



GASSNOVA



ANNUAL REPORT **2011**





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# Patient and impatient – at the same time

**The Norwegian State has given Gassnova the task of ensuring that Norway's work on the CO<sub>2</sub> challenge succeeds. Gassnova contributes to developing technologies for capture, transport and storage of CO<sub>2</sub>, and is a driving force in ensuring that the technology is put to use.**

Gassnova will also provide technical advice to the State on how the CO<sub>2</sub> problem should be handled.

The process of developing technological solutions for CCS is challenging. However, the oil and gas bonanza has given us knowledge, technology and financial resources which make it natural for Norway to assume a leading international role in this work.

We must be patient in our work on the CO<sub>2</sub> challenge because developing new technology takes time. And we must be impatient because this work is urgent.





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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.

## GASSNOVA'S OBJECTIVES AND KEY TASKS

- » 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

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## Preface

# We look forward to an exciting new year

**In 2011, we saw many plans for development of pioneer facilities for CO<sub>2</sub> capture falter in the international arena. Report No. 9 to the Storting on full-scale CCS laid out a course for a continued robust Norwegian commitment to CCS over the next few years.**

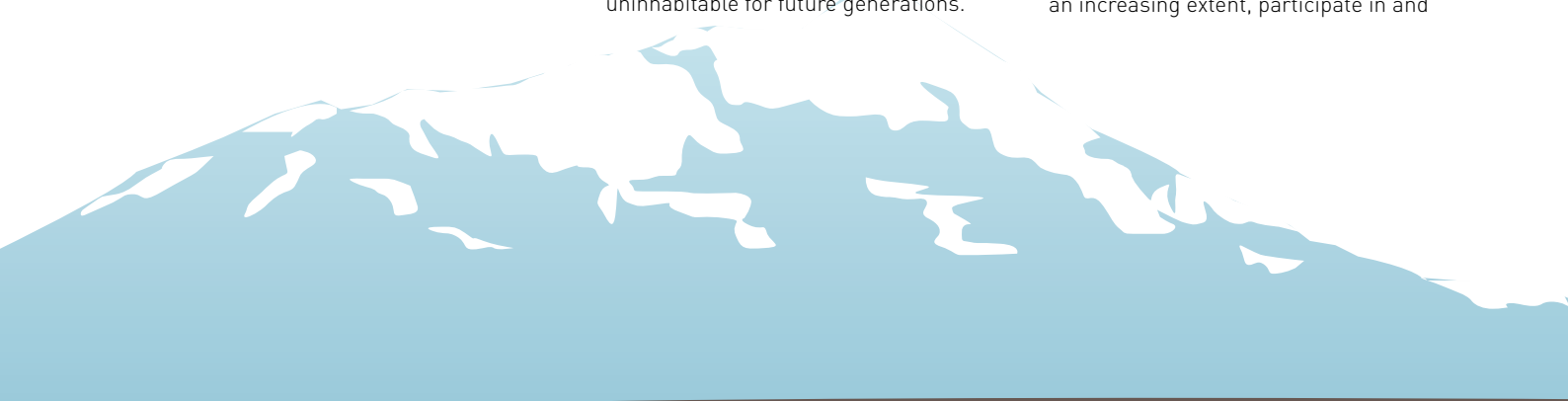
The CO<sub>2</sub> Technology Centre Mongstad will start up in 2012. In times characterised by international economic unrest, the Norwegian commitment to CCS in 2012 is even more important. Targeted efforts will be necessary over a period of many years in order to develop and mature climate technologies and ensure their global spread.

There is also a need to clarify the industry's framework conditions, as well as to increase the alternative costs, for example by putting a price tag on greenhouse gas emissions, or creating a sufficiently high global price on CO<sub>2</sub>. There is still quite a way to go. Gassnova is the Norwegian State's instrument, and we take this responsibility seriously. We are motivated and well-equipped for the task. Gassnova is an expertise enterprise with a unique mandate: we will contribute to solutions that allow CO<sub>2</sub> to be captured and stored so that humans don't render the planet uninhabitable for future generations.

Norway has taken on a leading role in the world's climate battle. In Gassnova, we use work methods taken from the industry. On the other hand, our social return cannot be measured against a normal commercial scale.

Gassnova will compare facts and evaluations with the economy and technology of CCS, and we will advise the authorities on these issues. Our ambition is to be an objective, competent and involved contributor to policy formation which supports both the political and social debate which surrounds the solution to the climate issue.

If we succeed in this, we can make a constructive contribution to ensuring that decisions made by the Government and in the Storting are based on the best possible array of facts. We understand that the climate issue and questions related to technology and economy can be difficult and therefore Gassnova will, to an increasing extent, participate in and

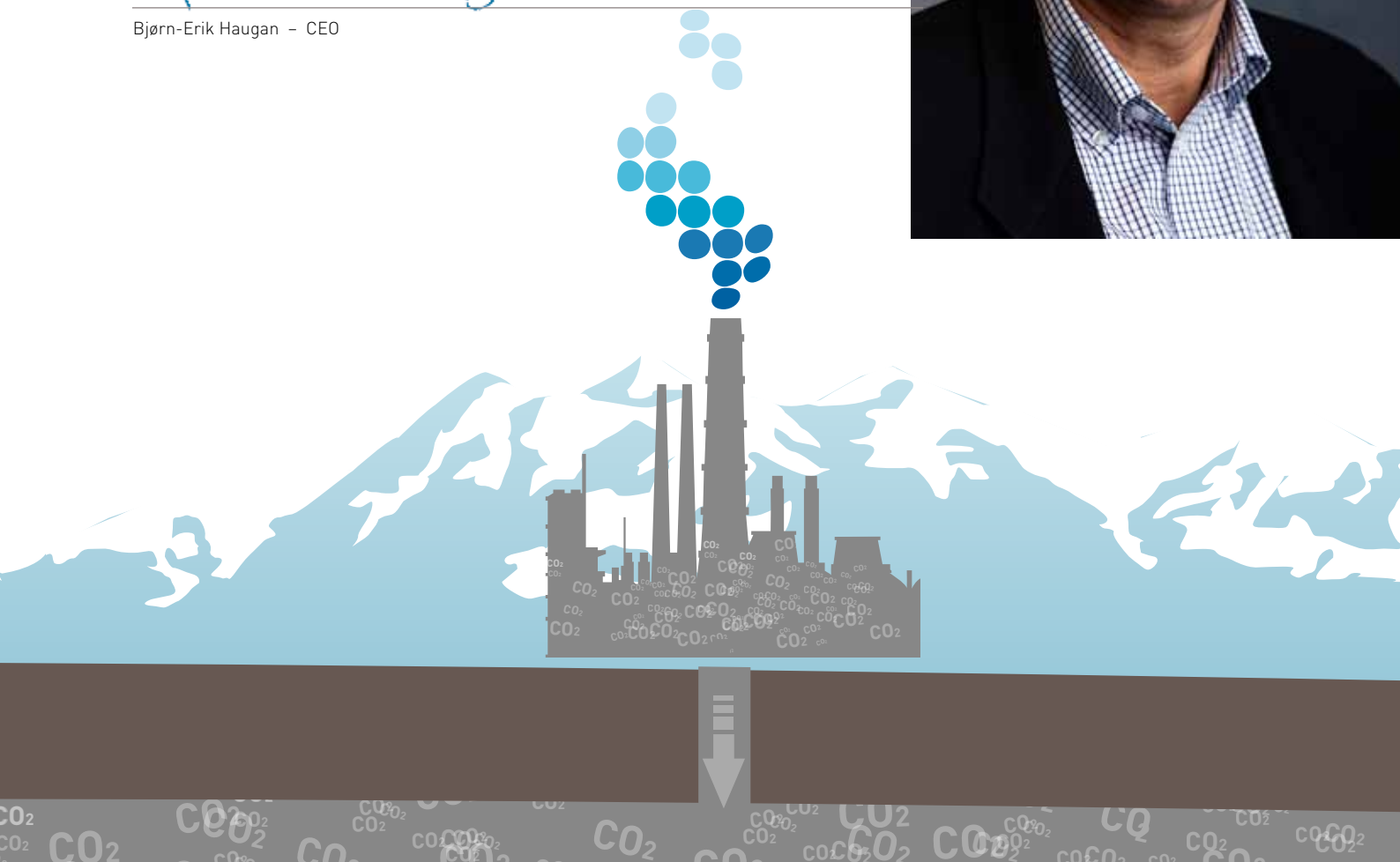


support the open debate which should and will accompany the allocation of major resources in our society.

