

Annual Report 2009

**Gas Technology Centre
NTNU-SINTEF**

Strategic partner:



Preface

Dear reader,

2009 was an intensive year for the Gas Technology Centre (GTS), with the new 5-year period 2008-2012 taking shape and getting the Centre up to cruising speed. The objectives and strategy for the new period were settled thanks to the support from NTNU and SINTEF and through the strategic partnership with Statoil.

The GTS management and organization saw some changes during 2009. Associate Professor Hilde J. Venvik replaced Professor Olav Bolland as NTNU's director of the Centre in October. Professor Edd Blekkan completed his term of office in the management group in October. In addition, Astrid Lilliestrålø was appointed as coordinator, replacing Paris Klimantos. Olav Bolland, Edd Blekkan and Paris Klimantos have all made an impressive impact, and the whole gas technology community at NTNU and SINTEF is grateful for their efforts.

The financial crisis has led to changed priorities for our industrial partners. This has resulted in some challenges in the R&D community in our sector in terms of funding. However, we find that where there is high levels of knowledge, understanding and innovation, such times also materialize into new opportunities. The joint expertise at NTNU and SINTEF in gas technology should be seen in a long-term perspective, and our ambition to deliver technological excellence and sustainable energy solutions to industry in Norway and abroad is our firm guideline.

Issues concerning climate change strongly affected the global political agenda in 2009. Research activities in CO₂ capture and storage (CCS) at NTNU and SINTEF started already in the 1990s and are now at an unprecedented level. With numerous national and international projects and partners, activities in CCS continue to grow. Here the support from GTS since 2003 has been a major factor.

The focus during this new period has primarily been directed towards natural gas R&D - processing, liquefaction and conversion, while important efforts in hydrogen and CCS continue to be supported.

An important task of GTS is communication with politicians to influence Norwegian national priorities. During 2009, new channels for communication were established. We also find great inspiration in contributing to educational events at NTNU such as the student excursion to Hammerfest and the establishment of the international master's programme in Natural Gas Technology.

We will naturally continue our efforts to promote gas technology R&D in 2010.

Maria Barrio and Hilde J. Venvik
Co-directors of the Gas Technology Centre NTNU-SINTEF



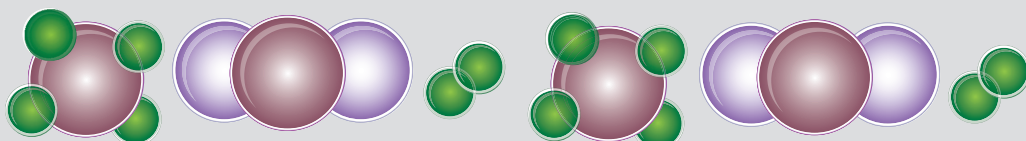
Maria Barrio



Hilde J. Venvik



Olav Bolland



The Gas Technology Centre NTNU-SINTEF

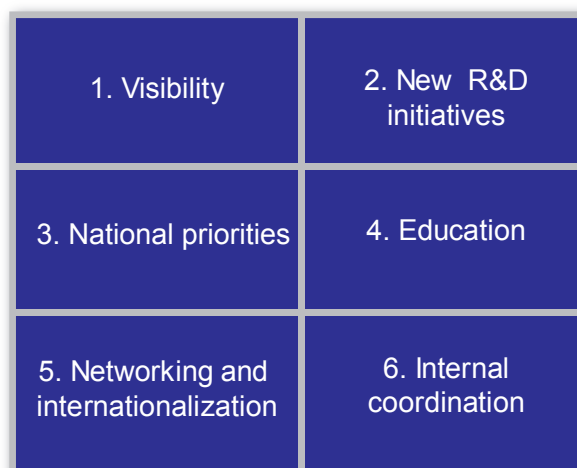
The Gas Technology Centre NTNU-SINTEF (GTS) was established in 2003 and is the largest centre for gas technology research and education in Norway. GTS provides new knowledge and technology which will contribute to efficient, environmentally friendly and profitable utilization of natural gas.

The GTS focuses on exploring and exploiting the synergism of multidisciplinary research based on NTNU and SINTEF's expertise that encompasses the entire value chain from the energy source to the end user.

