

# YEAR 2013

GASSNOVA SF - ANNUAL REPORT 2013



Gassnova shall contribute to facilitating solutions designed to ensure that CCS technologies are used and become an effective climate measure.

GASSNOVA 

OUR VALUES:

# INTEGRITY COURAGE RESPECT RESPONSIBILITY

## **GASSNOVA SF**

The Norwegian state's enterprise for CCS

The Enterprise General Meeting has decided that Gassnova shall manage the Norwegian state's interests in the following CCS projects:

- Technology centre for CO<sub>2</sub> capture at Mongstad (TCM)
- Transport and storage of CO<sub>2</sub> from Mongstad

In addition, it was decided at the Enterprise General Meeting that Gassnova shall safeguard the Norwegian state's interests under Step 2 of the Development Agreement related to full-scale CO<sub>2</sub> capture at Mongstad. On 20 September 2013, the Government announced that the work on the full-scale project at Mongstad would be terminated. In this context, the Enterprise General Meeting assumes that Gassnova shall also manage the Norwegian state's interests during the period the project is being phased out. Furthermore, Gassnova shall be able to quickly assist the MPE with advice and perform tasks associated with the purposes and projects the enterprise is following up.



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FOREWORD:

# SUCCESS MORE IMPORTANT THAN EVER



*Tore Amundsen*

TORE AMUNDSEN  
CEO



We must start using the climate measure CCS (CO<sub>2</sub> capture and storage) if the world is to reach its climate goals. The technology is ready for full-scale demonstration. Gassnova's most important tasks are contributing towards full-scale development, improvement and demonstration of the technology.

The UN's climate panel (Intergovernmental Panel on Climate Change) has never been clearer: The interim report from September concludes that global warming is real and man-made and that greenhouse gas emissions are the main reason for the warming. Experts point to CCS as the single most important technology to reduce emissions.

Norway has made extensive investments in developing technologies for capture and storage of CO<sub>2</sub>. As the Norwegian state's enterprise for CCS, Gassnova plays an important role. However, 2013 brought considerable changes in Gassnova's tasks. On 20 September, the Government announced that the full-scale project at Mongstad would be terminated. Uncertainty regarding the future of the refinery, and thus also the combined heat and power plant, was the most important reason for the decision.

At the same time, Norway's ambition to realise full-scale CCS by 2020 is stronger than ever before. Gassnova has assessed potential Norwegian CCS projects, and the work shows that several Norwegian emission sources could be relevant for full-scale CCS and appropriate candidates for further studies. Nevertheless,

Gassnova believes it will be challenging to achieve this by 2020, primarily because it will take time to develop storage sites. One possibility is international cooperation: This will allow Norway to contribute to realising a good foreign project in the near future, while we simultaneously continue working on a demonstration in Norway.

Realisation of full-scale CCS at Mongstad became more complicated than many imagined when the Implementation Agreement was signed in 2006. The Solberg Government will now draw up a new CCS strategy. Here it will be important to agree on what will be the main objective of this work, so that various measures can be evaluated and assessed against each other. Taken to the extreme, research, development and pilot testing are useless if the technology is not demonstrated in full-scale. Only after this step can the technology be used with acceptable risk.

Norway's most important tool in the work on promoting effective CO<sub>2</sub> capture technologies is the Technology Centre at Mongstad (TCM). In its first full year of operation, TCM helped mature new, commercial suppliers of CO<sub>2</sub> capture technology. Both Aker Solutions and

Alstom have participated in the technology qualification programme for Mongstad full-scale and used the facilities at TCM as their qualification plants. Both players have stated that the testing at TCM has been valuable and has improved their technologies. To create competition in the market for first-generation capture technologies and promote the next generation, TCM must be developed further and prioritised in upcoming years.

Gassnova manages the CLIMIT research and development programme together with the Research Council of Norway. Through the CLIMIT programme, Gassnova supports a number of technology development and demonstration projects for capture, transport and storage. A unique pilot project for CO<sub>2</sub> capture from Norcem's cement plant in Brevik, Norway started up in June with support from CLIMIT.