The enterprise's reputation is crucial in such a role. In 2011, Gassnova implemented a process to clarify the fundamental values which must be our trademark: integrity – to act in harmony with our convictions, respect – recognising the integrity

of others, courage – to take risks for our good cause, even if the outcome is uncertain, responsibility – to conscientiously steward our role and stand behind the result. Our values are ambitious and must permeate everything we do. They must be a standard and an example in difficult issues, and they must reflect how we see and treat each other in the enterprise.

Bjørn-Erik Haugan – CEO





# CCS

## - an important climate measure

**Access to sufficient energy is important for growth in the global economy, and is a prerequisite for fighting poverty in emerging countries. On the other hand, increased production and consumption of energy is also a main source of greenhouse gas emissions, particularly CO<sub>2</sub>. Our energy consumption and the CO<sub>2</sub> emissions this entails are the most important reason for the rise in global temperature, and for a climate in imbalance. That is why we must reduce CO<sub>2</sub> emissions.**

In its report "World Energy Outlook 2011", the International Energy Agency (IEA) lays out perspectives for the global energy sector. The report paints a sombre picture of the climate situation. There are few signs that indicate we are on the right track, or that we are proceeding fast enough, as regards climate measures. On the contrary, the time to implement measures is running short, and the task is becoming increasingly challenging and costly. The hope of achieving the 2-degree target in 2050 is fading rapidly. The window of opportunity for doing something now is starting to close. Without immediate, decisive action, we are well on the way towards an average temperature increase of perhaps as much as 3.5 degrees. This may not sound like much, but such an average entails that extensive areas will experience even larger increases, with dramatic consequences. The weather will become more violent and more unpredictable, and the climate will be more extreme. Rising sea levels and widespread drought are other examples.

A number of policy instruments must be put to work to achieve our climate objectives – it is not a question of individual technologies. Among other things, we must capture and store CO<sub>2</sub> from both energy and industrial production. Capture and storage of CO<sub>2</sub> (CCS) could contribute nearly 20 per cent of the necessary reductions up to 2050, and is thus one of the measures that will help the most in handling the CO<sub>2</sub> challenge. Other important efforts include renewable energy, energy conservation and changes in the transport sector.

2011 was also a demanding year for several of the planned international CCS demo projects. A number of countries

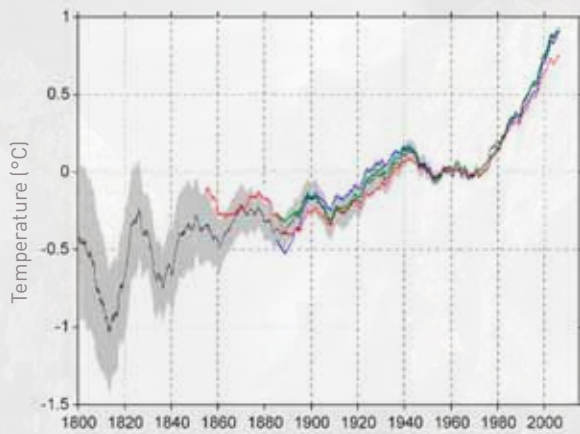
and major industry players announced that their projects had either been cancelled or tabled indefinitely. The reasons reportedly include the global financial situation, high costs, unclear framework conditions and the lack of a global price tag on carbon. This means that the Norwegian commitment will be even more significant in the next few years. It is important that Norway stands by its obligations and pursues a broad commitment to climate measures such as CCS. Efforts are urgently needed to acquire more experience and reduce costs, so that CCS can achieve the broad application needed in order for us to achieve our climate goals.

The Storting report on CCS considered in the spring of 2011 shows that the Storting and the Government stand firmly by our obligations and that we are willing to continue our commitment to CCS. Some measures and tasks can be postponed – but climate change waits for no one! There are several reasons for Norway's extensive commitment to CCS. First and foremost, Norway has its own emission obligations, and we are a global oil and gas nation which contributes to CO<sub>2</sub> emissions in other countries. We have our own long-term interest in making our exports sustainable in terms of the climate. Norway also has a high level of technological expertise, which enables us to find the best methods of capturing and storing CO<sub>2</sub>. And perhaps most important of all – Norway has the financial resources to go the distance. In 2011, the Government allocated NOK 2.7 billion to CCS work. Most of these funds were linked to the work on the CO<sub>2</sub> projects at Mongstad. These are among the most important measures in Norwegian energy and climate policy.





## TEMPERATURE GROWTH



Source: Berkeley Earth Surface temperature 2011, USA





# CO<sub>2</sub> Technology Centre Mongstad (TCM)

- the world's largest test centre  
for CO<sub>2</sub> capture goes online

## BUILDING THE CO<sub>2</sub> TECHNOLOGY CENTRE

At the end of 2011, construction of the CO<sub>2</sub> Technology Centre Mongstad reached its final stage, and the technology centre will go online during the spring of 2012. Gassnova manages the Norwegian State's 75% stake in the technology centre. "We are very proud of this quite unique technology centre, and we look forward to starting the testing," says Anne Strømme Lycke, Vice President Asset Management in Gassnova and head of the partnership meeting in TCM DA.

## A HISTORIC MILESTONE

TCM is an industrial arena for learning, where the objective is

to test, demonstrate and develop cost-effective technologies for commercialisation of full-scale CO<sub>2</sub> capture, as well as contribute to developing suppliers. There are high ambitions for the technology centre. TCM's owners want to develop the centre into a world-leading test centre for CO<sub>2</sub> capture technology. The opening of the technology centre at Mongstad is a milestone for Gassnova and for Norway's comprehensive commitment to climate technology. The planning and construction work have been demanding, but have also provided valuable lessons, both for the owners and for the two technology suppliers: Aker Clean Carbon and Alstom.

Now TCM will soon be ready for start-up, and will bring new knowledge and important experience in the years to come.

## OBJECTIVE OF CO<sub>2</sub> TECHNOLOGY CENTRE MONGSTAD (TCM)

TCM is an industrial arena for demonstration and development of cost-effective technologies for CO<sub>2</sub> capture. The primary goals of the technology centre are:

- » Testing, verification and demonstration of technology for CO<sub>2</sub> capture
- » Reduce costs, as well as technical, environmental and financial risk





## Facts

- » Total area: 63 000 m<sup>2</sup>
- » Capacity: 100 000 tonnes CO<sub>2</sub>/year
- » Capture method: Post-combustion
- » On 17 October 2011, the Norwegian Climate and Pollution Agency (Klif) issued TCM an emission permit to test the two CO<sub>2</sub> capture technologies
- » Cost estimate: NOK 5.8 billion
- » Around 2/3 of the project's development costs are linked to infrastructure and auxiliary systems, and about 1/3 are linked to the two capture technologies.
- » In total, 5.1 million hours have been worked at TCM since construction started
- » About 80 people will work at the technology centre at full operating capacity.

## Owners

TCM is a joint project between Gassnova SF on behalf of the Norwegian State, Statoil ASA, A/S Norske Shell and Sasol New Energy Holdings Pty Ltd, and a separate company has been established for development and operation of the technology centre, TCM DA.

Distribution of ownership is as follows:

Gassnova	75.12%
Statoil	20.00%
Shell	2.44%
Sasol	2.44%

- » Promote market development for carbon capture technology
- » Contribute to knowledge sharing and international deployment

To succeed in this, TCM relies on close cooperation between the owners and the industry.

### A UNIQUE TEST CENTRE FOR CO<sub>2</sub> CAPTURE

The technology centre is designed to capture 100 000 tonnes of CO<sub>2</sub> per year, and is the largest, most flexible facility of its kind anywhere in the world. TCM is being built with a capacity and surrounding infrastructure that can support multiple technologies simultaneously. TCM will initially test

two different technologies - an amine technology from Aker Clean Carbon and a technology from Alstom which uses chilled ammonia. After the initial phase, TCM will be responsible for developing future test programmes, and for facilitating innovation within CO<sub>2</sub> capture so that the solutions can be matured for commercialisation.

TCM has access to two different sources of exhaust gas with different CO<sub>2</sub> content: the thermal power station with approx. 3.5 per cent CO<sub>2</sub> and the refinery with approx. 13 per cent CO<sub>2</sub> in the flue gas. TCM is designed so that the two facilities can switch between which flue gas source is used for the testing, and the content of CO<sub>2</sub>

can be varied. The Technology Centre can offer suppliers flexibility and a multitude of possibilities. The specially designed infrastructure at TCM allows verification of a number of industrial processes from both gas and coal-fired energy sources in the very same test programme. This can be set up with minor modifications to the current connection lines.

### MANY VISITORS

Approximately 1500 visitors have come to TCM during 2011, including energy ministers from several countries. Gassnova regards this as an important part of the activity at TCM to ensure national and international distribution of knowledge.



# Full-scale CCS

**According to an agreement between the Norwegian State and Statoil, a test centre will be built at Mongstad, followed by a full-scale capture facility for CO<sub>2</sub>. Planning a full-scale facility to capture CO<sub>2</sub> emissions from the thermal power station is already well underway. The basis for a decision on a full-scale facility will be completed in 2016, at the latest. The Government will then make a decision on whether or not to construct such a facility.**

The work of developing full-scale CCS is a key issue of the Government's policy. The framework for continued work on full-scale CCS was laid down in connection with the consideration of Storting Report No. 9 (spring 2011). Work is proceeding both on a full-scale capture facility for the thermal power station at Mongstad, as well as finding a secure storage solution for the CO<sub>2</sub> volumes. In the spring of 2011, Gassnova was also assigned the task of mapping the possibilities for full-scale CCS in Norway, beyond the project at Mongstad.

## FULL-SCALE CAPTURE MONGSTAD

Project planning for full-scale capture is proceeding full force, led by Gassnova and Statoil. Statoil is the State's industrial partner under an agreement from 2006. Statoil is the operator of the refinery, and the company has secured an emission

permit for the thermal power plant, which came online in 2010.

Pursuant to Storting Report No. 9 (2010-2011) on full-scale CCS, the first step is to implement a three-year technology qualification programme to choose a technology, followed by detailed planning that will take two years. This will contribute to a thorough review of the technologies through close cooperation with various suppliers who participate in the programme.

On 8 November, Gassnova and Statoil announced the five technology suppliers that have been selected to participate in the technology qualification programme at Mongstad:

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

Potential environmental challenges associated with emissions from the plants will be studied during the course of the technology qualification process. There must be no new environmental problems as a result of CO<sub>2</sub> technologies that are developed. There are no facts supporting the claim that substantial risk is associated with amine technology, but we must invest in new knowledge to be quite certain. Studies will take place both through research and development, through projects under the auspices of the Mongstad project (from 2010) and experience gained at TCM. Other international activities are also expected to contribute to building up knowledge surrounding the environmental aspect of capture technologies.

In addition to health and environmental impact, we must also examine measurement and analysis methods,





work methodology, energy efficiency, capture degree, scaling factors, etc. Many comprehensive and challenging tasks remain in the next few years before we can submit a basis for investment to the Government.

#### TRANSPORT AND STORAGE SOLUTION FOR MONGSTAD

The Norwegian State will establish a capture, transport and storage solution for Mongstad. The transport and storage solution is being planned in parallel with the full-scale capture facility. Players and companies associated with the oil and gas industry possess the foremost expertise on CO<sub>2</sub> storage. This is certainly the case on the Norwegian shelf, where CO<sub>2</sub> storage has been under way for a number of years. In this context, Gassnova has considered various solutions as regards ownership and operation to facilitate realisation of a transport and storage solution

in close cooperation with industrial players. Five geological areas were nominated in the fall of 2011 which may be suitable as future CO<sub>2</sub> stores on the Norwegian shelf. Gassnova is responsible for managing the State's interests in the work to develop CO<sub>2</sub> storage on the Norwegian shelf, well in advance of the start-up of full-scale capture.

Studying projects beyond Mongstad Gassnova has been tasked with preparing a study to map and analyze the opportunities for full-scale CCS in Norway, beyond Mongstad. The study will map, analyze and assess various types of major point source emissions, including existing and potential new facilities in power production and industry. This work is to be completed in 2014.

The work will take place in parallel with technology qualification for

full-scale capture at Mongstad. It will be based on previous experience from projects such as Mongstad and Kårstø, Climate Cure 2020, as well as projects carried out abroad. Technical, financial and commercial issues will be considered. Substantial participation is expected on the part of industry players, both as regards business opportunities and technology. It is assumed that the players will contribute solid knowledge that can enable them to participate in feasibility studies and subsequent phases.

# Technological development – essential for future CCS





**Technological development through the CLIMIT programme is one of Gassnova's three foremost commitment areas in CCS. CLIMIT provides financial support for research, development and demonstration of CCS technology. The programme was established by the Ministry of Petroleum and Energy in 2005 to support development of CCS technology for gas power plants. The subsidy scheme was expanded in 2008 to include power production based on all fossil fuels, and in 2010, the CLIMIT programme was opened to include point source emissions from industry.**

CLIMIT is a collaboration between Gassnova and the Research Council of Norway. The programme includes the Research Council's subsidy scheme for research and development (the research part), and Gassnova's support for development and demonstration (the demo part). Gassnova has the overall responsibility and heads the programme's secretariat.

THE CLIMIT PROGRAMME HAS THE FOLLOWING OBJECTIVES:

- » Broad, long-term support for research and development.
- » Contribute to piloting and demonstration of known technology up to 2015. This technology will form the basis for the first full-scale demo facilities to be built during the period 2015-2020.
- » Stimulate development of new and more ground-breaking technologies that can be supported in pilot and demonstration projects after 2015.
- » Contribute to commercialisation of new and ground-breaking technology in the period after 2015-2020.

"In 2011 we have awarded NOK 36 million more than in 2010," says Dr. Klaus Schöffel, Vice President Technology and Competence in Gassnova, and head of the CLIMIT secretariat. "This is a marked improvement, and underlines that the commitment we have made through CLIMIT contributes to more activity. This work demands that we are both patient and impatient at the same time. We must be patient because we are often working with new, less mature technology where we cannot always succeed. We must also be impatient and inquisitive, so that we never rest in our endeavours to find the best solutions."

For the first time, funds were allocated for projects targeting point source emissions from industry. Norcem AS was the first applicant to receive subsidies. The pre-project will examine the options for facilitating testing of various technologies that can capture CO<sub>2</sub> from the cement factory's flue gas in Brevik, Norway. "It will be exciting to follow this project, and we obviously hope for ripple effects and more industry projects in the time ahead," says Klaus Schöffel.

21 new projects were started in 2011, several of which enjoy cooperation with international players. Cooperation across international borders in research and development programmes will be increasingly important in the years ahead. Cooperation with international players is on the rise, and this is an important factor in projects aimed at using captured CO<sub>2</sub>. "We believe that such projects can contribute to improved profitability earlier in the CO<sub>2</sub>-chain, and can thus help strengthen the application of CO<sub>2</sub> capture technology," concludes Klaus Schöffel.

#### A LINK BETWEEN RESEARCH AND INDUSTRY

The CLIMIT programme plays an important role as a link between the research, development and industrial communities in Norway. The secretariat wants to be a driving force when it comes to finding good projects and helping those with good ideas to mature the ideas further. CLIMIT's secretariat offers considerable breadth and insight. The CLIMIT Days were held for the second time in 2011, and the event has turned into a major conference with more than 140 participants. The entire Norwegian CCS community gathered for two days for lectures, discussions, exchange of information and group work.



**CLIMIT's secretariat has also conducted several workshops where leading experts from Norway and abroad have taken part in discussions of various topics:**

#### AMINO ACID SALTS FOR CO<sub>2</sub> CAPTURE

- » A so-called "Technology Deep Dive" workshop was organised in Porsgrunn, Norway in February 2011 to highlight international activities and the status regarding amino acid salts used as a solvent (bonding chemical) in post-combustion CO<sub>2</sub> capture. There were around 30 participants from various industries and research communities.

#### MINERALISATION – CO<sub>2</sub> STORAGE AND BUSINESS CONCEPT

- » On 20 June 2011, CLIMIT organised a workshop entitled "Mineral storage – climate measure, value creation or both". The meeting attracted around 25 researchers and experts from institutes, universities and companies with interests within this topic.

#### INNOVATIVE CO<sub>2</sub> CAPTURE

- » Thirty enthusiastic people from different professional groups within industry and research gathered for two days in late November to discuss how to promote more innovative CO<sub>2</sub> capture. Group work according to the "World Cafe" method, panel debate and inspiring technical presentations contributed to a very successful gathering.

#### AMINE EMISSION FROM POST COMBUSTION CO<sub>2</sub> CAPTURE

- » On 5 and 6 December 2011, CLIMIT and Gassnova organised a workshop on the topic of health and environment linked to use of amines. 52 participants from Australia, Belgium, Finland, Holland, Japan, Norway, Sweden, Germany and the US were gathered in Oslo. One of the important goals of the meeting was to exchange information across the projects.

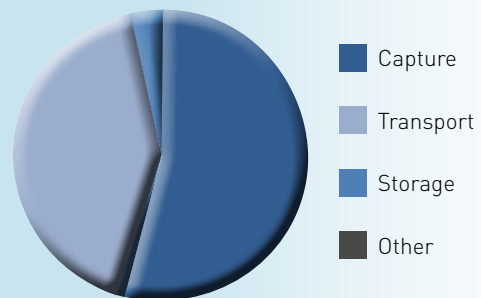
#### OTHER SEMINARS

- » CLIMIT has also organised a seminar for all PhD and PostDoc candidates in the programme. The CLIMIT programme finances around 60 doctoral students and post-doctoral students, and as many as 45 of them participated in the seminar in Oslo on 28-29 November. For CLIMIT, recruiting people with a high level of CCS expertise is extremely important, both for the business community and the research institutions. It is their knowledge that will create tomorrow's solutions.

The distribution of CLIMIT demo projects by area. The two dominating areas are capture and storage, which reflects the perception of the most challenging areas in terms of cost and technological risk.

#### CLIMIT DEMO: AREA

On-going projects, Dec 2011, funded (MNOK)

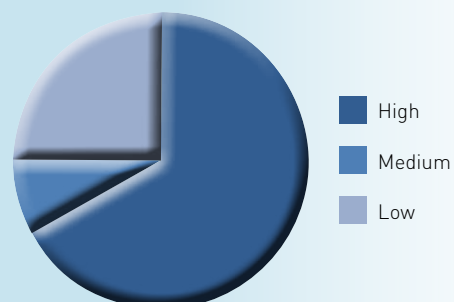


The "other" category represents smaller projects tied to expertise sharing, and non-technological projects.

CLIMIT projects distributed by an assessment of technology maturity.

#### DISTRIBUTED BY TECHNOLOGY MATURITY

Project portfolio as of Dec 2011







### GLOBAL SPREAD OF CCS TECHNOLOGY IS MORE REALISTIC

An external evaluation of the programme was launched in 2011. The evaluation was carried out by Oxford Research and encompassed 199 CLIMIT projects, of which 112 had been concluded when the evaluation started.

#### OXFORD RESEARCH CONCLUDED THAT:

- » The CLIMIT programme has played an important role in stimulating relevant research, development and demonstration projects.
- » Important results have been achieved, both within the research and the demonstration parts of the programme.
- » Research activities financed through the CLIMIT fund have reduced the knowledge gap, and provided opportunities for enhancing performance.

The evaluation report confirms that projects which receive support from the CLIMIT programme have developed better and more effective CCS technology, and have contributed to Norway reinforcing its position within several CCS areas.

The evaluation report provides a good basis for asking strategic questions, e.g. on topical and technical priorities, project implementation, weaknesses and how we can ensure the relevance and quality of the programme in the years to come.

## THE NORCEM PROJECT – A COMMITMENT TO REDUCE EMISSIONS FROM THE CEMENT INDUSTRY

The European cement industry wants to prepare for stricter framework conditions and emission requirements for future CO<sub>2</sub> emissions from their cement factories. Together with ECRA (European Cement & Research Academy) Norcem AS and its parent company HeidelbergCement therefore initiated a pre-project to study the possibility of applying CO<sub>2</sub> capture technology(ies) in their cement factories.

Norcem Brevik was selected as a host factory, as this facility has ample opportunity to condition its flue gas so that it also represents exhaust gases from other cement factories in Europe. 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 construction of the CO<sub>2</sub> capture facility. The facility has been designed for parallel testing of three technologies. In addition, the facility has been prepared so that at least one small-scale technology in the early stages of development can be tested simultaneously with the other three. Technologies and suppliers selected for pre-engineering were Aker Clean Carbon's (ACC) amine technology and Alstom's two technologies – chilled ammonia and carbonate recovery. Small-scale membrane testing will also be facilitated. Other small-scale technologies not mentioned here will be considered in the next phase of the project.



integrity  
respect  
courage  
responsibility



The Norwegian state enterprise  
for carbon capture and storage

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