



Gas Technology Centre NTNU – SINTEF



Annual report 2008

Strategic Partner:

StatoilHydro



Foreword

2008 was a year of transition for the Gas Technology Centre NTNU-SINTEF (GTC). At end of 2007, the 5-year contract with StatoilHydro ended. A new 5-year contract with StatoilHydro was signed August 28, 2008. Continuing support both from NTNU and SINTEF, as well as that of StatoilHydro ensures a sound basis for the GTC until 2012.

The NTNU director of GTC, Prof. Bjarne Foss, was replaced by Prof. Olav Bolland in January 2008. At the end of 2008, Dr. Nils Røkke, was replaced by Dr. Maria Barrio as the SINTEF director of GTC. A change of coordinator took also place. Ms. Åse Lekang Sørensen quit her position in May 2008, and was replaced by the current coordinator, Mr. Paris Klimantos.

Bjarne, Nils and Åse did a very good job, and the whole NTNU & SINTEF gas technology community is grateful for their efforts.

During 2008, the leader group was extended with Prof. Edd Blekkan and Dr. Steffen Møller-Holst.

There is still a lot of activity within the gas technology area. CO₂ capture and storage (CCS) has become one of the largest research areas ever for NTNU and SINTEF. We are well established with national programs, and we participate in most CCS-projects funded by the 6th and 7th Framework programs. The next to come is the European Carbon dioxide Capture and Storage Laboratory infrastructure initiative (ECCSEL), which was selected to be included in the ESFRI Roadmap. This implies influx of funding for the development of our laboratories. It will be a major challenge and a pleasure using ECCSEL to further strengthen the NTNU/SINTEF position within CCS. In addition to Nils Røkke, Prof. Arne Bredesen has been very important for the ECCSEL success so far.

We have a large activity with various projects funded by the Research Council program GASSMAKS and Norwegian industry. These projects are mainly focussed on the non-combustion conversion of natural gas.

In 2008, two 2-year international master programs related to natural gas were established. One is Natural Gas Technology, and the other is a Nordic collaborative master program, Innovative Sustainable Energy Engineering (ISEE), to which NTNU contributes with natural gas technology and industrial ecology. Hopefully, this will bring us a number additional students as well as increased awareness about NTNU and SINTEF in the global natural gas community.

On the following pages you can read more about the 2008 activities.



Prof. Olav Bolland,
NTNU



Dr. Nils A. Røkke,
SINTEF



Dr. Maria Barrio,
SINTEF



The Gas Technology Centre NTNU –SINTEF

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

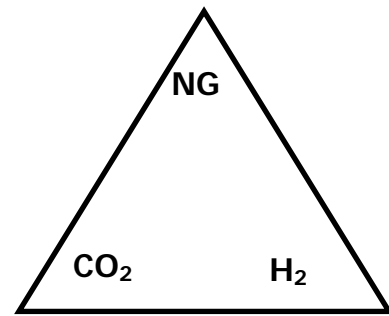
The objective of the Gas Technology Centre, NTNU-SINTEF is to increase the quality, efficiency and scope of gas technology education, research, development and innovation in Norway. This is to be achieved by coordinating and establishing new activities in the area at NTNU and SINTEF.

This includes the following actions:

- Contribute to strategies and interaction for value creation and innovation in Norway, and for the international business development of Norwegian companies based on natural gas.
- Initiate larger programs for knowledge development and innovation in the natural gas sector.
- Coordinate the strategic objectives, resources and activities at NTNU and SINTEF.
- Increase the visibility, cooperation and market orientation of in the Norwegian gas cluster both domestically and internationally.

Gas Value Chain R&D

The Centre focuses on exploring the synergism of multidisciplinary research into the natural gas value chain. The Gas Technology Centre has expertise in the entire value chain from the source to the end-user.



Main achievements in 2008

- A new operational period has been established: 2008-2012. StatoilHydro continues to support the Gas Technology Centre as strategic partner. The gas Technology Centre opens in this period for additional partners.
- The Gas Technology Centre has supported the European Carbon Dioxide Capture & Storage lab Infrastructure (ECCSEL). The proposal has been officially included into the EU Roadmap for Research Infrastructures (ESFRI).
- Two new International Master Programmes on gas technology have been established, with the involvement of the GTC.
- The GTC has contributed to the creation of a research-based educational programme within energy engineering in Hammerfest called EnergiCampus Nord.
- The GTC has co-sponsored the Norwegian Hydrogen Seminar 2008.
- Together with the Centre for Renewable Energy has participated in the exhibition SCAN-REF 2008.
- Participation as exhibitor in 9th Conference of Greenhouse Gas Control Technologies Conference, jointly with DNV and Aker Clean Carbon.
- Involvement in the preparation of two FME proposals: BIGCCS and CESTRA .
- Involvement in the preparation of a collaborative project proposal (iCap) on Innovative Capture Techniques with the EU 7th Framework Programme
- Preparatory work of the 5th Trondheim Conference on CCS
- Strategic participation in R&D forums and initiatives



