

# GASSNOVA

The Norwegian state enterprise for  
carbon capture and storage



**ANNUAL REPORT** 2012

## **GASSNOVA HAS BEEN ASSIGNED RESPONSIBILITY FOR A VOLUNTARY PROJECT FEW OTHER COUNTRIES THAN NORWAY COULD HAVE ACHIEVED.**

Finding the CO<sub>2</sub> answers of the future requires major resources. The Norwegian oil and gas adventure has also provided us with important knowledge and expertise. The reward of success will be worth the effort.

We are proud of the important job Gassnova does: We contribute to Norway's position as the world-leader in combatting climate change, and to the solutions that will help the world win this battle.

Gassnova SF

## **GASSNOVA SF**

THE NORWEGIAN STATE ENTERPRISE  
FOR CARBON CAPTURE AND STORAGE

One of Gassnova's goals is contributing to increased knowledge about CCS, nationally and internationally by spreading the results achieved.

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### **GASSNOVA'S OBJECTIVE AND MAIN TASKS RELATE TO:**

- » Managing the Norwegian state's interests in CCS and implementing the projects approved by the general meeting
- » Advising the Ministry of Petroleum and Energy in CCS issues
- » Contributing to technology development and expertise build-up through specific CCS projects and implementation of the CLIMIT programme.

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Our values:

**NTEGRITY RESPECT COURAGE RESPONSIBILITY**



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**PHOTOS IN THIS ANNUAL REPORT:**

Cover: Helge Hansen | Page 2-8: TCM DA | Page 13 og 16: Styrk Fjærtøft Trondsen | Page 20: iStockphoto.com

## NORWAY'S EFFORTS IN TECHNOLOGY DEVELOPMENT ARE CRUCIAL

**An alarming climate record characterised 2012: Never before has less ice been measured in the Arctic than in September. Scientists link the melting ice with higher temperatures and climate changes. This is most likely just the beginning. We need to fight climate change now!**

Gassnova will facilitate the birth of a climate technology the world cannot do without. Capture and storage of CO<sub>2</sub> from coal and gas power plants, as well as other industrial sources, could represent as much as one-fifth of the necessary emission cuts in 2050, according to the International Energy Agency (IEA).

Norway's efforts are crucial. Planning and realising CCS projects is time-consuming, but Gassnova and its partners reached a proud milestone in May 2012: The CO<sub>2</sub> Technology Centre Mongstad (TCM), which is the world's largest facility for testing and development of CO<sub>2</sub> capture

technology, was opened by Prime Minister Jens Stoltenberg on 7 May. The world's suppliers of CO<sub>2</sub> capture technology can come here to test, demonstrate and improve their solutions. The goal is to make the technology cheaper, safer and ready for use.

The opening of TCM was heard 'round the world. High-ranking representatives from a number of international organisations and companies were present. The event was covered in multiple international media. Apart from the Prime Minister, the Norwegian government was represented by Minister of Petroleum

and Energy Ola Borten Moe. Around 100 people attended the opening which helped reinvigorate CCS environments across the globe.

Many countries are working determinedly on CO<sub>2</sub> capture and storage. However, several CCS projects were shelved on a global basis in 2012. Although new projects were started, this delays the spread of CCS, since the road from identifying projects up to construction and operation is long. The EU's NER 300 programme was unable to finance a single CCS project, mainly as a result of a lack of financial commitment from national authorities.







In the US and Canada, where the projects are driven by the possibility for sale of CO<sub>2</sub> for improved oil recovery, projects are realised at a more rapid pace. In September we received the positive news that Shell in Canada will build the world's first CCS project for oil sand. In China, which arrived late in the CO<sub>2</sub> capture and storage game, things are now moving along nicely, and several new projects have been initiated.

Technology development is the key term for 2013. One of Gassnova's most important tasks is contributing to development of cost-efficient CCS technology which can be

commercialised. TCM is a perfect example of this and is ready to accommodate leading international technology suppliers. Several have already shown interest. Furthermore, TCM will contribute to share and spread knowledge and will participate in different global networks. The CLIMIT research programme will spearhead cutting-edge technologies. The technology qualification programme headed by Mongstad Full-Scale will be completed this spring. Thus, Norway's efforts could become an invaluable contribution in the world's climate struggles.