Norway must succeed in its efforts and promote effective technologies for capture and storage of CO<sub>2</sub> so that people do not render the world uninhabitable for future generations. Gassnova is Norway's most important tool.

## TECHNOLOGY DEVELOPMENT:

# Potentially ground-breaking

We currently have capture technologies that are ready to be used in full-scale CCS demonstration facilities. However, these technologies will never be cheap enough for all of the world's countries to afford them. Capture technologies are improved at the Technology Centre at Mongstad. At the same time, Gassnova, through the CLIMIT programme, supports a wide range of potentially ground-breaking solutions.

Many are of the opinion that the main goal of the Norwegian investment in CCS is to develop technologies that can be commercialised, in other words, technologies that are cost-efficient enough to be demanded in a market for emission-reducing solutions. This will naturally also depend on factors outside of the technology developers' control. As long as it is almost free to emit CO<sub>2</sub>, it will never be commercially profitable to start using the technology.

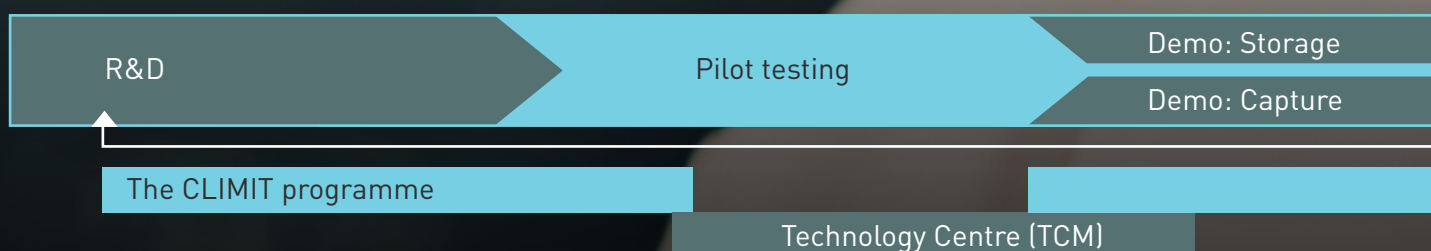
The CLIMIT programme includes the Research Council of Norway's subsidy scheme for research and development and Gassnova's support for development and demonstration of CCS technologies.

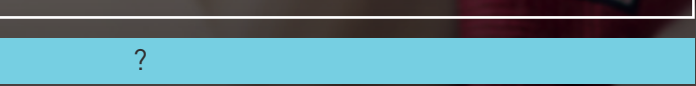
One of CLIMIT's goals is contributing to cost reductions and wide international application of technologies for capture, transport and storage of CO<sub>2</sub>. At the same time, CLIMIT contributes to exploitation of national advantages and development of new technology with international potential.

Through the CLIMIT programme, Gassnova supports a number of technology development and demonstration projects. The portfolio comprises capture, transport and storage projects. The common denominator for the projects is that they are tested in a smaller scale. This allows for testing a wide spectrum of technologies.

An important criterion for receiving support in this phase is that the technologies are potentially ground-breaking, which means that the energy consumption and cost profile is substantially better than for the mature technologies. If the results in laboratory and pilot-scale are promising, the technology is ready to be tested in a larger facility. Scaling up is not always successful. Several technologies fail at this stage. However, the possibility of finding a revolutionary solution is there, and a broad-based commitment is therefore necessary.

## TECHNOLOGY DEVELOPMENT CHAIN





TECHNOLOGY DEVELOPMENT:

# The CLIMIT project: Norcem

The Norcem cement plant is located in Brevik in Nedre Telemark, and is owned by the HeidelbergCement Group. This is the location of a unique CO<sub>2</sub> capture project.