The mission of GTS is to act as a common interface in gas technology R&D between NTNU/SINTEF and the market.

More specifically, GTS will:

1. Increase the visibility of gas technology R&D at NTNU/SINTEF, both externally and internally.
2. Promote new R&D opportunities and initiatives
3. Influence Norwegian national priorities
4. Ensure top quality education and recruitment of students and researchers
5. Be active in networking and internationalization activities
6. Promote internal coordination and synergism in gas technology R&D at NTNU/SINTEF

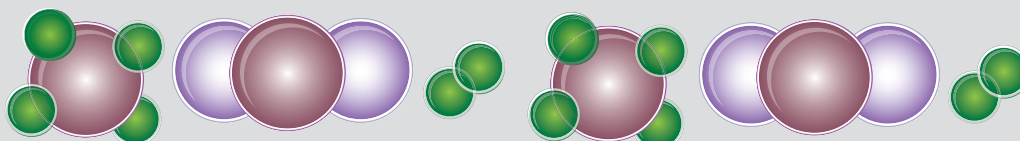


GTS Strategy

Main achievements in 2009

- The 5th Trondheim Conference on CO₂ Capture, Transport and Storage (TCCS-5) was organized in June. The conference received impressive feedback and was considered a great success in terms of technological progress and participation.
- The submission of the Preparatory Phase proposal for ECCSEL (European Carbon dioxide Capture and Storage Laboratory infrastructure) within the EU FP-7 ESFRI instrument, where GTS has contributed significantly.
- The 1st Trondheim Gas Technology Conference (TGTC-1), which took place in October. The conference received very positive feedback both from the scientific community and from the industry. Preparations for the 2011 conference are starting soon.
- The R&D project "A Green Sea" was granted support by the Research Council of Norway (NFR) PETROMAKS programme just before Christmas, a direct result of GTS promoting initiatives in midstream processing of natural gas.
- Several successful dialogue meetings with politicians have been arranged during 2009. The meetings have been focusing on the future of oil and gas R&D.

CCS	Carbon dioxide Capture and Storage
DNV	Det Norske Veritas
FCH JU	Fuel Cells and Hydrogen Joint Undertaking
GTS	Gas Technology Centre NTNU-SINTEF
LNG	Liquefied Natural Gas
NFR	Research Council of Norway
NTNU	Norwegian University of Science and Technology



Activities in 2009

1. Visibility

The 5th Trondheim Conference on CO₂ Capture, Transport and Storage (TCCS-5)



www.ntnu.no/tccs5

TCCS-5 was organized by GTS in collaboration with the BIGCO₂ project and held in Trondheim on 16-17 June. The conference had 300 participants from 24 countries, and the whole chain of CCS technology development was covered. There were 100 oral presentations in four sessions, including several inspirational keynotes. The poster session had more than 50 contributions. Selected papers are being prepared for journal publication. Sponsors: Statoil and CLIMIT (NFR).

1st Trondheim Gas Technology Conference (TGTC-1)



www.sintef.no/Projectweb/Trondheim_GTS

TGTC-1 was organized by GTS on 21-22 October with 85 participants from R&D institutions, universities and industry. There were 38 oral presentations and a poster session with 17 contributions. Basic and applied research within a broad range of gas technology was covered, with parallel sessions on gas conversion and LNG. In addition 13 contributions have been invited for journal publication. Sponsors: Gassco, Statoil and GASSMAKS (NFR).

Fuel Cells and Hydrogen Joint Undertaking (FCH JU)



ec.europa.eu/research/fch

2nd Stakeholders General Assembly took place in Brussels on 26-27 October. The purpose was to review the progress of the FCH JU (established in October 2008), exchange information on new and ongoing projects within FCH, discuss the potential of FCH technologies in the context of climate change policies and a rapidly changing global market, and identify synergies between FCH technologies and other related technologies. GTS contributed to the organization of the event through SINTEF's engagement in N.ERGHY.



