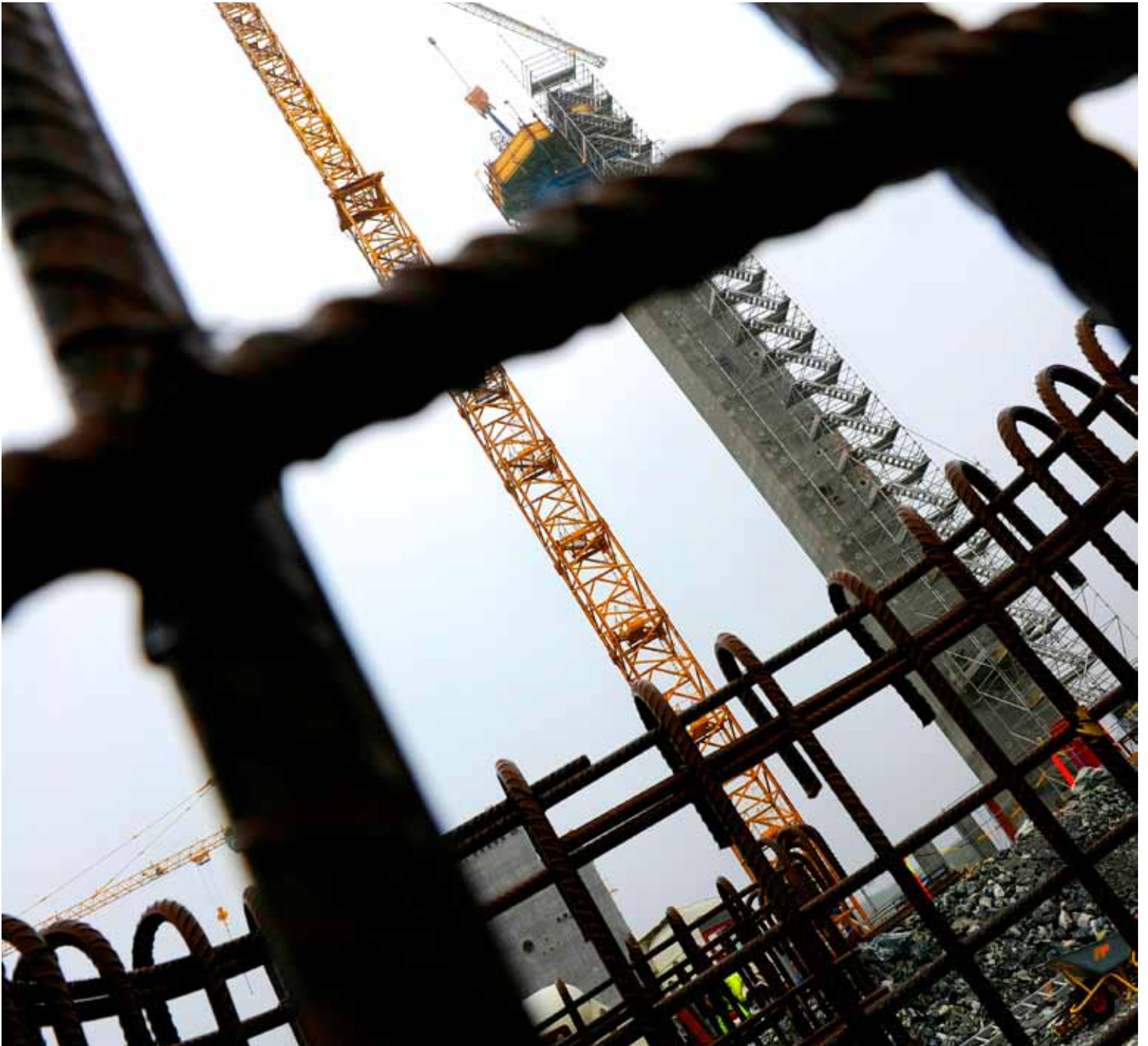
While the Gassnova organisation is meant to be small, we must also have top-notch expertise so that we can be a good steward of Norwegian interests and an attractive partner for the industry. This is a demanding mandate, and the development of our organisation and our strategy are meant to go hand in hand. We will bring in a few new employees in 2011 as well, in order to ensure continued, cautious growth.

Bjørn-Erik Haug
CEO



CARBON CAPTURE AND STORAGE

– **FROM** TECHNOLOGY DEVELOPMENT
TO A FUNCTIONING MARKET



"Norway is one of several nations pursuing development of an early full-scale CCS integrated facility."

A roadmap for carbon capture and storage

Carbon capture and storage (CCS) is an important tool in the work to reduce greenhouse gas emissions, and Norway has a strong and extensive commitment to the development of carbon management tools. Gassnova was established to safeguard the Norwegian state's interests and has overall responsibility for contributing to the development and realisation of efficient technologies for CCS. We will also make sure experience and knowledge are shared nationally as well as internationally.

So far, there is no full-scale plant for capture and storage of CO₂ anywhere in the world. The road to this target goes through technology development. The objective is commercialisation of CCS through financial stimulation of research, development and demonstration of several technologies as well as international implementation on a broad scale.

The national CLIMIT programme is important in the long-term work of technology development in this area. The new technology centre for CO₂ capture and storage at Mongstad (CO₂ Technology Centre Mongstad (TCM)) is a much-needed arena where the industry can gain knowledge and practical experience in designing, scaling up and operating such plants. This will help reduce the risks and costs in subsequent full-scale carbon capture plants. The State, represented by Gassnova, owns the technology centre together with Statoil ASA, A/S Norske Shell and Sasol New Energy Holdings Pty Ltd. It is important that the industry which causes the CO₂ emissions, participates. Those are the players who will participate in a future, functioning market for CCS.

Although we take a broad approach and are working purposefully with technology development and demonstration activities, we must recognise that the development of the first full-scale plant will be financially demanding. However, it will be a necessary

step in the work to reduce risks and costs, and it will provide valuable experience in project implementation and qualification, as well as in the development of technology and suppliers. It will also give us valuable operating experience. Commercial CCS is dependent on a functioning market. Both in Norway and internationally politicians are now preparing unified legal and financial framework conditions for the creation of such a market. The price of carbon emissions (quota price) must be increased to motivate players to use CCS technology. Norway is one of several nations pursuing development of an early full-scale CCS integrated facility.

Another of Gassnova's objectives relates to the sharing of knowledge and transferring experience. If CCS is to be widely used, particularly in a global perspective, it must be seen as a key climate measure. Gassnova is therefore active in communication and dialogue with the many different players nationally as well as internationally, and we are especially concerned to strengthen the facts base in the debate on CCS.



The research and development programme **CLIMIT**

CLIMIT is a programme for governmental financial support for research, development and demonstration of technology for CCS. CLIMIT was established by the Ministry of Petroleum and Energy in 2005 to support the development of technology for handling CO₂ from gas power plants. The support scheme was expanded in 2008 to include power production based on all fossil fuels, and in 2010 CLIMIT was opened for point source emissions from the industry.

Ensuring good coordination of R&D and demonstration activities within carbon management

The CLIMIT programme is managed by Gassnova and the Research Council of Norway. Gassnova has responsibility for the programme secretariat and manages the demonstration part, while the Research Council of Norway manages the research part.

The CLIMIT programme received a broader range of applications in 2010, and this is very gratifying since its objective is to develop several different technologies and suppliers. The programme plan for CLIMIT 2010-2012 contains the following objectives:

- » Long-term and wide-ranging support for research and development.
- » Contribute to pilot projects and demonstrations of known technology up to 2015. This technology will form the basis for the first full-scale demonstration plants, which will be built 2015-2020.
- » Encourage the development of new and more ground-breaking technologies that can be included in pilot and demonstration projects after 2015.
- » Contribute to the commercialisation of new and ground-breaking technology in the period after 2015-2020.

An external evaluation of the programme results will be conducted in the course of 2011. This will take place in parallel with the CLIMIT secretariat and programme board drawing up the strategy for the 2012-2015 period.

The secretariat of CLIMIT has during 2010 added resources in two important areas – commercialisation and cost estimates.

CO₂ capture

Research on CO₂ capture technologies has diversified further. Research is carried out in areas such as chemicals used for CO₂ capture, environmental challenges, new technologies, modelling and equipment. Work is also carried out on CO₂ capture from power plant flue gas and industrial emissions:

- » CO₂ capture chemicals for the next generation of capture facilities after combustion
- » Simulation and modelling in turbine development for hydrogen combustion
- » Development of membrane technology
- » Degradation studies of amines
- » Reduction of amine emissions
- » Amine recovery
- » Capture from industrial emissions
- » Studies of capture using a compact stripper
- » Cryogenic CO₂ capture
- » Alternative heat source for amine stripper

CO₂ transport

The objective in this technological area is to develop, confirm and demonstrate technologies for safe and cost-effective transport of CO₂. The work is based on established natural gas sector technology, but more basic knowledge and understanding of CO₂ transport is needed in areas such as improved thermodynamic models, hydrate formation, corrosion, water-solubility and coating formation

Ongoing projects:

- » A testing facility for research, qualification and improvement of technologies for CO₂ transport
- » Developing a roadmap for a possible CO₂ infrastructure for Europe from 2020.

CO₂ storage

As for developing and demonstrating safe CO₂ storage, we can to a great extent build on knowledge developed in the petroleum industry. The programme is to help develop and verify knowledge, technology and methods for safe storage and monitoring of CO₂. The EU Storage Directive will enter into force in July 2011, and guidelines for implementation of this directive were prepared in 2010. An industrial consortium led by Det norske Veritas has, with support from the CLIMIT programme, helped develop these guidelines, and they have done

a good, thorough job. Other ongoing projects in the programme are:

- » Testing and development of CO₂ storage in Longyearbyen
- » Determining the total storage capacity in the Utsira Formation
- » A pre-project for surface monitoring of sediments
- » Studies of long-term sealing properties of cap rock
- » A field laboratory in Svelvik for development of monitoring methodologies
- » Development of a simulation programme for injection and transport in the storage reservoir
- » Design of a CO₂ injection well
- » Development of a method for assessing storage potential
- » Detection of gas leaks

Other activities conducted and supported by CLIMIT in 2010

We organised the CLIMIT Days in 2010 – a two-day gathering for participants in projects supported by CLIMIT. The participants presented their projects, got to know each other and shared experiences. There were around one hundred participants during the two days. The event was a great success, characterised by positive attitudes and optimism. Some of the technical topics were later presented in the media. In addition, the CLIMIT secretariat has conducted several briefer work meetings where leading professionals from around the globe have taken part and discussed different topics:

- » Amines and environmental aspects
- » Capture from industrial sources
- » Capture with chilled ammonia
- » Estimating costs for a capture facility
- » CO₂ storage in cooperation with Geoforschungsinstitut in Potsdam

These work meetings have been well received. Experts have an international mindset and cooperate across national borders. The transfer of knowledge and sharing it internationally therefore begin at an early stage of development.

International cooperation

People linked to the CLIMIT secretariat represent Norway in several cooperation groups:

- » Representative and deputy rep. for Norway in the IEA Greenhouse Gas R&D Program
- » Member of the Government Group in the EU Zero Emission Fossil Fuels Power Plants technology platform (ZEP)
- » Member of a working group under ZEP
- » Norway's representative in the EII team for CCS
- » Head of the technical group under CSLF (Carbon Sequestration Leadership Forum, a political network forum where ministers of energy come together)

The CLIMIT programme has in the course of 2010 published six issues of its newsletter, discussing ongoing projects and other relevant topics. The CLIMIT projects have been discussed in the magazines KLIMA and GEO, and two articles were published on the website www.forskning.no.

Gassnova provided information about, and highlighted the CLIMIT programme at a number of major conferences and exhibitions in the course of the year. The biggest ones in Norway in 2010 were ONS (the oil and gas exhibition in Stavanger), NEREC (the exhibition and conference for renewable energy in Lillestrøm), and Tekna's course days in Trondheim. The major international conference in 2010 was GHGT-10 in Amsterdam. This has become the world's biggest and most influential research conference on carbon capture, transportation and storage attracting 1 550 delegates from 53 countries. Gassnova and TCM were financial sponsors for the conference.

The CLIMIT programme had supported 21 of the projects that presented research results at the conference, or 10 per cent of the total number of presentations. A further 10-15 players participated by highlighting their projects at GHGT-10.

GASSNOVA'S PROJECTS IN THE DEMONSTRATION PART OF CLIMIT IN 2010

Some of the projects run for several years, some are new, and other projects are now completed. We see a positive increase in the number of applications and allocations:

APPLICATIONS, ALLOCATIONS AND DISBURSEMENTS CLIMIT DEMO 2005-2010



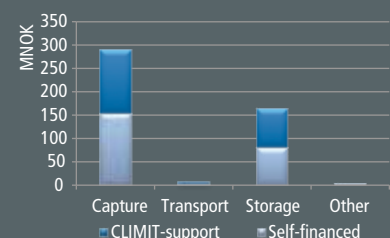
The early involvement of the industry responsible for the emissions as well as the suppliers and research institutions is crucial to ensure positive development. We have extensive cooperation, as is clearly illustrated in an analysis of the 2010 allocations to the demonstration part:

PROJECTS ALLOCATED IN 2010 Shown acc. to enterprise type



We have seen good diversity in research projects for quite some time, and this trend can now be seen in the next development step, the demonstration part. The figure below shows the diversity of all ongoing projects in the demonstration part:

ONGOING PROJECTS 2010 Total budgets, broken down by support and self-financing



Industrial demonstration



CO₂ Technology Centre Mongstad (TCM) approaches start-up: The technology centre at Mongstad is the world's largest facility for testing and development of CO₂ capture technologies.

Many want to visit Mongstad

Construction of the CO₂ Technology Centre Mongstad (TCM) is STEP 1 in the cooperation between the Norwegian state and Statoil, according to the implementation agreement established in October 2006. TCM is a necessary step in the development of technology. It is an industrial arena for learning, where the objective is to test, demonstrate and verify technologies for large-scale CO₂ capture and help develop suppliers.

There has been formidable interest in visiting the Technology Centre facility in 2010. More than 1 000 international delegations and Norwegian stakeholders came to Mongstad, and everyone is impressed by the size and complexity of the project.

Development of the plant

TCM is being built with two different technologies for CO₂ capture (amine from Aker Clean Carbon and chilled ammonia (from Alstom)), plus infrastructure and utility systems that have the capacity to support more technologies.

About two-thirds of development costs for the project are associated with delivery of infrastructure and utility systems, and about one-third with the two technology deliveries.

As of 31 December, the project has consumed a total of approximately 2.5 million work hours. The project has a good safety standard, and at year-end 2010 there has only been one injury that led to a brief absence from work. At the end of 2010, around 1 000 people are involved in the construction work, and the plant is about 70 per cent complete.

The administration complex at the plant was officially opened by Terje Riis-Johansen, minister of petroleum and energy, on 1 October. The TCM DA operating organisation has moved into the building.

Parts of the plant will be commissioned from as early as the autumn of 2011. Start-up is planned for the first quarter of 2012.

TCM DA preparing for operation

The operating organisation is now being built up. As of the end of 2010, 18 people work in the TCM DA administration – mostly personnel from the owner organisations.

An emission application was submitted to the Climate and Pollution Agency (Klif) in September 2010. This will lead to an emission permit and a measuring programme for the operation of TCM. One element in this emission application concerns the emission

and formation of other components when amine is used. There is some uncertainty regarding the impact such emissions might have on human health, and extensive work has been started to increase our competence in this field. The work is coordinated with other work being done in the full-scale Mongstad project and the CLIMIT programme.

TCM DA has signed an agreement with Statoil for operation of the facility. Personnel will be in place in the first half of 2011 to assist in preparation and commissioning of parts of the plant that have been completed.

Test agreements were prepared in 2010 for the first phase of TCM DA's test period, where the technology suppliers Aker Clean Carbon and Alstom define their respective test programs.

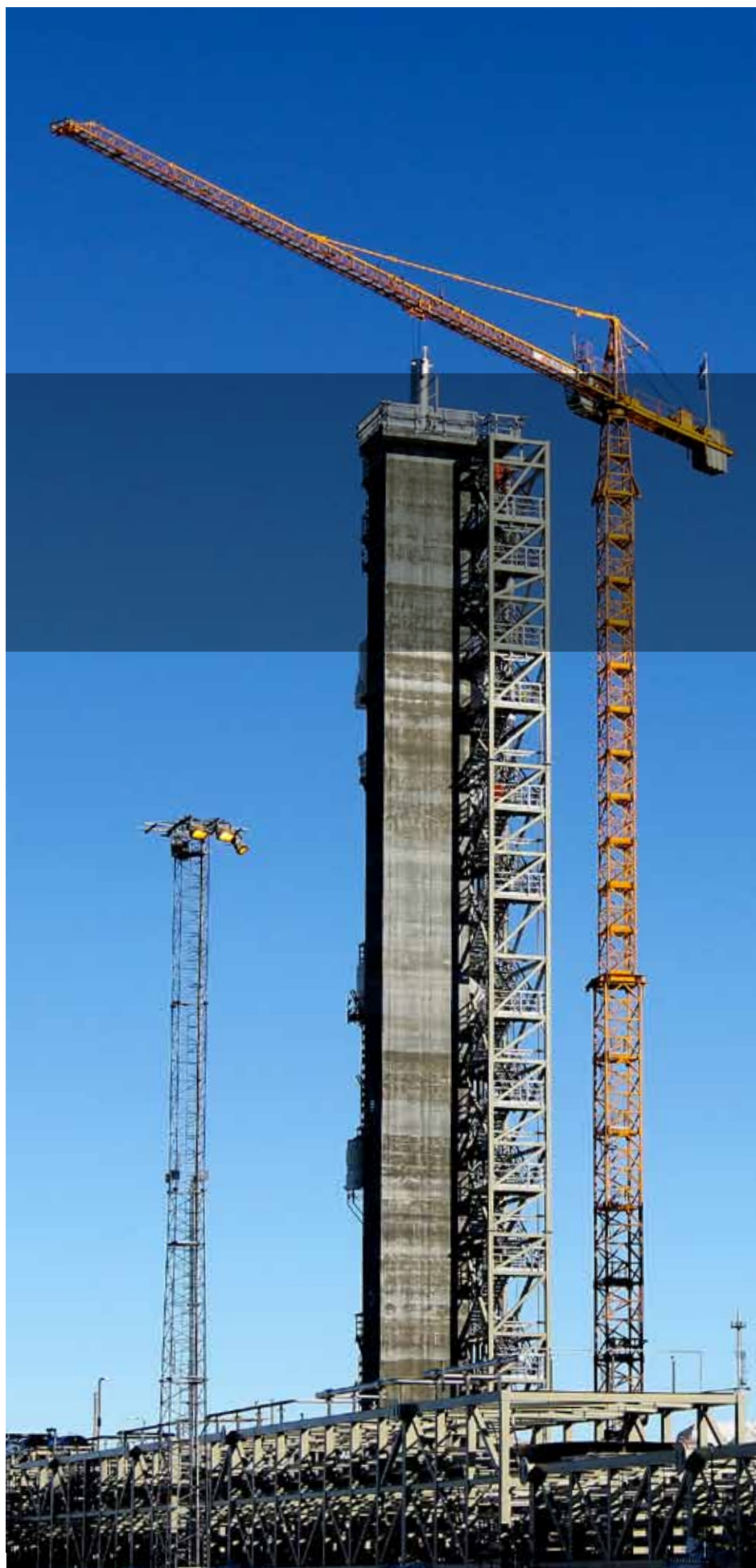
Full-scale CO₂ capture at Mongstad

The construction of a full-scale carbon capture facility for the combined heat and power plant at Mongstad will be regulated through a new agreement between the State and Statoil. This is in line with the said agreement of October 2006. CO₂ Capture Mongstad (CCM) was established as a project in July 2009.

The project was organised as a joint venture project organisation in 2010 and has representatives from Gassnova and Statoil, with Gassnova as the project manager. Statoil is the owner of the Mongstad industrial park. A steering committee has been set up for the project, with representatives from Statoil and Gassnova.

A detailed project plan has been developed with an associated budget for the phase up to the investment decision. Until September 2010 the project team prepared overall and specific procurement- and contracts strategies. Procurement processes were also initiated for a number of contracts, amongst others a major technology qualification programme for assessing possible health and environmental effects of amine emissions, and concept studies for steam production and tie in to the flue gas connection of the combined heat and power plant, conducted by the owner, Dong Energy.

In September 2010, Statoil informed the Ministry of Petroleum and Energy of its assessment of a potential increased risk of health and environmental impacts of emissions from amine-based CO₂ capture. At the same time, they recommended the inclusion of more technologies in the project. Statoil has also explained that, given this new situation, they recommend a project development where relevant technologies are qualified, so that the next stages of the project, with concept studies and preliminary engineering, only commence when at least one qualified technology is available. In connection with the state budget deliberations, the Government announced its intention to present a more detailed review of the CCS work at Mongstad for Stortinget (the Norwegian parliament) in early 2011.



Transport and storage of CO₂ from the carbon capture facility at Mongstad



The project work is well under way: Gassnova's project team has been working on assessing transport and storage solutions for CO₂ from the capture plant at Mongstad.

The project is developed in cooperation between Gassnova and Gassco, where Gassnova has overall responsibility for project implementation, plus special responsibility for qualification of the storage area, while Gassco is responsible for assessing different pipeline routes from Mongstad to the storage location. The project is currently in the concept study phase, where work is proceeding towards a choice of concept for the transport and storage of CO₂ from the capture facility. The schedule for the capture plant at Mongstad will also affect the transport and storage project.

The Johansen Formation

The main alternative for storage of CO₂ from the capture plant at Mongstad is the Johansen Formation. Activities needed to develop this into a CO₂ storage area include geotechnical work, primarily interpretation of seismic data in order to gain a better understanding and overview of the storage area.

New seismic data for the southern part of the Johansen Formation was acquired in

June 2010. The work of creating a complete geological 3D model of the Johansen Formation has begun. The model will be used to simulate the dispersion of CO₂ and, based on this work, a verification well can be placed at the optimal location.

Troll Kystnær

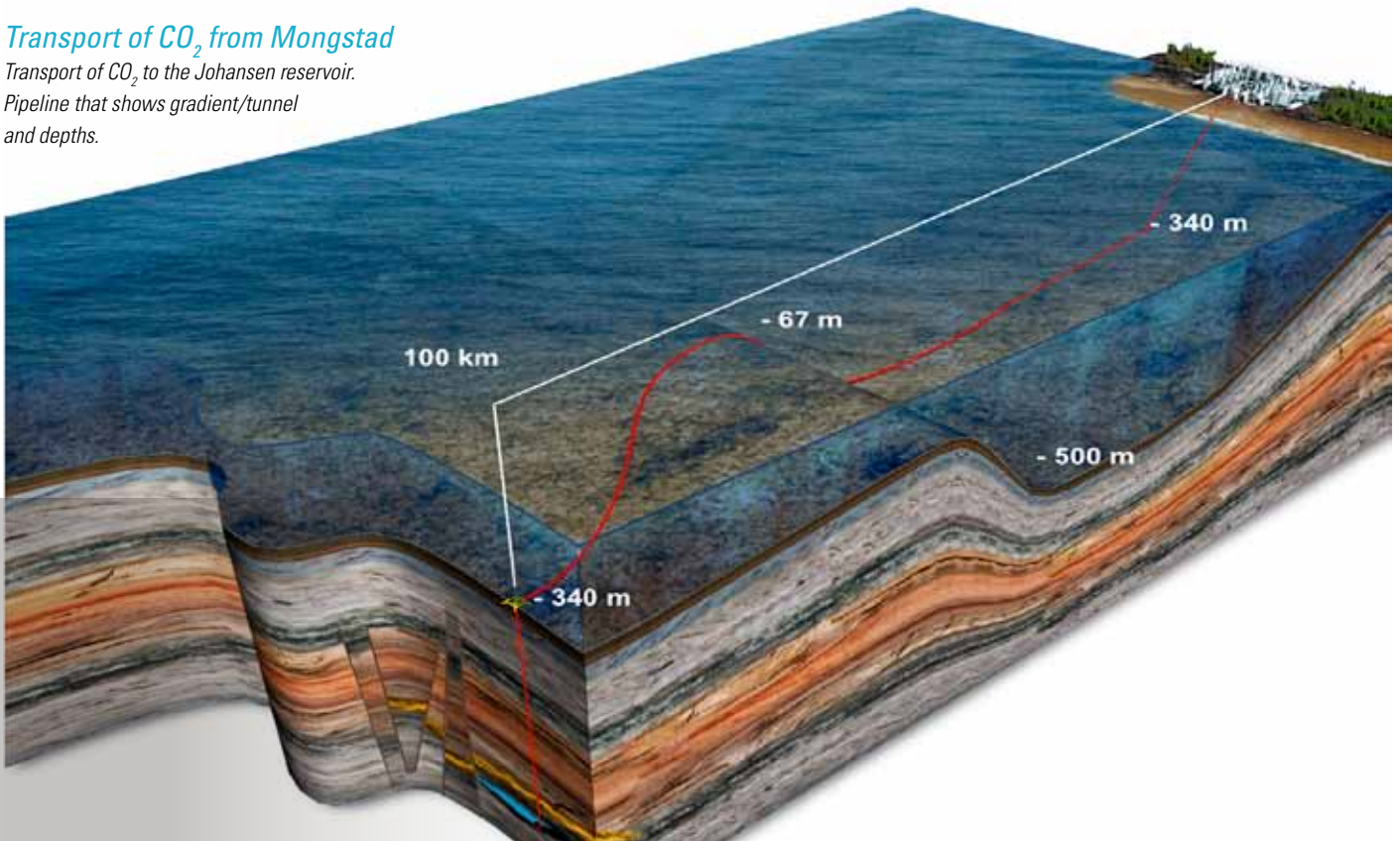
Since there is still some uncertainty whether the Johansen Formation will provide a suitable storage area, assessments were also started for three alternative locations within reasonable distance from Mongstad. These alternatives were identified in cooperation with the Norwegian Petroleum Directorate. Following an initial screening study, it was recommended that the "Troll Kystnær" (Troll Coastal) location be matured towards concept selection, as an alternative storage area to the Johansen Formation.

If Troll Kystnær is to be matured as an alternative, further 3D seismic information for this area will also be needed. A contract for acquisition of seismic data has been awarded, but the work was stopped in the autumn of 2010 due to ongoing mackerel fisheries in the area. The plan is to restart the seismic acquisition activity in the spring of 2011.



Transport of CO₂ from Mongstad

*Transport of CO₂ to the Johansen reservoir.
Pipeline that shows gradient/tunnel
and depths.*



"The project is currently in the concept study phase, where work is proceeding towards a choice of concept for the transport and storage of CO₂ from the capture facility."

Greater understanding of CCS in society at large

Considerable public funding are being spent on developing and implementing measures to protect our environment and climate. This work is rooted in our national climate and environmental policy.

Gassnova's role is to contribute to the realisation of CCS in Norway, and to the spread and internationalisation of such technologies. In order to promote this work we have established a dialogue with a number of community players, stakeholders and decision-makers on what, how, and why we are doing this, and when we might be able to realise our objectives, so that the society at large will gain a better understanding of CCS.

Gassnova communicates through extensive personal contacts, by participating in contact meetings, networks, conferences and exhibitions nationally and internationally, as well as through the work in our projects. To raise public awareness and create more understanding in the community, it is important for Gassnova to be visible in the public arena.

A media analysis conducted shows that Gassnova is most visible in the national media,

even though the number of features is higher in regional and local media. The explanation for this may be that the national media reach a larger audience. Gassnova is largely presented as an advisor and expert on CCS. The Mongstad issue was a focus in Norwegian media for large parts of 2010. Gassnova e-mails its newsletter to a wide network of recipients every week. Here we include relevant news on carbon management, copied from national and international media.





INTERNATIONALISATION

If commercial carbon management is to gain ground, a functioning market is needed. Together with 29 other countries, the government has started a joint international centre in Australia to encourage the implementation of CCS, the Global CCS Institute.

Authorities and politicians in Norway as well as abroad are working to develop unified legal and financial framework conditions for the creation of such a market.

The spread of technologies for CCS will best be realised

through broad international industry participation. For Norway, with few players, it is natural to cooperate internationally.

Norway's contribution to the deployment of CCS technologies will not least occur through those who participate in projects organised by the CLIMIT programme, the technology centre at Mongstad and the full-scale projects. The technology will also be spread through export of Norwegian technology, products and services, and participation in international projects.





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