Activities in 2008

ECCSEL-European Carbon Dioxide Capture & Storage Lab Infrastructure

ECCSEL is an initiative coordinated by NTNU and SINTEF, aiming at developing joint pan-European laboratories for CO₂ capture & storage R&D activities. The proposal has been officially included into the EU Roadmap for Research Infrastructures (ESFRI) and has been supported by nine organizations from Germany, Hungary, Switzerland, Poland, Croatia, Netherlands, France and Denmark. The total investment for ECCSEL is 81M€, to be allocated for the development of a unique network of 15 laboratories addressing the whole CCS value chain; five of them will be built in Norway. The initiative has been coordinated by Prof. Arne Bredesen NTNU and Dr. Nils A. Røkke from SINTEF. www.ntnu.no/eccsel



New International Master Programs on Gas Technology

The Centre has been involved in the development of two international Master Programmes: MSc in Natural Gas Technology and the Nordic Master in Innovative Sustainable Energy Engineering. NTNU contribution to the programme is natural gas technology and CCS. NTNU approved both programs on 12th of June and the first student will start during fall 2009. Prof. Olav Bolland is going to coordinate and is in charge of the MSc in Natural Gas Technology. <http://www.ntnu.no/studies/msc-natural-gas-technology>.



EnergiCampus Nord (ECN)

EnergiCampus Nord is a cooperation between NTNU and the universities in Tromsø and Stavanger, and the Colleges of Finnmark, Narvik og Tromsø, to create a research-based educational programme within Energy Engineering in Hammerfest. EnergiCampus Nord has in

the 2009 state budget allocated 3 mill NOK for operation and 5 mill NOK for infrastructure. The programme started with an engineering pre-course in autumn 2008. NTNU's course TEP10 Gas Processing and LNG was held as an intensive course with about 30 students. ECN has established a dialog with the local businesses and industry to better offer relevant education. At NTNU Professor Arne M. Bredesen is leading the work, and Eva Lien from the Gas Technology Centre is also involved. www.energicampus.no.

The Norwegian H₂ seminar, Bergen 2008

The Norwegian Hydrogen Seminar 2008, co-sponsored by the Gas Technology Centre NTNU-SINTEF, was held in Bergen on 25th and 26th of September. The seminar was attended by over 60 participants from R&D institutes, universities, industry and the Research Council of Norway. It provided a comprehensive update on R&D topics for hydrogen production, storage and utilisation as well as on the status of development of several industrial products and prototypes. Dr. Steffen Møller-Holst (SINTEF), and Prof. Edd Blekkan (NTNU), were members of the organising committee. <http://www.hydrogen.no/h2seminar2008>



Scandinavian Renewable Energy Forum 2008 (SCAN-REF 2008)

The Gas Technology Centre and the Centre For Renewable Energy participated in SCAN-REF with a joint exhibition where both the R&D and educational activities of NTNU and SINTEF were presented. The Centres granted free registration to the conference and travel expenses to 25 students. Prof. Olav Bolland organised a session on CO₂ value chain and Dr. Nils A. Røkke gave a presentation entitled, "CO₂ capture from power plants, technology maturity and development towards realisation".





9th International Conference on Greenhouse Gas Control Technologies (GHGT-9) Washington DC, 17-20 November 2008

The Centre participated as an exhibitor jointly with DNV and Aker Clean Carbon in GHGT-9 where the activities of NTNU and SINTEF on CCS were presented. The event was an



unique opportunity for networking with active actors in the development of CCS technologies. NTNU and SINTEF contributed to this event with 59 papers and one invited talk given by Prof. Olav Bolland. The 5th Trondheim Conference on CCS was announced and material promoting the event and calling for abstracts was disseminated.