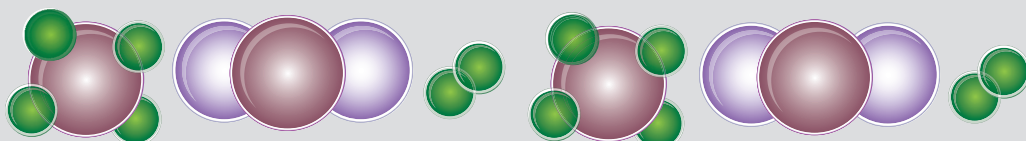
The 4th General Assembly was arranged in Brussels on 28 October, gathering 40-50 representatives from N.ERGHY's member R&D institutions. The objective was to review the achievements with respect to new projects, to discuss financial challenges within FCH JU and how to improve collaboration with European industry and prepare for the next call. Through SINTEF's representation on the board, GTS contributed to the organization of the event.

Nordic Hydrogen conference



www.hydrogen.no/h2conference2009

The conference was arranged by the Norwegian Hydrogen Forum and took place in Oslo on 24-26 November with almost 100 participants. The conference combined the annual HyNor conference and the Norwegian hydrogen and fuel cell seminar. The objective of the conference series is to give a comprehensive overview of fuel cell and hydrogen activities in the Nordic countries and strengthen the collaborative network within this field. NTNU, SINTEF, GTS, RENERGI (NFR) and Statoil were among the sponsors.



2. New R&D opportunities and initiatives

ECCSEL - European Carbon dioxide Capture and Storage Laboratory Infrastructure

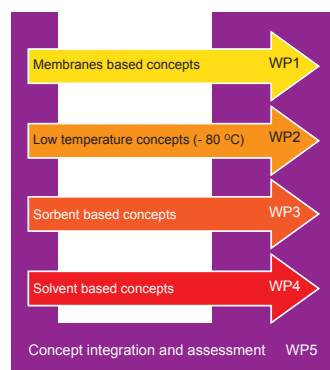
ECCSEL was put on the official European Strategy Forum on Research Infrastructure (ESFRI) Roadmap in December 2008 as the only new entrant in the energy theme. The mission of ECCSEL is to form a European distributed research infrastructure on CCS to be operational by the end of 2013. The investments needed for new and upgraded laboratories are estimated to more than 80M€. A proposal for funding a preparatory phase was submitted to the EU 7th Framework Programme in December 2009. The proposal, which included 15 participating countries, was officially coordinated by NTNU, and received large support from the GTS. The preparatory phase is estimated to start in late 2010.

www.eccsel.org



A GREEN Sea

The objective of the project is to identify and evaluate new technologies and concepts for removal of CO₂ and H₂S from natural gas, thereby avoiding CO₂ emissions to air and avoiding the use of harmful chemicals. PETROMAKS (NFR). This is a 5 year project.



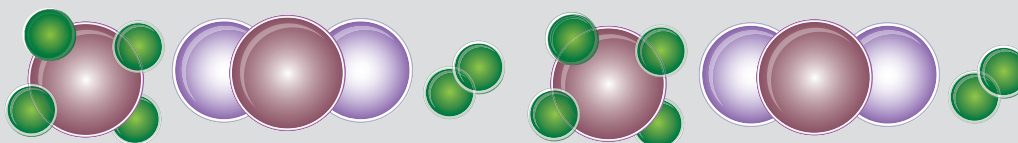
iCap - Innovative CO₂ capture

The iCap project focuses on innovative post-combustion CO₂ capture techniques using chemical absorption media on the combined CO₂/SO₂-removal as well as on the utilization of advanced polymeric and ceramic membrane materials. Contract negotiations were conducted in 2009. The consortium has 15 partners, including European R&D organizations, an industrial group, and partners from Australia and China. EU 7th Framework Programme. This is a 4 year project. Budget: 6.6 M€.



Hydrogen and fuel cell proposals granted support in 2009

- Large-scale laboratory infrastructure for pilot testing of H₂-technologies. SINTEF/NTNU pre-project. Budget: 2 MNOK.
- Socio-economic issues of introducing hydrogen as energy carrier (Danish Programme).
- Three proposals supported by the European FCH-JU:
 - o NEXPEL, Next generation Electrolysers for hydrogen production. Coordinated by SINTEF. This is a 3 year project. Budget: 3 M€.
 - o PreparH2, Preparing Socio-economic Evaluations of H₂-demoprojects. SINTEF is a partner of the project. This is a 1.5 year project. Budget: 0.6 M€.
 - o KEEPEMALIVE, Degradation studies of Proton Exchange Membrane (PEM) Fuel Cells. SINTEF is a partner in the project. This is a 3 year project. Budget: 3 M€.