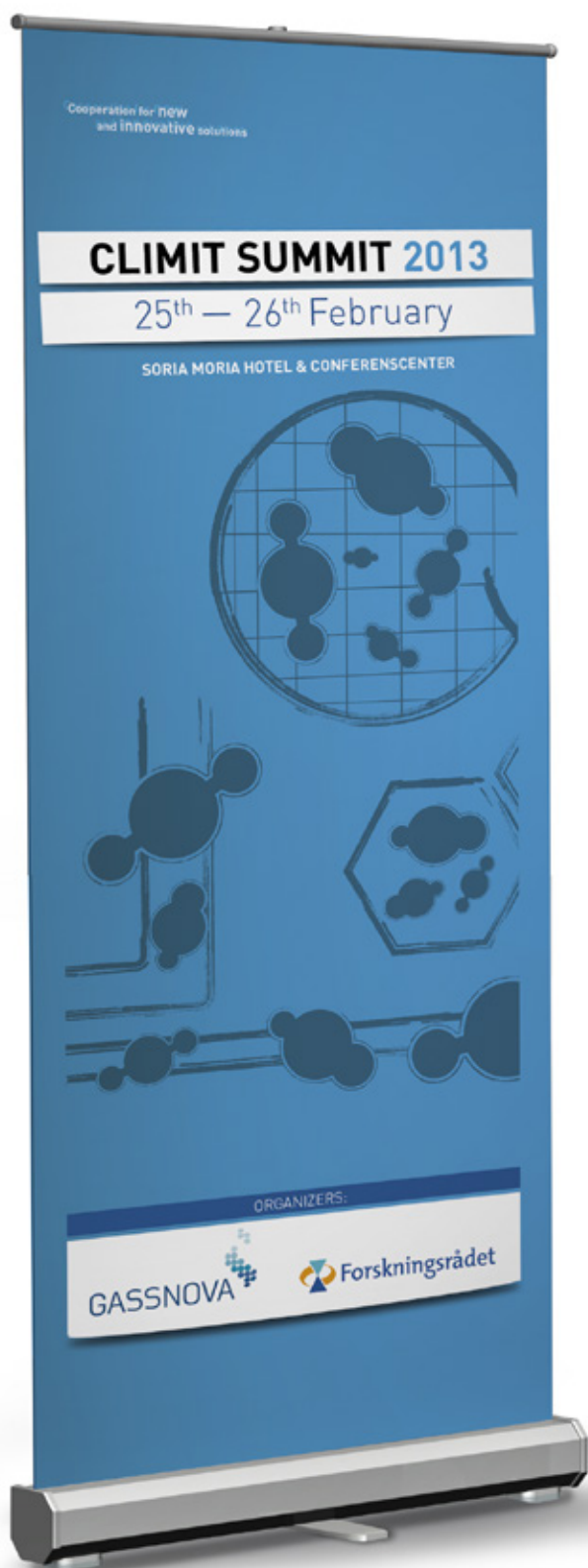


Heidelberg has a vision that their products will be carbon neutral in a lifecycle perspective by 2030. Carbon capture and storage is an important policy instrument in order to achieve this vision.

The cement plant in Brevik was chosen as a suitable location for testing, e.g. as a result of considerable financial support from Gassnova. Norcem has annual CO<sub>2</sub> emissions totalling 950,000 tonnes, and the flue gas contains an average of around 18 per cent CO<sub>2</sub>. The ambition is for the results achieved here to be utilised in other cement plants owned by Heidelberg.

The project started in May and will be ongoing until 2017. The capture facility consists of three units, and a total of four technologies will be tested in the first stage: Aker Solutions' amine technology, RTI's technology with solid adsorbents, DNV GL/NTNU/Yodfat Engineers' membrane technology and Alstom's technology with calcium cycles. The testing can take place in parallel and the composition of the flue gas from the plant can vary. There will also be opportunities for other suppliers to test their capture technologies.





# The CLIMIT summit 2013

Goal-oriented work has allowed Norway to achieve world class research within CCS in just a few years. At the CLIMIT summit in February, nearly 200 participants from research institutions, the industry and authorities gathered to share knowledge and experience.

The conference was held for the third time at the Soria Moria hotel and conference centre in Oslo. Researchers, the industry and representatives from the authorities all gathered here to share knowledge and experience. For the first time, the conference had an international element with presenters and participants from the US, UK, Sweden and Germany.