FME Centres for Environmental Friendly Energy Research

The Centre was involved in the establishment of two proposals, the BIGCCS focusing on CCS R&D and CESTRA focusing on hydrogen R&D. Both project proposals were invited to participate in the Phase 2 of the application process. BIGCCS was submitted as a application covering activities of the whole CCS value chain. BIGCCS is project proposal amounts to 398 MNOK with eleven R&D partners and eleven industrial partners. Final evaluation results are expected on 4th February 2009.



Technical Seminar Series

The following seminar series has been organized by the Centre during 2008.

- Oil sand - when going gets tough, Professor Olav Bolland, NTNU.
- State-of-the-art multi-phase flow simulation, Ruben Schulkes, StatoilHydro.

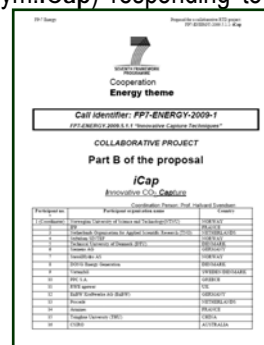
- Optimization of natural gas transport, Asgeir Tomasgard, NTNU (postponed)
- Fisher-Tropsch Analysis, Professor Edd Blekkan, NTNU

The seminar series were attended by scientist and students from NTNU and SINTEF as well as by people from industry working on gas technology R&D aspects.

EU -7th Framework Programme

The Centre has been involved in the preparation of a collaborative project proposal (Acronym:iCap) responding to the topic Energy 5.1.1

Innovative Capture Techniques of the 7th FP. iCap proposal, coordinated by Prof. Hallvard Svendsen NTNU, focuses on innovative post-combustion CO₂ capture techniques using chemical absorption media as well as on the utilization of advanced polymeric and ceramic membrane materials. iCap plans for a budget of 6.6M€ and a 16-partners consortium comprising of European leading R&D organisations (NTNU, SINTEF, TNO, IFP, DTU, Armines) an industrial group (Vattenfal, DONG, PPC, RWEnpower, EnBW, SIEMENS,Procede) as well as partners form Australia (CSIRO) and China (Tsinghua University).



The 5th Trondheim Conference of CCS, 16-17, June 2009 (5th TCCS)

The 5th TCCS is organised by GTC and will be held as a back to back event with CO₂NET 2009 Annual Seminar. Call for abstract opened on 1st of December. Prof. Olav Bolland and Dr. Nils Røkke are the organizers of the conference. www.ntnu.no/tccs5

European Conference on CCS, Oslo, 10-11 February 2009

The conference is organized under the auspices of the Decarbit project coordinated by SINTEF. The conference focus on the R&D activities of major European R&D funded projects like Decarbit, CEASAR, CESAR, CACHET. www.ccs-conference.com



National R&D Projects and Initiatives

BIGCO2

CO₂ Management Technologies for Future Power Generation *Knowledge building project with user involvement (KMB)*, CLIMIT, Total budget 2007 – 2011: 16 M€

BIGCLC

Demonstration of Chemical Looping Technology in Natural Gas Power Generation with CO₂ Capture, 2006-2009: *Knowledge building project with user involvement*, CLIMIT. Total budget 4 years: 12.0 M€

Efficient Hydrogen Liquefaction Processes

Improving the energy efficiency for liquefaction 2005-2009: User-led innovation project (BIP), RENERGI. Budget 5 years: 11 MNOK (1.4 M€)

Optimal Design and Operation of Gas Processing Plants

Increase the value of natural gas by better operation and design of processing plants for natural gas 2005-2008: User-led innovation project, RENERGI Budget 4 years: 11,7 MNOK (1.5 M€)

Enabling production of Remote Gas

Address the critical technology barriers related to floating production of natural gas from smaller fields through a coordinated effort by industry and research institutions. 2005-2009: Knowledge building project with user involvement, PETROMAKS Budget 5 years: 40 MNOK (5 M€)

IEA GHG Implementing Agreement

The Gas Technology Centre enjoyed a close cooperation with the IEA Greenhouse Gas R&D Programme during the arrangement of the GHGT-8 conference, and intends to continue regular contact

PhD-pool

The Gas Technology Centre partially finances 4 PhD students through the PhD-pool, funded by RENERGI. The focus of the PhD studies financed by GTC is membranes and combustion. A list of the Scientific publications during 2008 of the Phd-pool participants is available at the end of this report.

Increased value creation and innovation from natural gas R&D

National research program: GASSMAKS

GASSMAKS is a research program addressing industrial value creation from natural gas. The Gas Technology

Centre maintains an active communication with the GASSMAKS program.