3. National priorities

Dialogue meetings on the future of oil and gas R&D



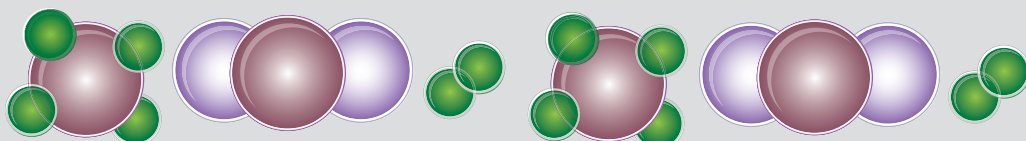
During the autumn, GTS has had meetings with the following Norwegian politicians: Erna Solberg and Linda Helleland from Høyre (Conservative), Gunn Karin Gjøl from Arbeiderpartiet (Labour) and Tord Lien from FrP (Progressive) to discuss the future of oil, gas and CCS research. It was communicated that oil and gas research must be strengthened to assure value creation and environmentally sound exploitation of fossil energy resources in the future.

The meetings included visits to the Multiphase Laboratories and the CO₂ Laboratory, both at Tiller. They were mutually experienced as highly valuable and the dialogue will be followed up.



European Economic Area Joint Parliamentary Committee Meeting

On 29 October, SINTEF with large support from GTS hosted the European Economic Area Joint Parliamentary Committee Meeting on the topic: "The EU's energy and climate policy; research on CCS and offshore wind technology". The programme included presentations about CCS and offshore wind technology, visits to the wind turbine lab at Gløshaugen and the Tiller Multiphase and CO₂ Laboratories, and presentations by Statoil about the Sleipner and Snøhvit CCS experience. Around 45 participants from the European Free Trade Association (EFTA), the European Commission and Stortinget (Norwegian parliament) took part in the one day programme.



4. Education

International master's programmes

GTS has been involved in the development of two international master's programmes; MSc in Natural Gas Technology and the MSc in Innovative Sustainable Energy Engineering.

The programmes are hosted by Department of Energy and Process Engineering, and the programme coordinator is Professor Olav Bolland. Eight students started the MSc in Natural Gas Technology in August 2009.

www.ntnu.no/studies/msc-natural-gas-technology
www.ntnu.no/studies/msisee



Energy from the North – Student excursion to Hammerfest

In September, GTS in cooperation with Statoil organized a student excursion to Hammerfest where Statoil's new plant for natural gas liquefaction was recently commissioned. Twelve master's students from different engineering programmes at NTNU participated in the 5 day programme. Among the topics were: health, safety and environment (HSE), interactive safety course, LNG plant with field course and training simulator, heat exchangers, LNG cooling processes, thermal power generation, gas purification technology, working processes and maintenance planning and rotating equipment.



Photo: Serkan Eren

EnergiCampus Nord (ECN)

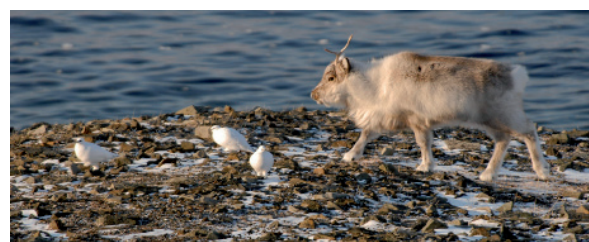
EnergiCampus Nord is the result of cooperation between NTNU, the University of Tromsø, the University of Stavanger, and the University Colleges of Finnmark and Narvik, to create a research-based educational programme in Energy Engineering in Hammerfest. EnergiCampus Nord had in 2009 a budget of 3 MNOK for operation and 5 MNOK for infrastructure.