There is a strong focus on CCS in Norway. "Few countries spend as much money on CCS as Norway", said Secretary General of the Ministry of Petroleum and Energy Elisabeth Berge in her opening speech at the summit.

The participants could learn about the CCS activities in the US and UK, among other things. The energy company EoN and the technology supplier Alstom presented their perspectives on CO<sub>2</sub> capture, and the Norwegian Petroleum Directorate gave a presentation on the storage potential on the Norwegian shelf. The results from the CLIMIT projects were presented during two parallel sessions. There was also a poster exhibition where more than 60 CLIMIT projects were represented. Both presentations and posters were of a high standard, and helped give the participants deeper insight into this important discipline.

After a successful event and inspiring summit, the CLIMIT secretariat is looking forward to organising the CLIMIT summit once again in 2015.

# Significant knowledge and valuable experience

TCM has completed its first full year of operation and helped mature new, commercial suppliers of CO<sub>2</sub> capture technology.

The purpose of TCM is to improve CO<sub>2</sub> capture technologies and make them cheaper, so they can be utilised and help the world reach its climate goals. The operating experience which the technology suppliers gained at TCM is very valuable. The challenges that arise and are handled along the way in the test programmes are value creation in practice. Though both the amine and ammonia facilities have run into challenges along the way, there have been no problems that could not be

solved. The solutions achieved help advance the technologies. We now have unique experience with a climate technology that the world must use.

## MARKET FOR DIFFERENT TECHNOLOGIES

The operating experience the suppliers gained from TCM is invaluable when they offer their technologies to industry owners with CO<sub>2</sub> emissions. Being able to show that the technology works in practice

on authentic flue gas from a gas power plant will be key in reducing the risk for the technology suppliers and their customers. There are currently no other industrial-scale test centres for CO<sub>2</sub> capture where the suppliers can examine how their capture solution works on flue gas from gas power plants.

In addition, the capture technologies have been tested on flue gas from the refinery. At TCM, we have experienced that the capture

## Milestone Mongstad 2

During Milestone Mongstad 2 on 17 September, TCM and its technology partners, Aker Solutions and Alstom, presented promising results from the test centre's first year in operation. More than 150 international CCS professionals attended this milestone for TCM.

On the right are some of the technical advances managing director of TCM Frank Ellingsen highlighted in his presentation:

- Development of documented and transferable experience from operation, start-up, run-down, etc., which will be very useful when developing full-scale plants.
- Developed and verified simulation tool for the total plant based on ammonia and amines, used for planning, operation and evaluation of the daily activities at TCM.
- Established a tool box for analyses at the laboratory.
- Operated with zero injuries and environmental impact.
- Developed a tool box for process monitoring including emissions.
- Extensive research on potential effect of amines. More than 55 external studies have been conducted.
- Established a test centre network with national and international institutes and research organisations.

technologies have different challenges with regard to the various flue gas sources. Impurities in the flue gas affect the absorbents differently. Many different flue gas sources from industry and power production must be cleaned in the future if the world leaders take the climate commitments seriously. We will therefore also need different capture solutions.

#### GOOD RESULTS

Both Aker Solutions and Alstom have participated in the technology qualification programme for Mongstad full-scale and used the facilities at TCM as their qualification plants. Aker completed the qualification programme with good results. Aker's technology has developed substantially during the time it was tested at TCM – from being a technology development project it has now reached a maturity level where the technology

is ready for first-time major-scale application.

The ammonia facility has also provided considerable knowledge. Among other things, two major modifications of the facility were carried out to increase energy efficiency. Alstom has achieved a high CO<sub>2</sub> capture rate and low emissions when the installation is in operation. As a result of technical problems, Alstom has had less uptime than planned, and the final results of the testing are not yet ready.

#### MANAGEABLE ENVIRONMENTAL RISK

Both the CLIMIT programme, full-scale project and TCM have carried out substantial work to close knowledge gaps when using amine as a capture chemical. Thanks to this work, the environmental risk associated with amines is currently

manageable and we see that emission-reducing measures work. The knowledge has already been transferred to other projects. The "tool box" developed to monitor the emissions has been put to use and has, according to SaskPower, contributed to preventing a delay in the Boundary Dam full-scale facility in Canada.