OG21

OG₂₁ is a Task Force established by the Ministry of Petroleum and Energy, Norway in 2001, to help the petroleum industry to formulate a national technology strategy for added value and competitive advantage in the oil and gas industry. The objective is to develop a more coordinated and focused approach to research and development throughout the oil and gas industry. The Gas Technology Centre is communicating views for the national gas technology research to the strategy of OG₂₁, and has been an active member in TT8 – Gas Technologies.



Multiphase flow test rig at the Department of Energy and Process Engineering, NTNU, (Photo : P. Klimantos)

Energi21

Energi21 initiated by the Norwegian Ministry of Oil and Energy aiming at defining the R&D strategy for the Norwegian energy sector. The strategic document prepared through this process presented on February 2008. The Gas Technology Centre participated in various committees and communicated views on CCS and gas value chain R&D strategy. www.energi21.no



EU- R&D Projects & Initiatives

1. ECCO: European value chain for CO₂
2. DECARBit : "Decarbonise it" - Enabling advanced pre-combustion CO₂ capture techniques and plants
3. DYNAMIS: Towards Hydrogen and Electricity Production with CO₂ management
4. ENGAS: Environmental Gas Management Research Infrastructure
5. ENCAP: Enhanced Capture of CO₂
6. CO2Remove: Geological storage of CO₂
7. COACH: Cooperation Action within CCS EU-China
8. CASTOR: CO₂ from Capture to Storage
9. ULCOS: Ultra Low CO₂ Steelmaking
10. INCACO2: International Cooperation Actions on CO₂ Capture and Storage
11. CO2GeoNet: Network of Excellence in Geological Storage of CO₂
12. NATURALLY: Preparing for the hydrogen economy by using the existing natural gas system as a catalyst
13. ETP ZEP, European Technology Platform Zero Emission Platform
14. CO₂ net –Thematic Network

ETP ZEP
ZEP aims at coordinating the establishment and implementation of a strategic research agenda to meet the needs of European Citizens and industry by 2020. In line with the proposed priority for "Near Zero Emission Power Generation" in FP7. This will include CO₂ capture and storage, as well as clean conversion technologies leading to substantial improvements in plant efficiency, reliability and costs. Prof Hallvard Svendsen and Dr. Nils A. Røkke are actively involved with ETP ZEP.

www.zero-emissionplatform.eu

CO2NET
CO2NET was initially set up under the European Commission's FP5 Programme, and the Network comprises over 50 companies or organizations, covering 18 countries.

The key drivers for CO2net are the development of CO₂ Capture and Storage (CCS) as a safe, technically feasible, socially acceptable option to help reduce the effects of human influenced climate change and meet the CO₂ emission reduction target set by the Kyoto agreement with a view to even greater emission reductions across Europe and beyond.

www.co2net.net



Development of strategic R&D interaction

Cooperation with strategic partner

StatoilHydro, is Strategic Partner of the Gas Technology Centre. StatoilHydro is an integrated oil and gas company with substantial international activities. The resources from StatoilHydro finance cooperation projects and activities relevant for realizing the "New Energy" Strategy of StatoilHydro. The resources fund PhD- scholarships, Post Doc scholarships, a professorship within hydrogen technology, laboratory equipment, network building, as well as management of the Gas Technology Centre. Additionally, the agreement aims to further develop the cooperation between NTNU-SINTEF and StatoilHydro.

New partners and sponsors in the Gas Technology Centre

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

Overview of project portfolio

Staff associated to the Gas Technology Centre

The Centre updates each year an overview of NTNU and SINTEF staff associated with the Gas Technology Centre. Approximately 75 professors / assoc. professors, 10 adjunct professors, 150 PhD-students and 25 Post Doc researchers are registered in the overview. This is available on the webpage of the Centre.

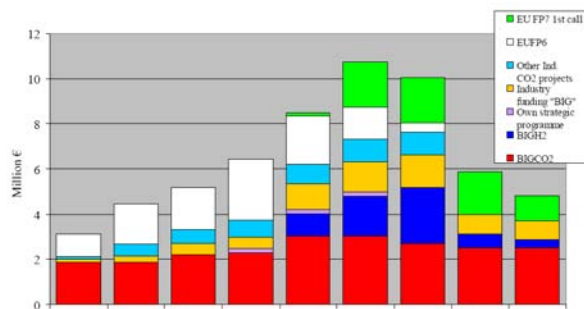


Figure 1. NTNU and SINTEF project portfolio on CCS R&D

Organization

A new agreement between NTNU, SINTEF and StatoilHydro for the continuation of the Gas Technology Centre was signed on August 28, 2008

The Board of Directors

The Gas Technology Centre NTNU-SINTEF has the following Board of Directors:

- Chairman: President Sverre Aam, SINTEF Energy Research



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

Management

In 2008 the Gas Technology Centre was managed by SINTEF's Centre Director Dr. Nils A. Røkke and NTNU's Centre Director Prof. Olav Bolland. From January 2009, Dr. Maria Barrio replaces Nils Røkke as the new SINTEF's Centre Director.

NTNU

NTNU, the Norwegian University of Science and Technology in Trondheim 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.

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.

Contact Information for the Gas Technology Centre, NTNU-SINTEF:

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Coordinator:

Paris Klimantos, paris.klimantos@ntnu.no



PhD Pool publications

1. A.L. Mejdell, H. Klette, A. Ramachandran, A. Borg, R. Bredesen, *Hydrogen permeation of thin, free-standing Pd/Ag23% membranes before and after heat treatment in air*, Journal of Membrane Science 307 (2008) 96-104
2. A.L. Mejdell, M. Jøndahl, T.A. Peters, R. Bredesen, H. Venvik, *Experimental investigation of a microchannel membrane reactor with 1.5 μm Pd/Ag23% membrane*, The 10th International Conference on Inorganic Membranes, 18-22 August 2008, Tokyo, Japan. Oral presentation.
3. A. Ramachandran, A. Mejdell, T.A. Peters, M. Stange, H. Venvik, A. Borg, R. Bredesen, *Hydrogen permeation and surface characterization of 1.5 μm PdAg membranes*, The 10th International Conference on Inorganic Membranes, 18-22 August 2008, Tokyo, Japan. Oral presentation.
4. M. Stange, T.A. Peters, A.L. Mejdell, H.J. Venvik, R. Bredesen, *Sputtering and application of thin Pd-alloy hydrogen separation membranes*, The 10th International Conference on Inorganic Membranes, 18-22 August 2008, Tokyo, Japan. Poster presentation.
5. A.L. Mejdell, M. Jøndahl, T.A. Peters, R. Bredesen, H. Venvik, *Experimental investigation of a microchannel membrane reactor configuration*, Norwegian Hydrogen Seminar 2008, 25-26 September 2008, Bergen, Norway. Oral presentation.
6. A.L. Mejdell, M. Jøndahl, T.A. Peters, R. Bredesen, H. Venvik, *Influence of CO and CO₂ on a ~3 μm Pd/Ag membrane supported by microchannels – effect of temperature and concentration*, 13th Nordic Symposium on Catalysis, 5-7 October 2008, Göteborg, Sweden. Poster presentation.
7. Liyuan Deng, T-J Kim, M-B Hägg, *Facilitated transport of CO₂ in novel PVAm/PVA blend membrane*, Journal of membrane science, May, 2008, submitted and under revision.
8. Liyuan Deng, T-J Kim, Marius Sandru, M-B Hägg, *PVA/PVAm Blend FSC Membrane for Natural Gas Sweetening*, 1st annual gas processing symposium proceeding, June, 2008, accepted
9. Liyuan Deng, May-Britt Hägg, *PVA/PVAm Blend FSC Membrane for Biogas Upgrading*, International congress of membrane, Hawaii, USA, Jul. 2008
10. Liyuan Deng, May-Britt Hägg, *Capture of CO₂ from natural gas with PVAm/PVA blend FSC Membrane*, the 11th nordic filtration symposium, Copenhagen, Denmark, Aug. 2008
11. I. Inzoli, J. M. Simon, S. Kjelstrup and D. Bedeaux, *Transport coefficients of n-butane into and through the surface of a silicalite-1 from non-equilibrium molecular dynamics study*, Microporous and Mesoporous materials, submitted.
12. I. Inzoli, J. M. Simon, S. Kjelstrup, *Adsorption isotherms and surface excess densities of n-butane in silicalite-1 by molecular dynamics*, Langmuir, submitted.
13. I. Inzoli, J. M. Simon, S. Kjelstrup and D. Bedeaux, *Thermal diffusion and partial molar enthalpy variations of n-butane in silicalite-1*, Journal of Physical Chemistry, accepted (jp-2008-04778u.R1).
14. S. Kjelstrup, D. Bedeaux, I. Inzoli and J. M. Simon, *Criteria for validity of thermodynamic equations from non-equilibrium molecular dynamics simulations*, Energy, 33 (2008), pp. 1185-1196.