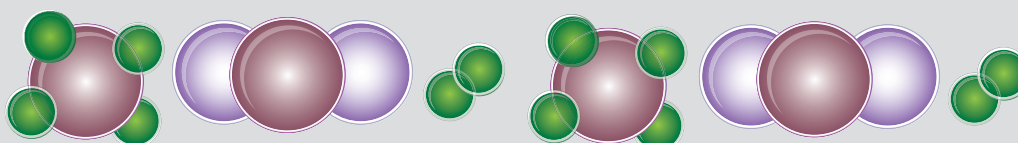
www.energicampus.no

IEA GHG International CCS Summer School 2010

The 4th International Energy Agency Greenhouse Gas R&D Programme (IEA GHG) International CCS Summer School will be organized by GTS in collaboration with the BIGCO2 and SUCCESS projects. The summer school will take place on 22-28 August 2010 in Longyearbyen, Spitsbergen. In 2009, GTS started the planning of the event and has contacted potential sponsors.



www.co2captureandstorage.info/SummerSchool/SummerSchoolIndex.html



PhD and Post Doc candidates

There are around 150 PhD and 45 Post Doc candidates within gas technology at NTNU/SINTEF. Most of the doctoral and post-doctoral work is affiliated with larger research projects or ongoing activities within established research groups and centres.

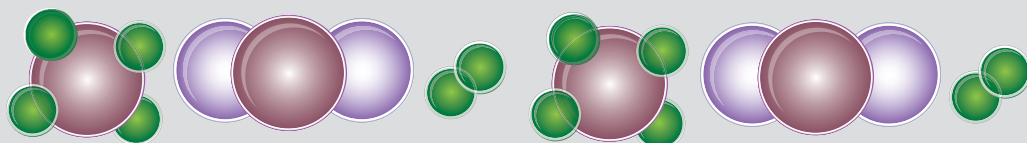
In addition, GTS fully finances two additional PhD programmes per annum and has partially financed four PhD candidates and one Post Doc through the PhD-pool, funded by RENERGI. The focus of the PhD pool is membranes and combustion. Efforts are being made to establish a new PhD pool in gas technology.

The following PhD candidates were fully financed by GTS in 2009:

- Ezequiel Manavela Chiapero. Topic: *Two phase flow instabilities and flow maldistribution in parallel channels*. Recent publications:
 - o Manavela Chiapero, E., Dorao C.A., Fernandino M. (2009). *Simulation of two-phase flow under constant heat flux using high order methods*, 1st International Conference on Computational Methods for Thermal Problems, 8-10 September, Naples, Italy.
 - o Manavela Chiapero E., Dorao C.A., Fernandino M. (2009). *Study of multiple solutions in two phase flow in parallel channels*. 1st Trondheim Gas Technology Conference, 21-22 October, Trondheim, Norway.
- Magnus Jacobsen. Topic: *Optimal operation of LNG processes*. Recent publications:
 - o *Control of maldistribution of flow in parallel heat exchangers*, Nordic process control workshop, 29-30 Jan 2009, Porsgrunn, Norway.
 - o *Optimal selection of controlled variables for the C3-MR process for liquefaction of natural gas*, 1st Trondheim Gas Technology Conference, 21-22 October, Trondheim, Norway.
- Tom-Gøran Skog. Topic: *Development of polymeric hollow fiber membranes for removal of CO₂ from high-pressure natural gas*. Started in October 2009.

Professorship

Since 2004 GTS has funded the position of Adjunct Professor in LNG technology held by Dr. ing. Geir Owren. The position is affiliated with the Department of Energy and Process Engineering, NTNU. Geir Owren is Senior Advisor at the Statoil Research Centre, in the field of gas processing and LNG.



5. Networking and internationalization

Cooperation with the Massachusetts Institute of Technology (MIT)

GTS has supported further collaboration between NTNU and MIT in Boston. The research groups at NTNU and MIT are collaborating on the design and optimization of LNG plants, as well as new technologies for synthesis gas production. The collaboration also addresses mathematical models related to gas transport infrastructure.



**Massachusetts
Institute of
Technology**

<http://mit.edu>

Internationalization grants

The following proposals were supported in 2009:

- Support of sabbatical visit to NTNU for Professor Gian Paolo Beretta, University of Brescia, Italy, (70 kNOK).
- Professor Anders Holmen: Core-shell nanostructured catalyst for Fischer-Tropsch synthesis, a researcher exchange between NTNU and the University of California at Berkeley (56 kNOK).