Several capture technologies are currently ready to be used in full-scale CCS facilities. These first-generation technologies all belong to the same "technology family" and are also relatively expensive. In the future, it is a goal for TCM to identify next generation CO<sub>2</sub> capture technologies. The objective is reducing costs, which is essential in order for the vast majority of emission sources to finally have the opportunity to start using the technology.

*Managing director of TCM  
Frank Ellingsen during  
Milestone Mongstad 2.*



# THE MONGSTAD PROJECT HAS PROVIDED IMPORTANT KNOWLEDGE

Planning of full-scale CCS at Mongstad was terminated in the autumn of 2013 because the Government believed the uncertainty associated with the project was too great. However, this work has generated important knowledge which others and future full-scale projects can benefit from.

In October 2006, Statoil was granted an emissions permit for a new combined heat and power plant at Mongstad. The Red-Green Government policy platform from 2005 – the Soria Moria declaration – stipulated that new licenses for gas power should be based on CO<sub>2</sub> removal. An agreement between the Norwegian State and Statoil regulated the CCS cooperation at Mongstad. As part of this agreement, Statoil delivered a master plan for CCS at Mongstad in February 2009.

## QUALIFIED CAPTURE TECHNOLOGY AND SAFE USE OF AMINES

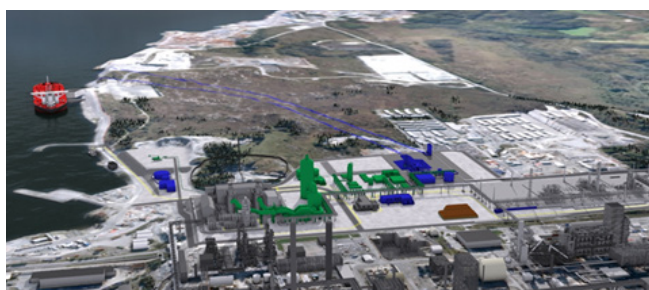
The work on planning the capture facility proved more complicated than first imagined, and the project was delayed twice. First, the investment decision was postponed from 2012 to 2014, following a comprehensive assessment of the scope of work and risk. The investment decision was then postponed to 2016, as a result of Statoil, in the autumn of 2010, reporting an increased health and environmental risk associated with use of amines and the need to carry out a more extensive technology qualification programme.

This led to broad-based research work on the health and environmental effects associated with the amine technology. Nitramines and nitrosamines can form when amines are emitted to air and discharged to water. Prior to starting

the research work, there was very little knowledge regarding how hazardous these substances were and how much the various technologies release.

A "tool box" has now been developed consisting of methods and tests to examine whether each amine technology is safe. We also know more about the substances' damage potential. Most importantly, however, we now know that amine technology can be used safely.

In parallel with the amine research work, five capture technology suppliers have undergone a technology qualification programme. Several of the technologies are currently at a maturity level ready to be used in a full-scale capture facility. More mature technologies provide competition in a market and normally lower prices.



“Today, several of the technologies have matured sufficiently for use in a full-scale capture facility”

### TRANSPORT AND STORAGE

For several years, Gassnova has been working on solutions for transport and storage of CO<sub>2</sub> from both Kårstø and Mongstad. The enterprise has studied a number of potential storage locations in the North Sea, which has a considerable storage potential.

The Johansen formation was considered the most suitable storage site for the full-scale project at Mongstad, due to its safety, distance and capacity within the project's timeframe. As of today, this is one of the most studied storage sites on the Norwegian shelf. In the summer of 2010, seismic data was collected on the Johansen formation, and it is assumed that Johansen can hold at least 160 million tonnes of CO<sub>2</sub>.

In a study phase, there will always be uncertainties associated with the properties of the storage formation. The uncertainty cannot be substantially reduced until e.g. data has been collected from a drilling operation. In order to ensure that a storage site would be available for the capture facility at Mongstad when it was ready to start up, a decision was made to investigate an alternative storage site. Troll Kystnær was chosen for this purpose. In the summer of 2011, seismic data was collected on Troll Kystnær, and the report was completed in the autumn of 2012.

### TECHNICALLY FEASIBLE

It is fully technically feasible to store CO<sub>2</sub> under the seabed on the Norwegian shelf. Statoil, for example, has stored

CO<sub>2</sub> from the Sleipner field in the Utsira formation since 1996. Data and models from Gassnova's transport and storage projects have been made available for research and development projects in Norway and internationally, and have thus contributed to further technological development.

Norwegian authorities are working to establish legal and commercial framework conditions for transport and storage of CO<sub>2</sub>. Gassnova plays an important role as an adviser to the Ministry of Petroleum and Energy in this work.



## USEFUL KNOWLEDGE FROM THE FULL-SCALE PROJECT

The work on planning the full-scale project at Mongstad was stopped in September. Despite the main goal not being achieved, the work has certainly not been in vain.

The technology qualification programme under the auspices of Mongstad full-scale has helped mature five supplier's capture technologies. The full-scale project has performed substantial work as regards closing knowledge gaps within health and the environment. The substance group amines, which is currently used by the majority of capture suppliers, forms decomposition products that could potentially be carcinogenic when emitted to air in large volumes. The full-scale project has developed a "tool box" to monitor the emissions. This "tool box" has already been put to use in the Boundary Dam full-scale project in Canada. According to SaskPower, which is constructing the facility, it has prevented a delay of the project.

Knowledge from the full-scale project is made available to the outside world. Gassnova publishes reports, participates in conferences and cooperates with various players on a global scale. This is how future projects – domestic and international – will reap the benefits from built-up knowledge and be more likely to succeed in full-scale CCS.

# Sharing important knowledge with the world

The Technology Centre and the full-scale project at Mongstad have yielded experience and developed knowledge which Gassnova and its partners want to share with the outside world. A full-scale project in Canada has already benefitted from the knowledge.

Challenges are often encountered along the way when developing and scaling up new technology. Most problems can be solved, but this could be time-consuming and expensive. It is therefore vital that the technological environments exchange experience and share knowledge with each other, so that there are no unnecessary mistakes.

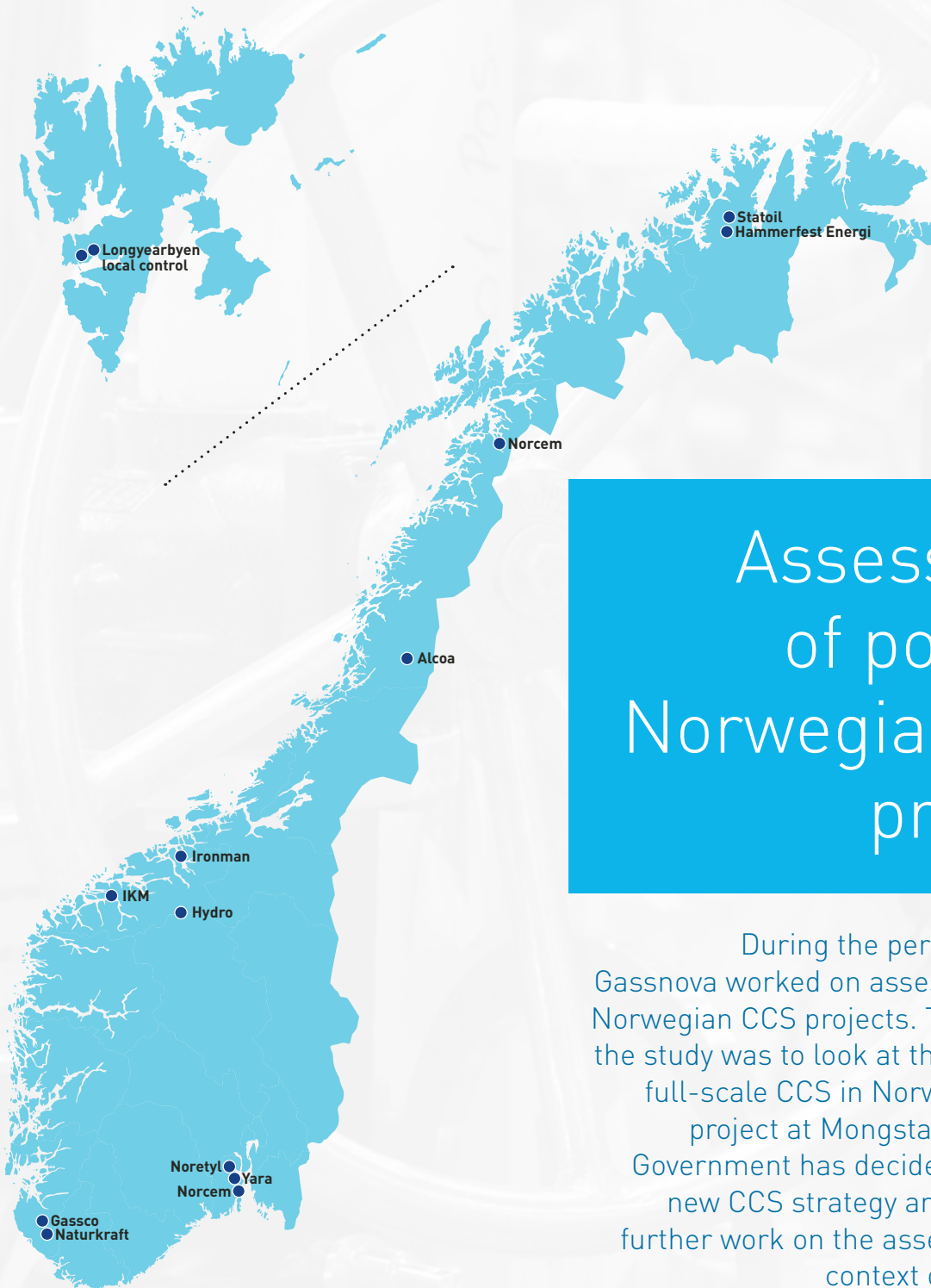
### NINE TEST CENTRES AT FIRST GATHERING

TCM has taken the initiative to establish an international network of large test centres. The purpose of the CCS test centre network is knowledge sharing.

At the Carbon Sequestration Leadership Forum's (CSLF's) Ministerial Meeting in Washington DC in November, US Minister of Energy

Ernest Moniz and Norway's Minister of Petroleum and Energy Tord Lien agreed to strengthen cooperation between test centres for carbon capture and support the CCS test centre network.

The first gathering was held in Brussels a few weeks later. Representatives from nine test centres attended, as well as one representative from the EU Commission. Apart from TCM, the organisations that participated in the network's first knowledge sharing gathering were: NCCC - Southern Company from the US, SaskPower from Canada, ENEL Engineering and Research from Italy, DOOSAN Power Systems from the UK, E.ON, RWE Group and EnBW from Germany and Ciuden from Spain.



## Assessment of possible Norwegian CCS projects

During the period 2011-2013, Gassnova worked on assessing potential Norwegian CCS projects. The purpose of the study was to look at the possibility of full-scale CCS in Norway beyond the project at Mongstad. The Solberg Government has decided to prepare a new CCS strategy and will view the further work on the assessment in the context of the strategy.

In December 2012, Gassnova delivered a status report to the Ministry of Petroleum and Energy (MPE) which pointed out five Norwegian emission sources that were considered relevant for further studies of full-scale capture, transport and storage of CO<sub>2</sub>. In 2013, Gassnova invited emission owners to participate in a competition to have CCS assessed for their activities. In November 2013, Gassnova was asked to cancel the procurement. Termination of the full-scale project at Mongstad

changed the preconditions for the study, and the new Government also wanted to look at the further work in the context of a new strategy.

According to their Sundvollen declaration, the new Government has an ambition to realise at least one full-scale CCS facility by 2020. Further work to assess potential CCS projects in Norway will be an important element in this work.

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