Tore Amundsen // CEO

The opening of the CO<sub>2</sub> Technology Centre Mongstad was heard 'round the world. Our Prime Minister and Minister of Petroleum and Energy were joined at the ceremony by high-ranking representatives from other countries and international organisations, as well as an international press corps.



## QUOTES ABOUT TCM:

**Prime Minister  
Jens Stoltenberg:**  
"Today we open the world's largest and most advanced laboratory for testing CO<sub>2</sub> capture technologies. A unique test centre which will address one of the biggest challenges of our time."

**Oil & energy minister  
Ola Borten Moe:**  
"The knowledge we acquire here at Mongstad will help facilitate future CO<sub>2</sub> capture initiatives and, in turn, combat climate change."

**IEA-chief  
Maria van der Hoeven:**  
"If CCS fails, we need to find other ways to slash CO<sub>2</sub> emissions, which will be very, very difficult: We must succeed!"

**TCMs CEO  
Tore Amundsen:**  
"TCMs unique flexibility allows us to test two or more technologies at the same time with access to flue gas from a gas-fired combined heat and power plant and a catalytic cracker. The opening ceremony is an important step towards commercialisation of this type of technology."

**Damian Carrington  
in The Guardian:**  
"CCS has been hobbled by the economic crisis, and Europe is far behind the US – but a new Norwegian plant provides hope."



# HEARD AROUND





# D THE WORLD

# TCM

## TESTING ARENA WITH HIGH AMBITIONS

The CO<sub>2</sub> Technology Centre Mongstad (TCM) is the world's largest centre for testing and improvement of CO<sub>2</sub> capture technologies. The goal is to produce technologies that are good enough to be utilised in full-scale facilities across the globe. CO<sub>2</sub> capture is vital in order to combat the climate changes the world faces.

### FACTS

- » **More possibilities** for technology development: amine, chilled ammonia and other (available lot)
- » **Capacity:** up to 100 000 tonnes CO<sub>2</sub>/year
- » **Capture method:** Post-combustion (CO<sub>2</sub> capture after combustion)
- » The facility is equipped with more than 100 sampling points and 4000 monitoring instruments are connected to a designated control room
- » Fully staffed 24/7

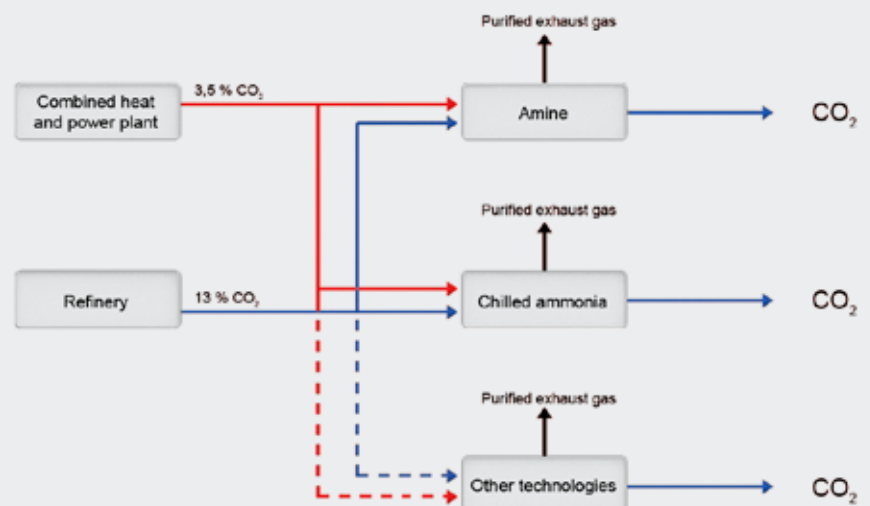
### OWNERS

TCM is a collaborative projects between:

- » Gassnova 75.12 %
- » Statoil ASA 20.00 %
- » A/S Norske Shell 2.44 %
- » Sasol New Energy Holdings Pty Ltd. 2.44 %

### AMBITIONS

- » Testing, verification and piloting CO<sub>2</sub> capture technology
- » Reduce costs, as well as technical, environmental and financial risk
- » Promote market development for carbon capture technology
- » Contribute to knowledge sharing and international application





Work is currently underway on several different CO<sub>2</sub> capture technologies. Most are still in early development phases, immature and have only been tested on a lab-scale or in small pilot facilities. Today, TCM is an arena for testing of the most mature technologies, where we can harvest experience with them, in order to justify building a full-scale CCS facility. The main challenges for the most mature CO<sub>2</sub> capture technologies are related to costs and energy use. If we succeed in TCM, technology that has been tested there can hopefully be applied globally in the near future.

The partners in TCM have initially agreed to operate the facility for five years. Gassnova and the partners are working on developing a strategy for use of TCM beyond the five-year period.

#### NEED FOR MORE ENERGY AND LOWER EMISSIONS

TCM focuses on so-called "post-combustion" technologies (CO<sub>2</sub> capture after combustion). The advantage of this technology is that it can be retrofitted on existing facilities and used on both power plants and industrial plants.

According to the International Energy Agency (IEA), half of the emission reductions which CCS can contribute to, come from industrial emissions. The IEA's statistics indicate that approx. 80 per cent of the current energy supply comes from combustion of coal and gas. Coal alone constitutes about 1 500 gigawatts of installed capacity, which corresponds to about 4 000 Kårstø power plants.

On a global basis, a whopping 1 200 new coal power plants are under development, according to an analysis from the World Resources Institute from November 2012. These power plants will release as much CO<sub>2</sub> as all of China does today.

The world's population needs more energy. The earth is dependent on reductions in greenhouse gases to limit the consequences of global warming. If we succeed in developing CCS technology, we can achieve both goals at once. If we do not succeed, the costs for society will be very high, according to the IEA.

The purpose of TCM is to gain knowledge and develop solutions that can reduce costs and technical and financial risk related to full-scale CO<sub>2</sub> capture from both coal and gas power plants, as well as other industrial plants.

### WORLD LEADING: TCM is unique in several ways:

- » Firstly, multiple technologies can be tested at the same time. Currently, Aker Clean Carbon is working on improving its amine technology and Alstom on their carbonate technology. As part of the technology qualification programme for Mongstad Full-Scale, Aker Clean Carbon and Alstom will verify that their technologies can be scaled up and used at the power heating plant at Mongstad. This work is done at TCM. Several other international technology suppliers have already shown interest in testing at TCM. The third lot is available for new, cutting-edge technologies. When Aker and Alstom have completed their test periods, other suppliers will be able to test their technologies in these facilities as well.
- » Secondly, TCM is one-of-a-kind with regard to flexibility with access to flue gas with different CO<sub>2</sub> concentrations. The suppliers have access to flue gas with a low percentage of CO<sub>2</sub> from a natural gas power heating plant and flue gas with a high percentage of CO<sub>2</sub> from the oil refinery at Mongstad. This has similarities with the exhaust from a coal power plant.
- » Thirdly, the technology centre is planning to share and spread much of the knowledge accumulated here. This is why TCM has taken the initiative to form a global knowledge network for major test facilities for CO<sub>2</sub> capture. The participants in the CCS Test Centre Network met for the first time at the GHGT-11 conference in Japan in November. They will hold a new meeting at Mongstad in spring/summer 2013. The founders of the network are eight leading international players with test centres for CO<sub>2</sub> capture, and there are possibilities for even more major test centres within CO<sub>2</sub> capture.

# THE CLIMATE TECHNOLOGY OF THE FUTURE IS WITHIN REACH

**CCS is often associated with expressions such as “moon landing” and pictures of gigantic steel pipe structures. However, the CCS discipline is so much more than this. In laboratories and pilot plants across Norway, the future of climate technology is being determined.**



The Norwegian research programme CLIMIT supports projects that drive technology development for CO<sub>2</sub> capture, transport and storage forward. The programme is jointly administered by Gassnova and the Research Council of Norway.

In the future, the programme will place even greater emphasis on new ideas and innovation, as well as technical and international collaboration. The goal is to contribute to lower costs for this completely necessary environmental technology, and for CCS to have an international role earlier than what would have been possible otherwise.

Norway's CCS efforts are supported by a wide spectrum of political parties. These efforts have spawned internationally competitive technologies and research communities. The CLIMIT programme awards about NOK 180 million each year for research, development, pilots and demonstration of CCS technology.

## NEW STRATEGY AND PROGRAMME PLAN

The CLIMIT programme is directed at Norwegian companies, research institutes, universities and university colleges, often in collaboration with international companies and research institutions that can help accelerate commercialisation of CO<sub>2</sub> capture, transport and storage. An external evaluation from 2011 concludes that projects which received support from CLIMIT have achieved better and more effective CCS technology, and have contributed to confirming Norway's position within a number of areas in CCS. With a new strategy and programme plan, CLIMIT will be even more effective.

In the future, CLIMIT will prioritise support of next generation technologies and more cutting-edge solutions that can help reduce costs and increase safety for CCS.

Today, the most mature technologies for CO<sub>2</sub> capture are both energy-intensive and costly, and there is no clear winner as regards capture technology. CLIMIT

will have broad focus on different types of technologies and applications. CO<sub>2</sub> is currently transported by pipeline and ship. The challenges associated with transport of CO<sub>2</sub> from power production or industrial exhaust gases are unknown effects of impurities in the gas, safety and operational aspects. CLIMIT wants to support projects that will contribute to increased knowledge about these topics. There are a total of eight full-scale storage projects on a global basis, two of which are in Norway. Projects supported by CLIMIT will contribute to cost-efficient and safe implementation of CO<sub>2</sub> storage in compliance with regulatory requirements and international agreements.

Unlike most other countries, the majority of CO<sub>2</sub> emissions in Norway come from outside the power sector. This means that CCS for industrial emission sources is relevant here. CLIMIT wants to support pilot plants for industrial processes, as well as prioritise development of optimal technology for CCS from gas power plants.

## NORWEGIAN ADVANTAGES AND ENVIRONMENTAL CONSEQUENCES

Norway has a considerable CCS infrastructure. The CO<sub>2</sub> Technology Centre Mongstad (TCM) opened in May 2012, and is the world's largest test centre for CO<sub>2</sub> capture technology. There are also a large number of test pilots, storage pilots and laboratories. The projects which CLIMIT will support in the future should utilise and contribute to further development of the already existing infrastructure.

It is not acceptable to develop climate technology which creates new environmental problems. This is why CLIMIT has supported a number of projects which have examined environmental aspects of amine-based CO<sub>2</sub> capture. The conclusions from this extensive research work – done in collaboration with TCM and Mongstad Full-Scale (CCM) – open the door for further development of amine-based CO<sub>2</sub> capture. CLIMIT will continue to support projects that can contribute to closing knowledge gaps within this field.

## NORCEM WANTS TO CAPTURE CO<sub>2</sub> FROM A CEMENT PLANT

**Norcem wants to build a test facility for CO<sub>2</sub> capture at its cement factory in Brevik and has applied to CLIMIT for support.** The size and level of support means that the project must be processed by the EFTA's Surveillance Authority (ESA). At year-end, the ESA has not made a final decision in the matter. The second phase of the project includes establishment of infrastructure, as well as testing of CO<sub>2</sub> capture with amines, membranes and solid-phase absorbents. The project will examine whether the technologies are suited for capturing CO<sub>2</sub> from a cement plant.

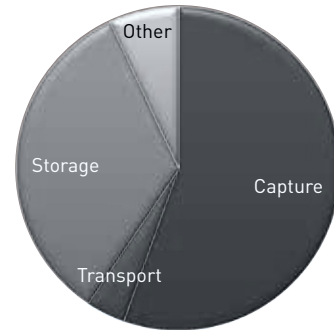
The first phase of the project, completed in 2011, consisted of a concept study and pre-engineering of a test facility for CO<sub>2</sub> capture. Potential capture technologies and suppliers were identified through the concept study. Three capture technologies, with varying degrees of maturity, were selected as a basis for designing the CO<sub>2</sub> capture facility.

## PROJECTS SUPPORTED BY CLIMIT AT GHGT-11

**"Greenhouse Gas Technologies no. 11" (GHGT-11) is the world's largest CCS conference.** Of the 300 presentations at the conference in Japan in November 2012, a whopping 30 were Norwegian. Most of the research projects that were presented received support from CLIMIT.

### CLIMIT DEMO: AREA

On-going projects, Dec 2012, funded (MNOK)



### Distribution by technology areas

Gassnova believes it has an appropriate distribution between projects directed at CO<sub>2</sub> capture, transport and storage, despite the fact that the project portfolio contains relatively few transport projects.

The two dominant areas are capture and storage. These areas have been identified as the areas with the largest challenges as regards reducing costs and technological risk.

## CLIMIT-PROGRAMME'S GOALS

Long-term and broad-based support for research and development.

Contribute to pilots and demonstration of known technology up to 2015. This technology will form the basis for the first full-scale demo facilities that will be built in 2015-2020.

Promote development of new and more cutting-edge technologies that can be supported in pilot and demonstration projects after 2015.

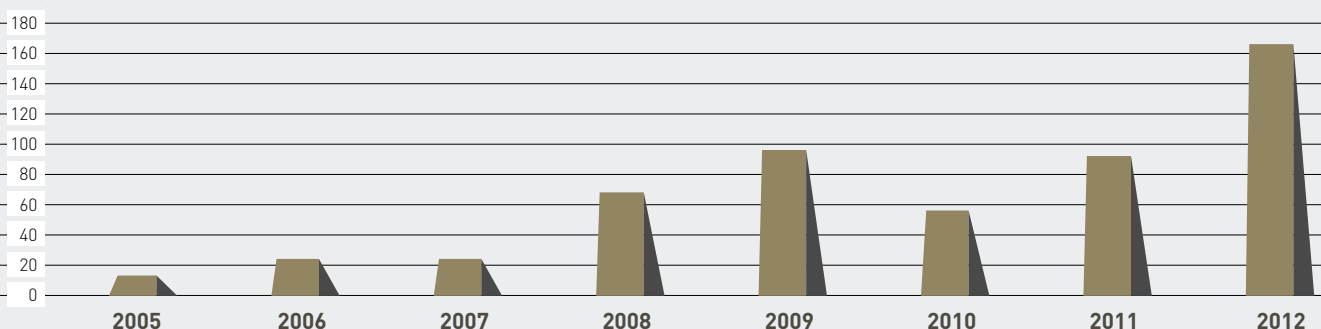
Contribute to commercialisation of new and more cutting-edge technology in the period after 2020.

Prioritise projects from Norwegian players which have a major CCS potential.

This year's award of MNOK 165.9 is the largest award since the fund was established in 2005. About half will go to capture projects, while the other half will go to storage and other projects. Since its inception, CLIMIT Demo has allocated a total of about MNOK 510 for 138 small and large projects. Through this, the programme has triggered, or will trigger, project costs totalling more than NOK 1 billion.

## AWARDS 2005-2012

MNOK





# FULL-SCALE CCS

## – AN ABSOLUTE NECESSITY

**The work on establishing a basis for an investment decision for full-scale CCS for the combined heat and power plant (CHP) at Mongstad is progressing according to plan. In 2012, Statoil was assigned project manager responsibility for planning the CO<sub>2</sub> capture facility, while Gassnova transitioned to a follow-up role. Gassnova is also working to establish a qualified CO<sub>2</sub> storage site on the Norwegian shelf.**

In 2006, the Norwegian state and Statoil entered into an agreement to establish a full-scale CO<sub>2</sub> capture facility at the planned combined heat and power plant (CHP) at Mongstad. The CHP plant, which was completed in 2010, is one of Norway's largest sources of point source emissions. From October 2009 to April 2012, Statoil and Gassnova collaborated in a joint project team to develop the CO<sub>2</sub> capture facility. The basis for the investment decision will be submitted to the Storting (Norwegian Parliament) in 2016 at the latest.

### SAFER AND BETTER CAPTURE TECHNOLOGIES

In accordance with Storting Report No. 9 [2010–2011] full-scale CCS (2010–2011), the project development will take place in several stages. First, a three-year technology qualification programme will be carried out, which includes testing in a verification facility, combined with feasibility and concept studies. The goal is to achieve at least one capture technology. The chosen technology will then be matured up to submission of an investment decision.

The technology qualification programme started in autumn 2011, when contracts were signed with five leading international suppliers of capture technology:

- » Aker Clean Carbon
- » Mitsubishi Heavy Industries, LTD.
- » Huaneng-CERI Powerspan Joint Venture
- » ALSTOM Carbon Capture GmbH
- » Siemens AG

The technology qualification programme will provide a considerable contribution to supplier development and will ensure selection of the best technical solution at the lowest possible cost. Even now it can be confirmed that the programme contributed to maturing the five suppliers' capture technologies. This helps ensure sound competition for the day when a technology will be chosen for Mongstad Full-Scale. The suppliers can also compete for international assignments thanks to the programme.

The project has carried out extensive research and development work to shed light on possible health-related and environmental effects of emissions from amine-based processes. The programme has been ongoing since 2010 and involves development and verification of methods, as well as testing of suppliers' amines. The work is now completed. The programme led to an extensive collection of methods, models and procedures which, together, form a tool box which is now used to calculate the spread and exposure level for the different technologies' amine solutions.

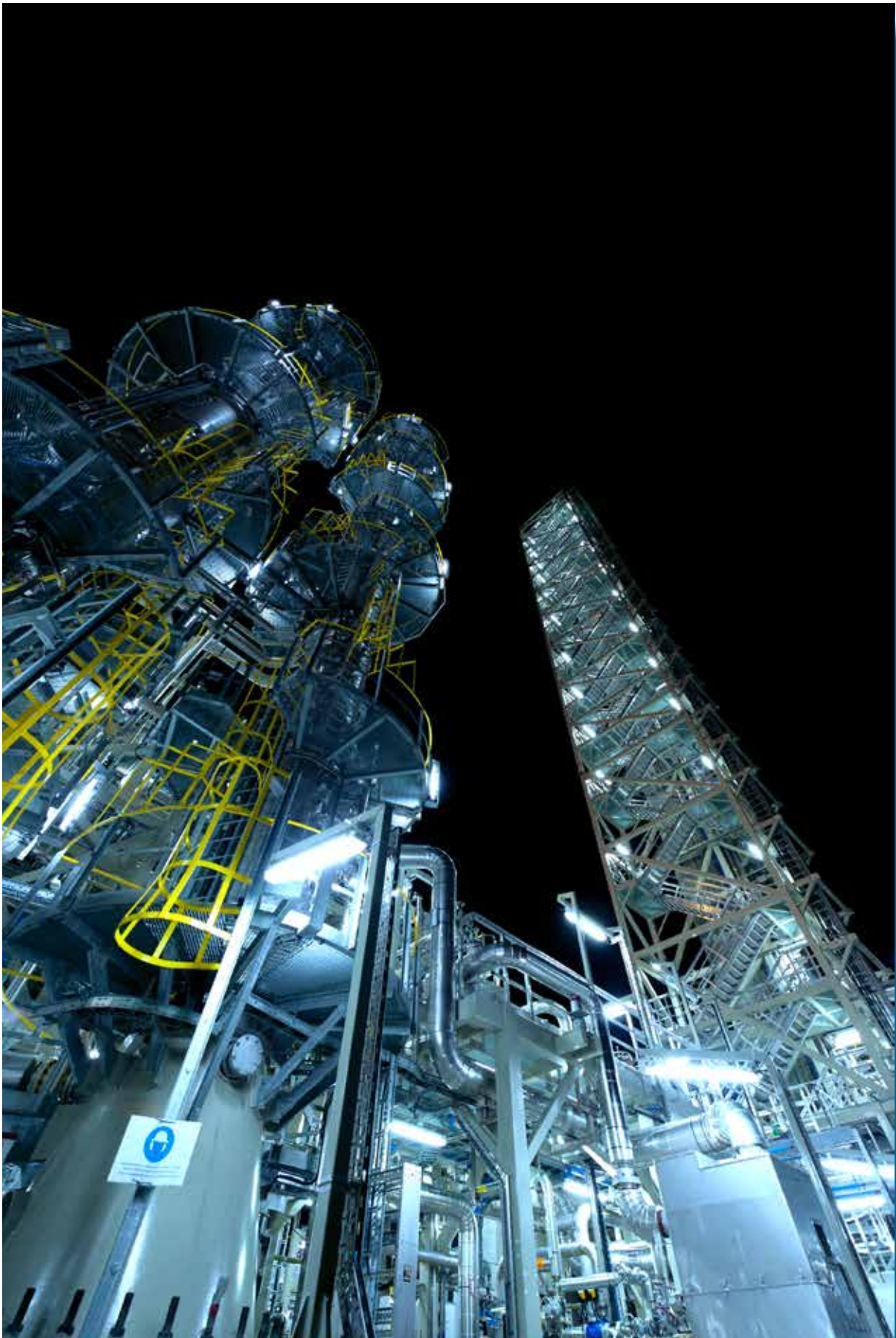
### SAFE CO<sub>2</sub>-STORAGE

Gassnova assists the Ministry of Petroleum and Energy in the work to establish a concept for how to organise a transport and storage solution for CO<sub>2</sub> from Mongstad. A qualified storage site will form part of the overall decision basis (including capture, transport and storage of CO<sub>2</sub>) which will be submitted to the Storting in 2016 at the latest.

A safe solution must be ready when the full-scale CO<sub>2</sub> capture facility is started up.

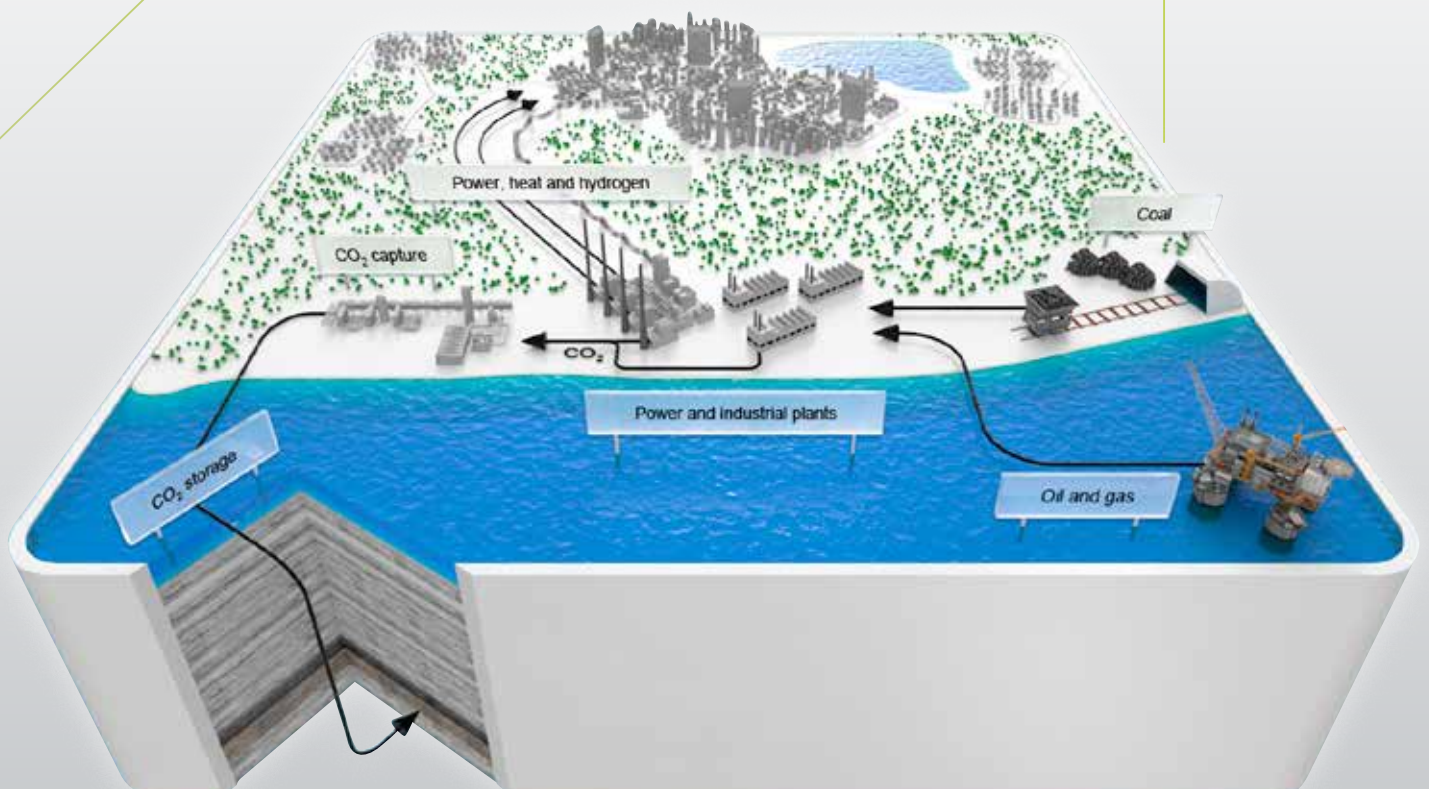
CO<sub>2</sub> storage means storage in geological formations. Some formations are suited for storage and others are not. In Norway, aquifers are being assessed, i.e. storage in pores with aquiferous layers on the continental shelf. Depleted oil and gas fields, as well as solutions that involve providing CO<sub>2</sub> for improved oil recovery could also be a possibility. A storage atlas prepared by the Norwegian Petroleum Directorate shows that there is a considerable potential for safe storage of CO<sub>2</sub> on the Norwegian shelf.

It is crucial to have full-scale CCS in place in order for the world to utilise this absolutely necessary climate technology. We are demonstrating that this is possible with a full-scale facility, and we are gaining new knowledge that can be shared. Norway possesses the expertise needed through our experience with oil and gas activities, our financial strength and, not least, the political ambition to be a pioneer within climate and the environment.



## FIVE CO<sub>2</sub> EMISSION SOURCES ARE RELEVANT FOR FURTHER STUDY BASED ON THE EMISSION OWNERS' OWN RELEVANCE ASSESSMENT:

- |   |  |   |   |  |
|---|--|---|---|--|
| <p><b>Norcem, Brevik:</b><br/>Cement production, existing emission source</p> | <p><b>Yara Norge, Porsgrunn:</b><br/>Mineral fertiliser/ammonia production, existing emission source</p> | <p><b>Industrikraft Møre, Elnesvågen:</b><br/>Electricity production (gas power), potential emission source</p> | <p><b>Ironman, Tjeldbergodden:</b><br/>Iron production, potential emission source</p> | <p><b>Longyearbyen Bydrift, Svalbard:</b><br/>Electricity production (coal power), potential emission source</p> |
|---|--|---|---|--|





# REALISATION

## OF FULL-SCALE CCS IN NORWAY: AREAS OF FEASIBILITY

**Gassnova has started an initiative to see whether there are possibilities for other CCS projects in Norway. Before Christmas, Gassnova delivered a status report to the Ministry of Petroleum and Energy (MPE) which identified five CO<sub>2</sub> emission sources that can be further examined.**

During spring 2011, Gassnova was tasked by the MPE to examine the possibilities for realisation of full-scale CCS beyond the project at Mongstad. In autumn 2012, the mandate was expanded to include assessment of the possibility for CCS in a potential new coal power plant in Longyearbyen on Svalbard. The final report will be delivered in the first half of 2014.

"Gassnova has headed extensive work which mapped and assessed point source emission sources in Norway in relation to the possibility for CCS. The chosen approach is exceptional. Never before has such work been done in Norway," says Tore Amundsen, CEO of Gassnova.

Gassnova developed the evaluation method for the feasibility study in cooperation with Mott MacDonald. The evaluation method is based on acquired, relevant, international experience, Gassnova's own experience from the CCS projects at Mongstad and Kårstø, as well as Mott MacDonald's expertise and experience with assessment of international CCS chains. The feasibility study mapped, evaluated and analysed both existing and potential CO<sub>2</sub> emission sources in

Norway. The method clearly stands out from our previous work: The project cooperated closely with the industry, whose assessments were assigned decisive weight.

"If we are to succeed with CCS, we need the industry on board. That is why the emission owners' own assessments are key with regard to whether a project is considered relevant for further study," says Tore Amundsen.

No significant obstacles against realisation of CCS have been identified for these five emission sources. However, only the capture aspect of the process has been assessed, which means that we have not looked at the possibility for transport and storage of the CO<sub>2</sub>.

Since CCS requires substantial investments, the emission should be large enough to ensure cost-efficiency in the project. Internationally, 400 000 tonnes of captured and stored CO<sub>2</sub> is considered the lower limit for "full-scale", and Gassnova has therefore looked at emissions larger than this.

Much work remains before we can determine whether the CO<sub>2</sub> from one or more of these sources can be captured and stored, and thus contribute to lower CO<sub>2</sub> emissions and increased experience with this absolutely necessary climate technology. The feasibility study will be completed in 2014, and Gassnova will present a final report with an extensive and up-to-date mapping of the feasibility area for realisation of full-scale CCS beyond Mongstad, i.e. entire chains with capture, transport and storage of CO<sub>2</sub>.

However, the work on the feasibility study shows that Norway still is and will continue to be a pioneer in the work on realising CCS – on both a national and global basis. CCS will be an important part of the solution to the world's energy and climate challenges.



**Gassnova SF**

Dokkvegen 10  
NO-3920 Porsgrunn, Norway  
Tel +47 40 00 59 08  
[www.gassnova.no](http://www.gassnova.no)