DNV-NTNU workshop on the Cost of Power, Renewables and Fossil Fuels with CCS

The workshop was organized by GTS and DNV, and involved DNV, SINTEF and NTNU communities. It took place on 27 August in Trondheim and had 60 participants. Topics were state of the art on the cost of power for renewable technologies and fossil fuel technologies with CCS, and the basics for CCS cost calculations.



www.dnv.no

N.ERGHY

The New European Research Grouping for HYdrogen (N.ERGHY) represents around 60 R&D institutions in Europe with over 2000 researchers working in the field of hydrogen and fuel cells. NTNU is a member of N.ERGHY and SINTEF is represented on the Executive Board.



research on fuel cells & hydrogen

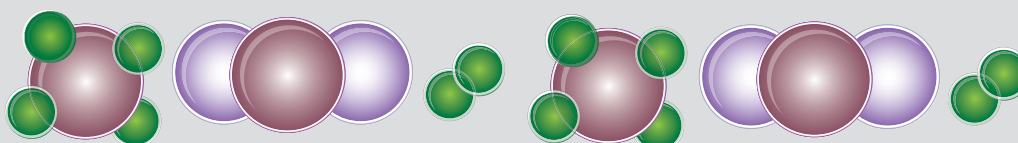
www.nerghy.eu

CO2NET

CO2NET is a Carbon Dioxide Knowledge Sharing Network, which was initially set up under the EU 5th Framework Programme. It is now an industry-led, self-funded network and comprises more than 30 major companies and organizations in Europe, USA and Australia extensively involved in the development of CCS.



www.co2net.com



6. Internal coordination

Technical seminar series 2009

- *Scaling-up Carbon Dioxide Capture and Storage (CCS) - from Megatonnes to Gigatonnes*, Howard Herzog, Massachusetts Institute of Technology (MIT), 12 March
- *GassMat: Integration models for Industrial Clusters Producing Materials and Energy*, Jack Ødegård, SINTEF Material & Chemistry, 2 April
- *Acid Gas Removal: Problem Description and Experiences from Sleipner Field*, Even Solbraa, Statoil, 28 April
- *The route from fundamental knowledge to problem solving: example from LNG research*, Mona Mølnevik, SINTEF Energy Research, 6 May
- *World Energy Consumption and Resources: an Outlook for the Rest of the Century and the Role of Research in Thermodynamics*, Gian Paolo Beretta, University of Brescia, 3 November
- *Catalytic conversion of biomass to liquid fuels*, Hilde J. Venvik, Department of Chemical Engineering, NTNU, 8 December, a joint seminar with the Centre for Renewable Energy

The seminars were attended by scientists and students from NTNU and SINTEF as well as representatives from industry working on gas technology R&D aspects.

Scientific equipment

The following proposals received funding for scientific equipment. Total budget 500 kNOK.

- Characterization of solvents for carbon dioxide capture from low and high pressure/temperature gas streams (165 kNOK), SINTEF Materials and Chemistry
- Photocatalytic membrane reactor for natural gas conversion (100 kNOK), SINTEF Materials and Chemistry
- Safety equipment connected to powder technology (CLC) (135 kNOK), NTNU Department of Engineering and Process Engineering and SINTEF Energy Research
- Equipment for thermal conductivity measurements of porous materials for hydrogen storage (100 kNOK), NTNU Department of Engineering and Process Engineering

Development of strategic R&D interaction

Cooperation with strategic partner

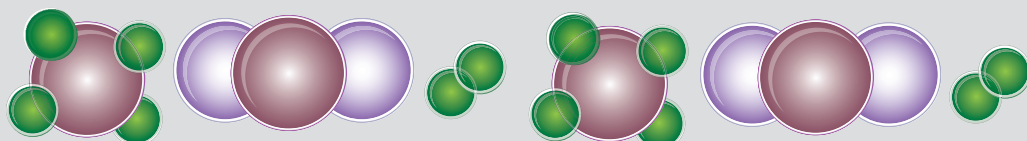
Statoil is an integrated oil and gas company with substantial international activities and is a strategic partner of GTS. The resources from Statoil finance cooperation projects and activities relevant for realizing the New Energy strategy of Statoil. The resources fund PhD and postdoctoral fellowships, laboratory equipment, network building and management of the GTS. During 2004-2009 a full professorship in hydrogen technology has been funded by Statoil under the GTS cooperation. The position is held by Associate Professor Hilde J. Venvik, Department of Chemical Engineering, NTNU. The agreement aims to further develop the cooperation between NTNU/SINTEF and Statoil.

New partners and sponsors

During the new working period (2008-2012), GTS is open for new partners and sponsors to join the strategic R&D interaction.



www.statoil.com



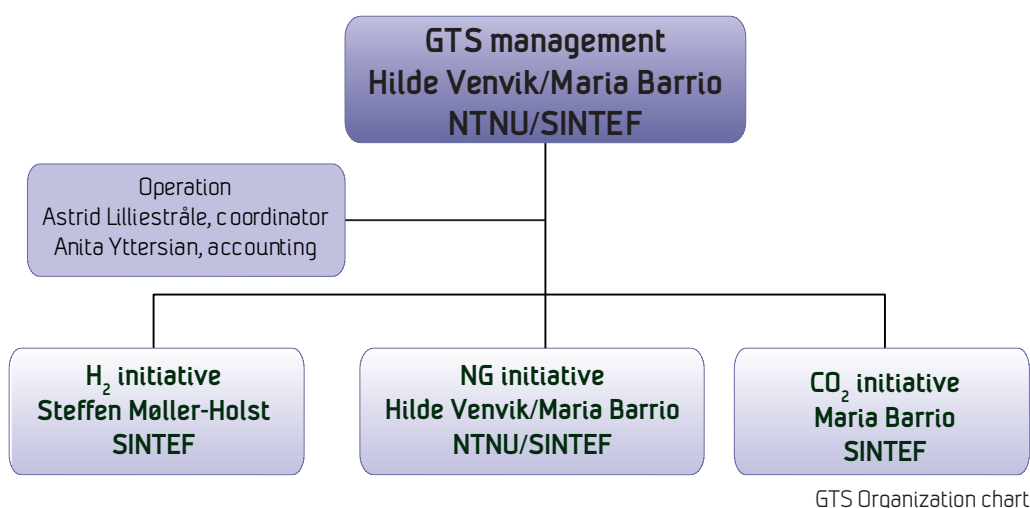
GTS in short

Board of Directors

- Chairman: President Sverre Aam, SINTEF Energy Research
- Director Siv Aasland, Statoil R&D
- Research Director Ole Wærnes, SINTEF Materials and Chemistry
- Professor Arne M. Bredesen, NTNU Director of the Strategic Area, Energy and Petroleum – Resources and Environment
- Professor May-Britt Hägg, NTNU Department of Chemical Engineering

Management

- SINTEF's director of GTS, Vice President, Dr. ing. Maria Barrio
- NTNU's director of GTS, Associate Professor Hilde J. Venvik



Maria Barrio



Hilde J. Venvik



Steffen Møller-Holst



Astrid Lilliestråle



Anita Yttersian

Staff

75 professors/associate professors, 10 adjunct professors, 150 PhD candidates, 25 Post Doc researchers at NTNU and 200 research scientists at SINTEF are associated with GTS.

Norwegian University of Science and Technology (NTNU)

NTNU represents academic eminence in technology and natural sciences as well as in other academic disciplines. Its academic scope ranges from technology, the natural sciences, the social sciences, the humanities, medicine, architecture to fine art. Cross-disciplinary cooperation at NTNU results in innovative and creative solutions.



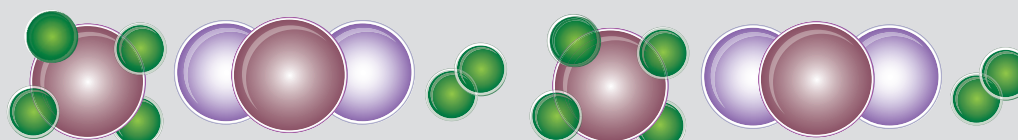
www.ntnu.no

SINTEF

The SINTEF Group is the largest independent research organization in Scandinavia. SINTEF's goal is to contribute to wealth creation and to the sound, sustainable development of society. SINTEF generates new knowledge and solutions for its clients, based on research and development in technology, medicine, the natural sciences and the social sciences.



www.sintef.no





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Strategic partner:

