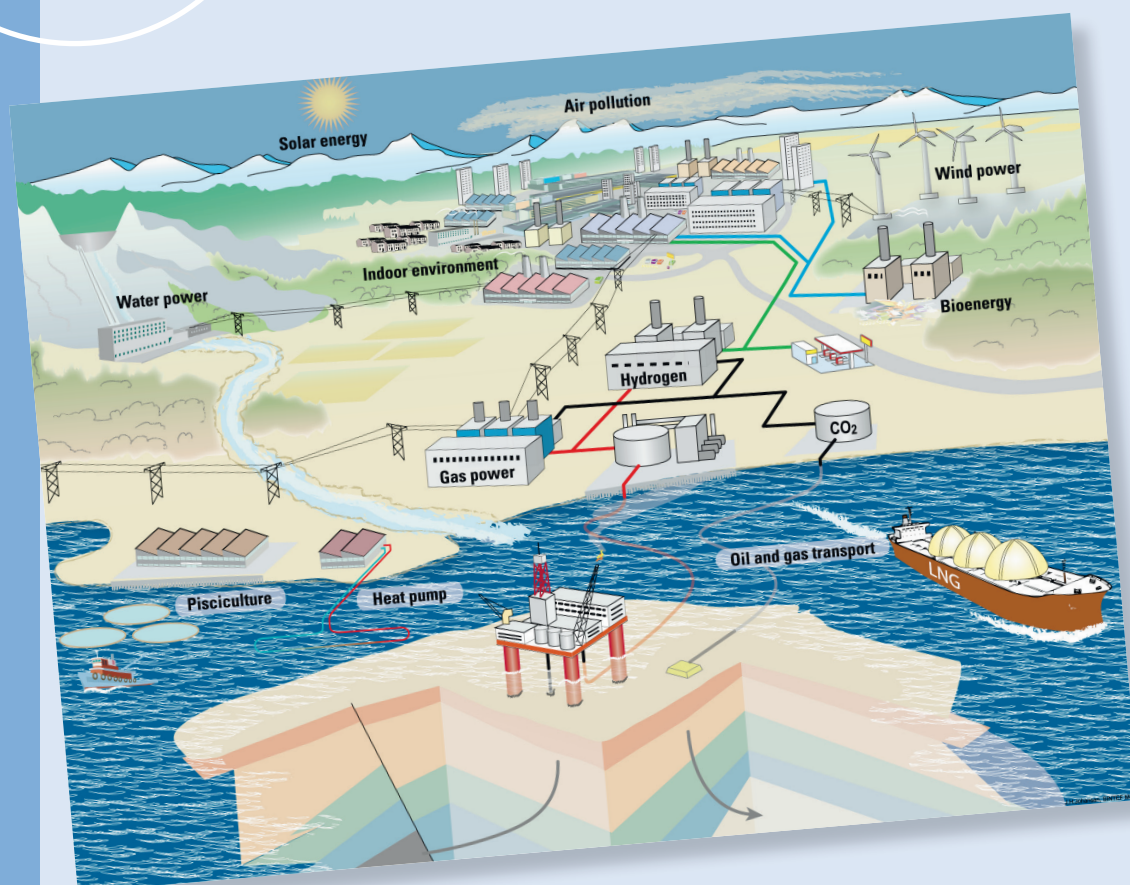


## STRATEGIC AREA Energy and Petroleum – Resources and Environment



## What are NTNU's Strategic Areas?

One of the main goals of NTNU is to be useful to society, by developing and maintaining the national technological skills needed to build a sustainable society. To realize this goal NTNU has given priority to six strategic areas where multidisciplinary teamwork produces high-quality research with substantial long-term social impact. These are:

- Energy and Petroleum – Resources and Environment
- Globalization
- Information and Communications Technology (ICT)
- Marine and Maritime Technology
- Materials
- Medical Technology

Visit us at <http://www.ntnu.no/strategicareas>

## About Energy and Petroleum–Resources and Environment

**Energy is not just about money and economic growth. Energy is essential to the life of people on this planet.**

We need energy to provide essential human needs such as food, housing, clothing, transportation, health and recreation – in short, everything that is needed to live a good life on this planet.

By the end of this century, the countries of the world must collectively make substantial cuts in the emissions of heat-trapping greenhouse gasses. At the same time several billion new world citizens will join us at the global dinner table. Providing **sufficient clean energy** to ensure a peaceful future and sustainable society for everybody is the largest challenge facing humankind today.

There will be an increasing demand for new knowledge, new technology, new solutions and new innovations to meet this global challenge. NTNU and SINTEF want to play an active and productive role in supplying the scientific and technological information and innovations essential to the global transformation process we need to achieve a sustainable future.

Our overall goal is to develop new knowledge and technology in the clean energy field and educate people who can utilize that knowledge to create new clean energy solutions.

A successful transition to clean and sustainable energy systems will depend on global innovations. Although the solutions that will be implemented will reflect local resources and conditions, they will emerge from the application of a mixture of key technologies, with which NTNU and SINTEF are actively working.

By virtue of its hydropower and petroleum resources, and its favourable conditions for renewable energy, Norway may be considered an “energy country”. For this reason, government and industry have invested in the research that is conducted in Trondheim, which has enabled NTNU and its research partner SINTEF to expand their energy-related research. Today, nearly 1000 scientists are involved in efforts to create a cleaner energy future. This “family” includes roughly 170 professors and 350 doctoral students and post-doctoral researchers who are conducting fundamental energy-related research. NTNU also educates around 300 master’s students each year, which in turn supplies the energy sector with highly qualified job candidates.



To increase our utility to society and improve the way that we meet future challenges, beginning in January 2000, the strategic area has developed an organization based primarily on goal-oriented multi-disciplinary research centres. This enables us to handle complicated large-scale problems that can only be dealt with through multi-disciplinary teamwork. Today this organization consists of the following six research centres:

- Centre for Energy and Society
- Centre for Sustainable Buildings
- Centre for Renewable Energy
- Gas Technology Centre
- Petroleum Centre for Better Resource Utilization
- Centre for Electric Energy and Energy Systems

In addition, we have developed strategic initiatives that involve cross-disciplinary work between the centres:

- CO<sub>2</sub> Capture and Storage (CCS)
- Hydrogen Technology
- Green Innovation
- NanoLab

Research teams from the strategic area participate in the following national Centres of Excellence:

**Centres for Research Based Innovation (CRI)**

- Integrated Operations
- Multiphase Flow Assurance
- Innovative Natural Gas Processes and Products

**Centres for Environment-Friendly Energy Research (CEER) (start up 2009-2010)**

- BIGCCS – International CCS Research Centre
- Centre for Environmental Design of Renewable Energy (CEDREN)
- Bioenergy Innovation Centre (CenBio)
- Norwegian Research Centre for Offshore Wind Technology (NOWITECH)
- The Norwegian Research Centre for Solar Cell Technology
- The Research Centre for Zero Emission Buildings (ZEB)
- Centre for Sustainable Energy Strategies (CenSES)



These CEERs constitute a total research investment of more than 2 billion NOK over 8 years and will be organized as a close cooperative effort among universities, research institutes and industry. The industrial partners will cover 25% of the investment. The remaining amount will be covered by the Research Council of Norway (50%) and NTNU-SINTEF. Close to 200 PhDs and postdocs will be educated.

NTNU and SINTEF are therefore in a good position to contribute to the challenging work that lies ahead. Our main strategic cooperation partners are the Norwegian government, the Research Council of Norway and the Norwegian energy industry.

**Our vision is “Sufficient and clean energy for a sustainable and peaceful society”**

The strategic area relies heavily on cooperation and coordination with the different NTNU faculties. The organization of teamwork involves highly professional and unique research groups that handle strategically important areas in science and technology. There are close to 30 such research groups in our strategic area. The teams consist of NTNU professors, SINTEF researchers and PhD and MSc students who work in state-of-the-art laboratories. These research groups have been created by the faculties through the allocation of personnel resources and laboratory investments. The development of new research groups to handle new technology areas thus relies on good communication between the strategic area and the faculties. The Faculty-Centre-Matrix below shows how our strategic area has developed these cooperative networks with almost all of NTNU's faculties.

As a result of Norway's location close to the North Sea and the Arctic Basin, with large reserves of both renewable energy sources and natural gas, the NTNU-SINTEF team has given priority to several key technology areas where we want to contribute to the global innovation process. We want to develop new technology and solutions for:

- Efficient end use of energy
- Utilization of renewable energy sources (offshore wind, solar and bio energy)
- Carbon Capture and Storage (CCS) to allow the use of fossil fuel and still reduce CO<sub>2</sub> levels
- Smart energy systems that integrate sources and end-users in an efficient way
- Utilization of natural gas in an environmentally friendly way
- Hydrogen technology
- Better resource utilization and energy from the Arctic region

**Faculty - Centre - Matrix**

Faculty of:	Contribution to Centres						
	Professors	BRU	GTC	CRE	ELES	Build	CES
Architecture and Fine Art	5			X		X	
Engineering Science and Technology	86	X	X	X	X	X	X
Natural Sciences and Technology	32	X	X	X			
Information Technology, Math-ematics and Electrical Engineering	31	X	X	X	X		
Social Sciences and Technology Management	7		X				X
Humanities	6						X
<b>Total</b>	<b>167</b>						

## Main events in 2009

- Centres for Environment-friendly Energy Research (CEER): On 4 February 2009, eight CEER teams received their certificates from the Norwegian Minister of Petroleum and Energy, Terje Riis Johansen. **NTNU and SINTEF were heavily involved in 6 of these.** This huge achievement was possible thanks to excellent team work between research groups within our existing centres for Renewable Energy, Gas Technology, Sustainable Buildings, and Energy and Society.
- In December 2009, NTNU and SINTEF, together with our European partners, brought forward an application to ESFRI on a "Preparatory Phase Project" for the start-up of the laboratory initiative ECCSEL (European Carbon Capture and Storage Laboratory Infrastructure). This will be the first stage in the development of ECCSEL.
- The Centre for Renewable Energy coordinated a "think tank" project, which involved the participation of MSc and PhD students from the appointed CEERs. The "Energy Think Tank" was created by the Minister of Petroleum and Energy, Terje- Riis Johansen in February and the students presented their work for the Minister in September.
- On 16-17 June, the Gas Technology Centre organized the "5th Trondheim Conference on CO<sub>2</sub> Capture, Transport and Storage" (TCCS-5). This was a great success in terms of technological progress, participation and feedback and has contributed to put Trondheim on the international CCS map.
- On 26-27 October, the Gas Technology Centre organized the "1st Trondheim Gas Technology Conference" (TGTS-1), with parallel sessions on gas conversion and LNG. This conference will develop to an international meeting place for gas technology in the future.
- On 28-29 September, the fifth annual IO Conference (IO = Integrated Operation) was organized by the Petroleum Centre in Trondheim. The successful conference attracted 290 participants. For the first time the conference included a "Young Professional Programme".
- The Centre for Electric Energy successfully participated in helping to establish a new EU project, MARINA, which is focused on offshore platforms that convert several energy forms (such as wind and waves) into electrical energy. The project starts in 2010.
- New industrial collaboration agreements in 2009 for the Petroleum centre include Statoil (Academia Agreement), Schlumberger (University Agreement) and Statoil (Norne Agreement).
- Another highlight for 2009 was the establishment of CenSES (Centre for Sustainable Energy Studies), in which the Centre for Society and Energy plays a major role.
- On 6-9 September, NTNU hosted the fourth "KIFEE Symposium on Environment, Energy, Materials and Education" in Trondheim. The successful symposium had 150 attendees, including 53 participants from Japan, and included a total of 130 lectures and posters.
- In March 2009 a Joint Seminar and Workshop between Tsinghua University, NTNU-SINTEF and StatoilHydro was organized in Beijing. The workshop was co-financed by the Research Council of Norway and had approximately 40 participants.
- The KIC proposal SEEIT brought forward by a consortium headed by DTU and joined by NTNU and SINTEF, was selected to participate in the final round with the Governing Board of EIT in Budapest in December. Unfortunately, SEEIT was not selected for funding by EIT, but we have decided to organize a consortium to carry out our plans using EU programme resources.
- In 2009 the ENGAS project (Environmental Gas Management Research Infrastructure) was successfully finalized. ENGAS was our first strategic research infrastructure project and was in fact the first step towards ECCSEL. ENGAS started in 2005 and has been managed by Dr. Morten Grønli. During the project our laboratories have been used for 1000 experimental days.
- The MIT-NTNU-Statoil programme has been extended with a new "professor-pair" project on offshore wind.



## Energy & Petroleum – Resources & Environment in 2009

The strategic area had its most successful year ever in 2009, due to all the work and preparations made in 2008 to follow up on initiatives related to the new national “Energy21” energy policy and the Climate Agreement in the Parliament. Because we had prepared ourselves and developed a goal-oriented research organization, which was accustomed to bringing forward multidisciplinary proposals for thematic programmes, NTNU and SINTEF were successful partners in six of the eight new Centres for Environment-friendly Energy Research (CEERs) that were awarded in February 2009. This means that six eight-year research and innovation programmes have been started in 2009, in close cooperation with industrial partners and with a total budget of around 2 billion NOK. The programmes also involve almost 200 PhDs and postdocs, which will result in new knowledge of great strategic importance for our educational efforts.

This is the largest preparation process that NTNU and SINTEF have been involved in to date. The preparations were handled by the research groups involved and their management teams. The main challenge of the strategic area will be to employ the results from this intensive activity in other strategic areas, for instance in education and international cooperation (EU, US, China, Japan and India). Another ambition is to strengthen the networks between CenSES and the CEERs.

The Centre for Sustainable Energy Strategies (CenSES) proposal, developed by the Centre for Energy and Society, qualified for the final round but was not awarded a CEER. Since this is a strategically very important area, NTNU’s Rector has decided that CenSES will be developed anyway with all our partners, and resources have been allocated to start up CenSES. The Research Council has also awarded as large strategic KMB (“Projects with User Involvement”) named LinkS.

- Our various research groups have also met with considerable success, descriptions of which may be found under the reports from each of our centres.

We have worked strategically and systematically to improve our performance. Based on the reports from the 2007 evaluation process, NTNU’s Board decided to institute new working procedures to improve the operation of the university’s six strategic areas. The strategic areas will continue to develop as modern action-oriented organizations, able to handle initiatives both in the interface towards society and industry (outside – in), as well as from researchers and research groups (inside – out).

The development of the strategic area will also be guided by a strategic council. This new council is headed by the Dean of the Faculty of Engineering Science and Technology and consists of representatives from industry, the political arena and central organizations in the energy sector. We have been lucky to recruit a very strong team that was appointed by our Rector in the spring of 2009. The strategic council has had a meeting in May and November. These two meetings have been devoted to developing a thorough overview of the activity in the strategic area. The main task for 2010 has already been determined, which is to develop a new strategic plan for 2011 – 2015.

One important task of the strategic area is to develop overall goals and strategies for the total activity and to initiate teamwork and coordination between the different activities of the strategic area. We also identify opportunities between centres and initiate projects to take advantage of these opportunities.

We also work on behalf of the whole strategic area in areas where this may be advantageous, such as Energy21 (see below) and international cooperation.

We will now give higher priority to:

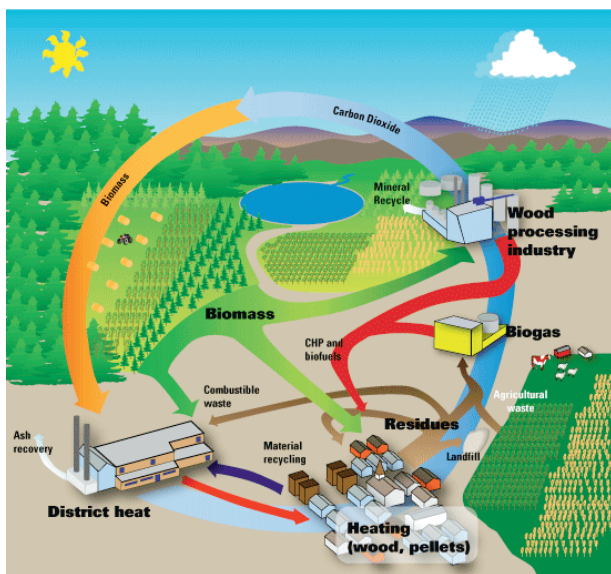
- Communication and teamwork with NTNU’s seven faculties, so that we can work together to develop unique research groups throughout the strategic area.
- Further develop systematic cooperation between “Energy and Society” and the technological centres.
- Develop a new set of goals and strategies that reflect and address in a better way public awareness of and political commitment to climate change issues, including the need for change in the energy system.
- The innovation processes that may result in new solutions for energy issues, taking into account the role of technology development.

On the administrative side, NTNU decided to strengthen the management of the strategic area by adding a new assistant leader. Dr.ing. Trond Kvilhaug was appointed and started his work in January 2009. This has substantially improved our ability to handle strategic initiatives.

Energy21 will play an important role in the large national campaign to create a new energy revolution, which may make Norway the most environment-friendly energy nation in Europe. According to the Energy21 strategy and the Climate Agreement in the Parliament, six main strategic

areas will be given priority:

- Efficient use of energy
- Climate friendly power (offshore wind, solar, bio and hydro)
- CO<sub>2</sub>-neutral heating (including bio and heat pumps)
- Energy systems
- Frameworks and social analysis
- CO<sub>2</sub> capture and storage (CCS)
- Environment-friendly transport



In 2009, Energi21 was established as a permanent organization with a board appointed by the Ministry of Petroleum and Energy. It is now responsible for the long-term realization of the nation's energy strategy. Both NTNU and SINTEF have representatives on the board.

Starting up the CEERs in 2009 was only the first strategic initiative. In 2010, Energy21 will establish task forces in the strategic areas to develop plans for goal-oriented research programmes. NTNU and SINTEF will participate actively in these task forces.

## Energy Campus North

The Arctic will be an important energy region in the future, but only if we explore and develop valuable energy sources (oil, gas and renewable sources) in a sustainable way. The Norwegian government has put the Arctic region on their agenda through the High North Initiative, and NTNU wants to contribute with its skills and competence to achieve the initiative's ambitious goals.

One important area is education. Here we have teamed up with the University of Tromsø and the University Colleges in Finnmark and Narvik to create Energy Campus North (ECN) in Hammerfest. A long-term goal is to develop an integrated education programme in energy technology, consisting of bachelor's and master's degrees, and continuing education and teacher training programmes. The long-term vision is to increase the energy expertise in the region so that it is prepared for a future where energy and fisheries dominate the economy.

The Energy Campus North is under development. The main events in 2009 were:

- Moving into permanent offices and teaching facilities at the University College of Finnmark in Hammerfest.
- Starting up the first class for network-based engineering education, organized by University College in Narvik and with Hammerfest as a “study workshop” for students from Finnmark County (12 students).
- Preparations for starting up a bachelor’s degree in “Energy Technology” in 2010.
- Developing financial models to develop a sustainable economic foundation.
- Organizing NTNU master’s courses in gas technology at the Hammerfest LNG plant at Melkøya.

Energy Campus North is an initiative that has been fronted by NTNU's Rectorate, because it is an important strategic initiative that will demonstrate how NTNU can make its national expertise available to innovative programmes in other parts of the country. The initiative is being handled by the strategic area on behalf of NTNU's Rectorate.

## Centre for Sustainable Buildings

This centre is a continuation of the Energy and Petroleum – Resources and Environment (EPRM) strategic area's former thematic activity "SmartBuild – Smart and Energy-Efficient Buildings". This former centre also carried out a large research project by the same name, which was mainly financed by the Research Council of Norway (RCN). The current strategy of the Centre for Sustainable Buildings (CSB) is to establish and maintain a common multidisciplinary research programme at NTNU and SINTEF, which will pursue cooperation among all the researchers active in this field. Components of this strategy are:

- Establishment and support of extensive multidisciplinary research projects based on cooperation in the centre, in line with the SmartBuild project.
- Additional scientific activity in the form of seminars, etc., which contribute to cooperation within the centre.
- Scientific and social activities for the centre's group of PhD and postdoc candidates.
- External activities in Norway and internationally to further knowledge of the centre's existence and expertise, and establish international cooperation, especially focused on the EU research area.
- Scientific and economic support for individuals and separate research groups that plan to use external funding to establish new projects within the centre's work area.

### Main results 2009

#### *Multidisciplinary centre research collaboration*

Throughout 2008, several NTNU and SINTEF units from the SmartBuild family prepared an extensive application to the RCN for the establishment of a research centre for environmental-friendly energy (CEER) – "Zero Emission Buildings (ZEB)". The centre application was accepted early 2009 and ZEB arranged its kick-off meeting on March 3 with all industry participants present. This was a very important

event for the CSB centre, because it means active cooperation among the majority of centre participants on an effort that is extremely broad in scope, with an impressive budget and time schedule – 300 million NOK and 8 years. The centre was established during the course of 2009 and contracted to NTNU, research activities were planned and commenced, and a several PhD and postdoc candidates were hired.

#### *PhD and postdoc candidates*

During 2009, two PhD candidates, a Canadian engineer and an Italian architect, were contracted with scholarships financed from EPRM. They are both now associated with ZEB activities. ZEB has also financed several candidates and more will follow in 2010. In this way the CSB will, with the addition of candidates financed other ways, have access to a substantial group of young researchers, which is perfect for common seminars and other social activities. Several events are planned for 2010.

#### *Educational activities and support for research training*

In 2009 the NTNU board accepted the launching of an international master's degree in Sustainable Architecture, and efforts are also underway for establishing a similar programme for Renewable Energy. CSB will play an important role in scientific support in the planning and launching of these educational programmes.

CSB has also supported the formation of two other centres that will launch researcher training in relevant fields. These are a Centre for Sustainable Infrastructure and a Centre for Indoor Climate and Energy Use, both at the Faculty of Engineering Science.

#### *International cooperation*

Efforts were carried out in 2009 in order to apply for new projects financed through EU's 7th Framework Programme, but they were unfortunately unsuccessful. This work will continue in 2010. The CSB also participated in NTNU and SINTEF's application for a Knowledge and Innovation Community (KIC) named SEEIT, Sustainable Energy Education Innovation Technology, which reached the final evaluation stage for EU financing, but was ultimately not successful. The cooperation established here may, however, continue in 2010.

The ZEB also established formal cooperation agreements in 2009 with several internationally known research organizations and universities in other countries. A researcher from Tsinghua University in Beijing spent the summer in Trondheim on an exchange stipend.





## Centre for Electric Energy and Energy Systems

The research centre plays an active role in developing technology for the production, transportation and utilisation of electric energy. The Gemini Centre unites the research activity at the Electric Power Department of NTNU and the Electric Power Technology and Energy Systems Departments at SINTEF Energy Research. During 2009, the centre continued its research activities in the following main areas:

### Methods for planning and operating energy supply systems

- Energy markets: Trading arrangements, financial issues and the environment
- Supply reliability in non-regulated power systems
- End-users: Quality and reliable power supply

### Transport of electricity

- Materials and components for HVDC
- Condition monitoring, maintenance and renewal
- Over voltage calculations and insulation coordination

### Generation, transforming and use of electrical energy

- Renewable sources of energy and new efficient energy systems
- Maritime systems: Shipping, offshore, power supply to subsea oil and gas installations
- Installation systems and energy consumption in buildings
- Power electronic drives and control of electric motors

### The Energy and the Environment Study Programme

The study programme is a cooperative effort between the Department of Electric Power Engineering and the Department of Energy and Process Engineering. The recruitment of students to the programme was record high in 2009, 155 attended, of which 38% are women. The admission requirements show an increasing trend despite the increasing number of students. In 2009, the study programme had its 10<sup>th</sup> anniversary and an evaluation process was started for the development of the future Energy and the Environment study programme (FREMS), beginning in 2012.

### Research

A research centre that addresses offshore wind energy, NOWITECH (CEER), has been established, with NTNU, SINTEF and IFE as partners and in close coordination with Norwegian industry. The research activities at the centre are related to offshore wind power generation, conversion, transmission and integration both from a technical and economic aspect. The centre is also increasing its focus on the power systems of the future (often termed SMARTGRID).



The centre also successfully participated in helping to establish a new EU project, MARINA, with a focus on offshore platforms that convert different energy forms (such as wind and wave) into electrical energy. The project, which is starting in 2010, will be partially supported by the centre's contribution of 3.5 years full-time equivalent.

Our close cooperation with SINTEF Energy Research is carried out through the continuation of a GEMINI centre (for two more years). Several new KMB projects were established in 2009, which helped bringing new PhD candidates to the centre. Four PhDs defended their theses in 2009. We also recruited three new postdocs and ten new PhD candidates, mostly international students.

### International collaboration

The scientific personal at the centre actively participate in international research groups and technical committees and are in the leadership of several groups. In 2009, the centre also took responsibility for the organization of several international electric power systems conferences. One of the conferences, IEEE PowerTech, will be held in Trondheim in June 2011.

### Industrial collaboration

The centre works closely with the industry, particularly in energy conservation, where the direct interaction is quite strong. A part-time professorship and several PhD students are funded directly by the industry, and a significant number of MSc final projects are conducted as joint projects with industry partners.

### New personnel

In 2009 Kjetil Uhlen joined the centre as a professor. Uhlen took his Dr.ing-degree from the Department of Electric Power Engineering (NTNU) in 1994, but has since then worked with SINTEF. Frank Mauseth accepted an associate professor position. Previously he held a postdoc position at the centre. Gerd Kjølle accepted a professor II position, with her main position at SINTEF.

## Centre for Renewable Energy

The main goal of Centre for Renewable Energy (SFFE) is to increase Norway's ability to provide teaching, research, development and innovation in renewable energy. This is being achieved by coordinating existing and establishing new activities at NTNU, SINTEF and IFE; pursuing the development of new knowledge; and implementing the use of renewable energy sources and energy technologies.

The Centre for Renewable Energy was established in 2004 and was first developed as a cooperative unit between NTNU and SINTEF. In December 2005 IFE became an equal partner in the centre.

The SFFE is a part of the Energy and Petroleum – Resources and Environment strategic area, while at SINTEF and IFE, SFFE is considered to be a part of the management area.

NTNU, SINTEF and IFE's internal network on renewable energy is comprised of more than 250 scientific researchers and 150 PhD candidates.

In 2009, SFFE activities were divided into the following categories:

- Influence
- Networking and coordination
- Promotion and information
- Recruitment

The Centre for Renewable Energy's main strategies are:

- Influence: The centre will work with decision takers, politicians and industry to strengthen research, development and construction of renewable energy in Norway.
- Networking and coordination: The centre should initiate to better cooperation and coordination between central research institutions and areas in Norway and internationally. SFFE should further offer common meeting places for research institutions, industry and government.
- Promotion and information: The centre will spread information and contribute to increased knowledge about renewable energy in Norway.
- Recruiting: The centre will promote renewable energy as a desired study topic and career for young people.

### Some highlights from 2009

- The creation of the CEERs in February 2009 was one of the biggest national leaps when it comes to research on renewable energy in Norway. Eight centres in total received 200 million euros over eight years to do research on renewable energy, energy efficiency and CCS. SFFE has

close connections to all CEERs associated with renewable energy and SINTEF, NTNU or IFE as project leaders, and works as a meeting place for individuals involved in the effort.

- The SFFE homepages were given a facelift in February, resulting in a drastic increase in popularity. The number of hits increased by a factor of three compared to 2008, and the site had visitors from 145 different countries.
- A R&D seminar about wind power was arranged in January in Trondheim. In addition, SFFE arranged a solar cell workshop in Oppdal.
- SFFE has coordinated a think-tank consisting of students and PhD candidates from the different CEERs. The think-tank was created by the Minister of Petroleum and Energy, Terje Riis Johansen. The group presented its work to the minister in September.
- SFFE has had several visitors this year, from the Chinese ambassador and several other research and education institutions from China, Thailand, Poland and Finland.
- It was decided to arrange an international research conference for renewable energy in June 2010. The conference is expected to attract 400-500 participants, which would make it the largest research conference on renewable energy in Norway.



*The think-tank participants and Minister of Petroleum and Energy, Terje Riis Johansen (photo: OED)*

## Gas Technology Centre

The Gas Technology Centre (GTS) was established in 2003 and is the largest centre for gas technology research and education in Norway. GTS provides new knowledge and technology that 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 research and education between NTNU-SINTEF and the market. More specifically, GTS will work to:

- Increase the visibility of gas technology research and education at NTNU-SINTEF.
- Promote new research opportunities and initiatives
- Influence Norwegian national priorities
- Ensure top quality education and recruitment of students and researchers in gas technology.
- Be active in networking and internationalization activities.
- Promote internal coordination and synergism in gas technology at NTNU-SINTEF.

### Main achievements in 2009

- The 5th Trondheim Conference on CO<sub>2</sub> Capture, Transport and Storage (TCCS-5) was a great success in terms of technological progress, participation and feedback.
- Preparatory Phase proposal submission for *ECCSEL* (European Carbon dioxide Capture and Storage Laboratory infrastructure) within the EU FP7 ESFRI instrument.
- The 1st Trondheim Gas Technology Conference (TGTC-1) in October.
- The research project "A Green Sea" was awarded by the PETROMAKS programme.
- Dialogue meetings with Norwegian politicians on the future of oil and gas R&D.

### GTS management and organization 2009

Since 2008, Maria Barrio has served as the SINTEF director of the GTS. Associate Professor Hilde J. Venvik replaced Professor Olav Bolland as NTNU director of the GTS in October. Professor Edd Blekkan also completed his term of office in the management group in October. Astrid Lilliestr le replaced Paris Klimantos as coordinator. The gas technology community at NTNU and SINTEF is grateful to Bolland, Blekkan and Klimantos for their efforts.

## Activities in 2009

### Visibility

- The 5th Trondheim Conference on CO<sub>2</sub> Capture, Transport and Storage (TCCS-5) on June 16-17 was organized by GTS in collaboration with the BIGCO<sub>2</sub> project.
- The 1st Trondheim Gas Technology Conference (TGTC-1) was organized by GTS on October 21-22 with keynotes and parallel sessions on gas conversion and LNG.
- Through SINTEF's engagement in N.ERGHY, GTS contributed to the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) 2nd Stakeholders General Assembly on 26-27 October and the 4th General Assembly for representatives from N.ERGHY's member R&D institutions on 28 October, both in Brussels.
- The Nordic Hydrogen Conference took place in Oslo on 24-26 November, arranged by the Norwegian Hydrogen Forum with sponsorship from GTS and others.

### New R&D opportunities and initiatives

- ECCSEL ([www.eccsel.org](http://www.eccsel.org)) – the European Carbon Dioxide Capture and Storage Laboratory Infrastructure – was put on the official European Strategy Forum on Research Infrastructure (ESFRI) Roadmap in December 2008 as the only new entrant under the energy theme. A proposal coordinated by NTNU for funding the preparatory phase was submitted to the EU FP7 in December 2009, with 15 participating countries.
- The 5-year project "A Green Sea", targeting new technologies and concepts for CO<sub>2</sub> and H<sub>2</sub>S removal from natural gas to avoid emissions and the use of harmful chemicals, was funded by the Research Council of Norway (RCN) PETROMAKS programme as a result of GTS promoting initiatives in midstream processing of natural gas.
- The iCap – innovative CO<sub>2</sub> capture – EU FP7 4-year project completed contract negotiations between 15 partners from European R&D organizations and industry, as well as from Australia and China. The focus is on innovative post-combustion CO<sub>2</sub> capture techniques using chemical absorption media on the combined CO<sub>2</sub>/SO<sub>2</sub>-removal as well as advanced polymeric and ceramic membrane materials.
- Several hydrogen and fuel cell proposals were granted national (1), Nordic (1) or European FCH-JU (3) support in 2009.

**National priorities**

- Dialogue meetings with the Norwegian politicians Erna Solberg and Linda Helleland (H), Gunn Karin Gjøl (Ap) and Tord Lien (FrP) took place in the period leading up to the 2009 parliamentary elections, to discuss the future of oil, gas and CCS research. GTS communicated the importance of research in assuring value creation and environmentally sound exploitation of fossil energy resources.
- SINTEF, with significant support from GTS, hosted the European Economic Area Joint Parliamentary Committee Meeting on October 29 on the topic: "The EU's energy and climate policy; Research on CCS and offshore wind technology". The programme included research and industrial presentations and laboratory visits with 45 participants from the European Free Trade Association (EFTA), the European Commission and the Stortinget (Norwegian Parliament).

**Education and recruitment**

- GTS was involved in the development of two international master's programmes: MSc in Natural Gas Technology and MSc in Innovative Sustainable Energy Engineering, with the latter a joint Nordic programme between six Nordic universities.
- Energy from the North – a student excursion to Hammerfest in September – was organized by GTS in cooperation with the recently commissioned Statoil LNG plant.
- Approximately 150 PhD candidates and 45 postdoctoral fellows work on gas technology at NTNU and SINTEF. GTS

fully finances 2 PhD candidates and has partially financed 4 PhDs and 1 postdoc through the PhD pool awarded by RENERGI, RCN.

- GTS has since 2004 funded the Adjunct Professor position in LNG technology held by Dr. ing. Geir Owren, who is Senior Advisor at the Statoil Research Centre in Trondheim.

**Networking and internationalization activities**

GTS has been active in a research collaboration with MIT (US) and networking activities with industry and within the European Union.

**Internal coordination**

The GTS Technical Seminar Series 2009 included 6 presentations on different topics, and were attended by scientists and students from NTNU and SINTEF as well as from industry. GTS also awarded funding for scientific equipment considered vital in building new activities.

Please consult the *Gas Technology Centre NTNU-SINTEF Annual Report 2009* for additional information.



## Petroleum Centre for Better Resource Utilization

In September 2004, NTNU's Board of Directors included the upstream petroleum area as a member of the Energy and Petroleum – Resources and Environment strategic area. During 2004-2005, a major effort was invested in developing a new strategic plan for petroleum exploration and production at NTNU. An important element of the development has been visits to and discussions with around 50 oil and gas companies, service companies, governmental agencies, organizations, and the Research Council of Norway. Based on these visits and on discussions at a seminar at NTNU in August 2005, the final BRU Report was published on 15 September 2005. The report may be downloaded from

<http://www.petroleum.ntnu.no/~kleppe/BRUreport.pdf>.

The strategic plan identified four key areas for research in the years to come:

1. Finding and Producing
2. Drilling and Subsea Technology
3. Integrated Operations in the Petroleum Industry
4. Arctic Technology

Task forces in each area have subsequently been developing plans for activities to be started in order to enhance research activities.

### Current major research programmes in petroleum exploration and production

- ROSE - the rock-seismic programme
- 4D seismic - reservoir simulation programme
- Improved oil recovery programme
- Seafloor separation programme
- Subsea programme
- New drilling methods programme
- Smart Fields/Integrated Operations programme (SFI)
- Unconventional oil recovery programme
- Subsurface storage of CO<sub>2</sub> (FME)

### Some highlights from 2009

#### International academic collaboration

NTNU has a wide range of international partners in the petroleum area. Current key countries are Angola, Bangladesh, Brazil, Canada, France, Italy, Mozambique, the Netherlands, Russia, Spain, Ukraine and USA. Close to 50% of the MSc and PhD candidates in exploration and production are non-Norwegian. Some of the collaborating institutions in 2009 were: Agostinho Neto Universidade (Angola), ASOA (Azerbaijan), BUET (Bangladesh), Carnegie Mellon University (USA), EMU (Mozambique), Stanford University (USA), TU Delft (Netherlands), Pontifícia Universidade Católica do Rio de Janeiro (Brazil), University of Oklahoma (USA) and Mines ParisTech (France)

#### International Conference in Trondheim – ROSE09

On 21-22 April 2009, the 5th International Conference on Rock Physics and Seismic was arranged at NTNU. The conference included sessions on rock physics, time lapse and reservoir characterization, and imaging and inversion. There were approximately 75 participants. The conference was followed by a two-day short course in 4D seismic, conducted by David Lumley and Martin Landrø.

#### International Conference in Trondheim – IO09

On 28-29 September 2009, the 5th International Conference on Smart Fields/Integrated Operations was arranged by the Center for Integrated Operations (SFI) in Trondheim. The theme of the conference was Science and Practice, and presentations were held by academia and industry from all over the world. For the first time the conference included a Young Professional Programme. Around 290 persons participated in the conference. The conference is organized annually, and the next conference will be in September 2010.

#### Graduates

Approximately 80 MSc candidates graduated from the disciplines of Petroleum Engineering and Petroleum Geoscience.

Around one-third of the graduates were non-Norwegian, while among the Norwegian students, around one-third went on a one-year exchange at a foreign university, primary in the US, Canada, Brazil and Australia. In addition, seven PhD candidates defended their dissertations in 2009.

#### Publications

A total of 138 titles, including refereed journal publications, conference presentations and posters were produced, of which 59 were in refereed journals. As calculated using the Norwegian publication point system, these efforts totalled to 44 points, as compared to 29 in 2008 and 44 in 2007.

#### New laboratories

Two new Virtual Reality visualization rooms were opened in 2009, mainly financed through a grant from Norsk Hydro (before its merger with Statoil). These rooms will be used for research related to Integrated Operations, and for research and education related to subsurface data. A new Micro CT Scanner was opened in 2009, for imaging pore structures in rock samples. The resolution of the scanner is around 3 µm.



*From the virtual signature ceremony in the new visualization rooms at NTNU between NTNU and Statoil - Executive VP of Statoil in Bergen and Rector Torbjørn Digernes in Trondheim*

#### Industrial collaboration

A close collaboration with industry insures that our education and research are relevant, and provides financial support for new facilities and research. Key industrial partners during 2009 were Aker Solutions, BG Norge, Bridge Energy, BP, CGGVeritas, Chevron, ConocoPhillips, Det norske, DnV, ExxonMobil, ENI, FMC, Fugro-Jason, GdF Suez, IBM, Kongsberg, Lundin, Petrobras, PGS Geophysical, Revus Energy, RockSource, Schlumberger, Shell, Statoil, TOTAL and Wavefield Inseis. New agreements in 2009 included Statoil (Academia Agreement), Schlumberger (University Agreement) and Statoil (Norne Agreement).



## Centre for Energy and Society

The development of sustainable energy production and use are major challenges for Norwegian society, not the least related to cultural and political issues and the need to develop strategies for the social accommodation of new energy solutions. The Energy and Society research group aims to contribute to the knowledge base of developing strategies to construct a more environmentally friendly energy regime in Norway as well as internationally. Also, we want our research to illuminate social and cultural aspects of energy and climate concerns more generally, to promote broader reflection about life in a post-carbon society and the transitions needed to achieve sustainable living. These aims are to be achieved by analysing the articulation of concerns and practices with respect to energy and climate in Norway today, and more specifically, to engage in research on economic and cultural dimensions of energy use in dwellings and businesses, social aspects of the development and deployment of new energy technologies, and political and financial strategies to achieve a sustainable production and consumption of energy.

Energy and Society research interests are integrated with the overall efforts of NTNU's Energy and Petroleum – Resources and Environment strategic area. The Energy and Society research group collaborates closely with the strategic area's building, wind, gas technology and renewable programmes. In this way, humanists and social scientists are engaged in state-of-the-art interdisciplinary research where much effort is put into exploring how such interdisciplinary collaboration may be made even more productive.

Mainly, the Energy and Society research group frames its research by drawing on the field of science and technology studies (STS) and studies of science, technology and innovation (STI). This means that the projects are in dialogue with broader theoretical concerns related to technology policy, the social shaping of technology, innovation, design/user interfaces, domestication, social learning, and transition management. Thus, the research group tries to balance its efforts to participate in interdisciplinary interaction with architects and engineers with contributing to humanist and social science understanding of phenomena related to sustainable use of energy, design of sustainable energy systems and environmentally friendly living more broadly conceived.

### Research Areas

The research areas covered by the centre include:

- Energy policy and the politics of new renewable energy
- Energy and everyday life

- Energy, energy use and the design of buildings
- The cultural dynamics of new renewable energy technologies
- Energy markets and energy actors
- Climate change and climate knowledge: How it is understood and how it is acted upon
- Transition to post-carbon society.

The Centre for Energy and Society has identified four strategic goals that we see as particularly important in order to be productive, relevant and visible in the years to come:

1. To have a large portfolio of externally funded interdisciplinary projects
2. To improve the dissemination and publication activities
3. To enhance our understanding of the knowledge needs of relevant stakeholders
4. To recruit and educate good students

### Highlights from 2009

In 2009, we succeeded in receiving external funding for five new research projects:

- E car, a strategy for electrification of road transport in Norway (lead: SINTEF Energy Research), Work package 2: User preferences and user strategies (funding: Research Council of Norway)
- Public Acceptance of Post-Carbon Strategies (funding: Research Council of Norway)
- The Research Centre on Zero Emission Buildings (ZEB), Work package 4: Energy Efficient Use and Operation (funding: Research Council of Norway and NTNU)
- Towards Carbon Neutral Settlements – processes, concept development and implementation (funding: Research Council of Norway)
- Scrutinizing the impact of CCS communication on the general public and local citizenry (funding: FENCO-ERA).

Thus, the research group has had considerable growth in 2009. Four new projects started in the autumn of 2009. Three new PhD candidates and two postdocs were engaged, and a coordinator was hired for the start up of CenSES.

Another major highlight of 2009 was the establishment of CenSES – the Centre for Sustainable Energy Studies – in which the Centre for Society and Energy plays a major role. CenSES was started 5 April 2009 by NTNU, the University of Oslo, SINTEF (Trondheim), the Institute for Energy Technology (IFE, Kjeller and Halden), the Norwegian School of Economics and Business Administration, the Institute for Research in Economics and Business Administration (Bergen), Sogn og Fjordane University College and Vest-

lands-forskning (Sogndal). The Centre will be chaired by NTNU with the Faculty of Humanities as the administrative host faculty. As a result of the establishment of CenSES, our centre received three new PhD scholarships, Marianne Ryghaug was engaged as deputy director of CenSES (50%) and Ola Edvin Vie as co-coordinator (100%).

In February 2009, the Centre for Energy and Society was assigned to lead one of the five work packages for the newly established Research Centre on Zero Emission Buildings (ZEB). The ZEB centre has as its vision to develop competitive products and solutions for existing and new buildings that will lead to market penetration of zero emission buildings. The Centre for Energy and Society will help to achieve this goal by contributing new knowledge about a) use and operation of zero emission buildings and b) their implementation. The ZEB centre is one of eight new national Centres for Environment-friendly Energy Research (CEER) and will be funded for eight years. In 2009, the main focus was on setting up the infrastructure and the consortium. Besides these administrative tasks, three state-of-the-art reports

were commissioned, one on the evaluation of zero emission buildings, one on their operation and one on their design

Among scholarly achievements, we would like to emphasize the article "How energy efficiency fails in the building industry", published in *Energy Policy* and written by Marianne Ryghaug and Knut H. Sørensen. This paper argues that energy-efficient construction has been seriously restricted by three interrelated problems: (1) deficiencies in public policy to stimulate energy efficiency, (2) limited governmental efforts to regulate the building industry, and (3) a conservative building industry. It concludes that innovation and the implementation of new, energy-efficient technologies in the building industry require new policies, better regulations and reformed practices in the industry itself.

Furthermore, this has been an active year regarding outreach. During 2009 we published six papers in journals and edited collections, presented 19 scientific conference papers in addition to 34 other outreach activities.

## Strategic Initiative "Green Innovation"

The Green Innovation strategic initiative combines insights into broader energy and environmental issues with knowledge about innovation and implementation of technology. A main goal is to study how innovation processes and in particular how barriers and driving forces may help us adapt to, and mitigate, the major change in the energy picture that now lies ahead. The research focus includes strategy and innovation theory, economic growth and technological change, as well as system dynamics and optimization of activities operating together in value sequences.

Green Innovation has now reached a point where direct links can be seen between dynamic feed-forward situations and opportunities for large-scale change that will allow society to meet the energy-related changes ahead in an adaptive manner. Prigogine (1997) tells us, based in the theory of open thermodynamic systems, how systems away from equilibrium become mechanism-dependent, and how change takes the form of bifurcations in dissipative systems (autocatalytic systems with a flow of energy that maintains non-equilibrium and builds order; living organisms and cities are examples). The mechanisms involved in adapting

to change are situations of economic feed-forward, or in economic parlance, "increasing marginal utility". The task now is to devise these concrete systems and evaluate their economic robustness and path-dependent behaviour. As a concrete example, Green Innovation is studying the broad potential of dynamic thermal storage as a means of drastically reducing the requirement for energy to heat and cool buildings.

### Results in 2009

- A new project, "Active Dynamic Thermal Storage for Industrial Processes" (KMB) was funded by the Research Council of Norway. In addition, the North Trøndelag County Council has contributed significant financial and technical support to the project.
- A PhD defence by Per-Ivar Karstad on "Norwegian opportunities beyond oil and gas - strategic opportunities in sustainable energy production".
- Publication at the European Council for an Energy Efficient Economy (ECEEE), 2009, ISBN 978-91-633-4454-1.
- Participation in Technical Annex 22, partly funded by the Research Council of Norway.

## ENGAS Research Infrastructure

NTNU and its technology transfer partner SINTEF have jointly developed an 8 000 square metre, 38 million euro research facility, the ENGAS Research Infrastructure, where energy researchers investigate ways to clean up CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub> and other greenhouse gases, as well as studying the removal of these gases from the oil and gas production processes and their use in industry, buildings and transport.

The research infrastructure offers foreign researchers access to an integrated complex of 14 unique laboratories for focused and trans-boundary research in environmental gas management. These laboratories are designed to solve

problems related to reducing emissions from the entire technology chain from energy source to end-user. The laboratories have been successfully used to develop new innovative technology and solutions, together with global industrial partners.

The ENGAS project was successfully finalized in 2009. ENGAS was our first strategic research infrastructure project, and was in fact the first start towards ECCSEL. ENGAS started in 2005 and was managed by Dr. Morten Grønli. During the project, our laboratories have been used for 1000 experimental days.

## International Cooperation

All centres that are part of the strategic area have developed substantial international collaborative networks. On behalf of NTNU, the strategic area puts a strong emphasis on developing long-term strategic collaboration with selected universities in regions and countries where "Team Norway" wants to develop industrial cooperation, particularly the European Union, Asia (Japan, China and now India) and North America. These long-term cooperative efforts are shaped in part by the challenges posed by the different countries and typically involve several research areas and several centres. The strategic area remains active in building cooperative partnerships until the networks and projects between professors and an organization have been established.

We have an excellent collaborative relationship with the Research Council of Norway (RCN), which has been co-financing most of this strategic network development.

### European Union

As a result of our systematic and strategic teamwork since 2003, NTNU and SINTEF have been able to establish a successful presence in the European Research Area during the development of the 6<sup>th</sup> and 7<sup>th</sup> Framework Programmes. Thus, we are involved in a substantial number of projects (see separate list) under the topics of Energy and Society,

Energy in Buildings, Renewable Energy, Hydrogen and Fuel Cells, and Carbon Capture and Storage (CCS). These EU projects have a total NTNU-SINTEF budget of approximately 25 million euros.

### ECCSEL - ESFRI

As described in the 2008 Annual Report, Norway was successful in getting our ECCSEL initiative included in ESFRI's new Road Map for 2008. (ECCSEL = "European Carbon Capture and Storage Laboratory Infrastructure", ESFRI = "European Strategic Forum for Research Infrastructure"). This was due to the close cooperation between the Ministry of Education and Research, the Research Council of Norway (RCN) and NTNU-SINTEF. ECCSEL involves 13 partners from 10 countries and the plan is to develop a Pan-European integrated research infrastructure for CCS. This will involve an investment on the order of 730 million NOK in order to build 15 new unique laboratory installations in the years ahead. Of this, roughly 210 million NOK will be spent in Norway.

The follow up on ECCSEL has received a great deal of attention at NTNU and SINTEF in 2009. In accordance with the ESFRI procedure, ECCSEL will be developed by carrying out an approved Preparatory Phase Project. This will include all the activities needed to achieve a successful development.

Our main work in 2009 has been to bring forward a Preparatory Phase Project Proposal for ECCSEL with our European partners. A successful kick-off meeting was organized on 22 April at the offices of the Norwegian delegation in Brussels, with contributions from the Ministry and the RCN. We were ready to submit our proposal by the 3 December deadline, thanks to a close and good working relationship with our partners and support and financing from the RCN. We hope to be able to start up the Preparatory Phase Project in 2011.

It should also be mentioned that our laboratory director, Morten Grønli, has been appointed as an advisor in ESFRI's new advisory group on energy (ESFRI Energy WG). This may be regarded as an acknowledgement of our involvement in strategic research infrastructure development.

#### European Institute of Innovation and Technology (EIT)

As described in the 2008 Annual Report, NTNU and the strategic area have been involved in strategic activities related to the European Institute of Innovation and Technology. Due to our substantial energy research and educational activities, it makes sense for NTNU-SINTEF to want to be a partner in a Knowledge and Innovation Community (KIC) in the energy sector.

EIT is headed by a governing board of 18 members appointed on 30 July 2008. The board had its first official EIT seminar in Bratislava on 24 November, where the members laid out plans and a vision for the EIT and the Knowledge and Innovation Communities (KICs). The board officially announced the three areas that have been selected for the first round:

- Sustainable energy
- Climate change mitigation and adaptation
- Future information and communication society

The call for KIC proposals was officially announced on 2 April 2009, with the deadline for submissions 27 August 2009. The main strategy of the KICs is to create more innovation by strengthening the knowledge triangle between academia, research institutes and industry.

As mentioned in the 2008 Annual Report, NTNU and SINTEF were partners and participated actively in the Pilot Project SUCCESS, which was headed by TU Karlsruhe. SUCCESS started in 2008 and aimed at developing improved models for cooperation between academia, research and industry, so it was a good "training camp".

In the autumn of 2008, NTNU and SINTEF were also invited to participate in the preparation of a KIC initiative in "Sustainable Energy". We became members of a consortium head-

ed by TU Karlsruhe, which included universities, research institutes and industrial companies from Germany, Switzerland, Belgium, the Netherlands, France, Spain, Portugal, Italy, Denmark, Sweden, Finland and Norway.

We participated very actively in the preparations for this KIC from January to May. For reasons that will not be further discussed, NTNU and SINTEF decided after careful consideration to leave the Karlsruhe team in the end of May and join a new initiative from the Danish Technological University (DTU). The KIC "Sustainable Energy Education Innovation Technology" (SEEIT) had a clear environmental profile with five focus areas: Wind energy, Solar energy, Bio-energy, Energy Efficiency and Energy Systems (Grids). Thus it will involve the activity of 4 of our CEERs (Centres for Environment-Friendly Energy Research).



The consortium consisted of Aalto University, ALU Freiburg, Aston University, Copenhagen Business School (CBS), ENEA, Fraunhofer ISE, the Norwegian University of Science and Technology (NTNU), Politecnico di Torino (Polito), Technische Universität München (TUM), Technische Universiteit Delft (TU Delft), Technical University of Denmark (DTU), SINTEF and VTT.

After the start-up Meeting on 4 June, we carried out three workshops in München, Torino and Copenhagen during a hectic summer, and submitted our KIC-SEEIT application by the deadline of 29 August.

The quality of the SEEIT consortium and our KIC application was such that it was ranked as one of the two best applications in the “Sustainable Energy” area. We were thus invited to participate in the final round with the EIT Governing Board in Budapest on 16 December. Unfortunately SEEIT was not selected for funding by EIT.

Because of the team spirit we developed through the application process, and the strong belief in the plans we have brought forward, the SEEIT family decided unanimously to form a consortium to carry out our original plans, by taking advantage of the resources in the different EU programmes. Thus, there will be a report about SEEIT in the 2010 Annual Report.

## Japan

Supported by the Research Council of Norway and Innovation Norway (IN) in Tokyo, collaborative efforts with the Kyoto International Forum for Environment and Energy (KIFEE) strategic network was further developed in 2009. NTNU and SINTEF also participated in delegations and workshops organized by Innovation Norway, and also welcomed important visitors from Japanese research and industry.

KIFEE, which was founded by Professor Yasuhiko Ito, is developing into a most successful arena for Japan–Norway cooperation on environment and energy. In 2008, the organization was strengthened when the University of Oslo joined the team. The group has decided that it will include education on energy and environment as a part of its efforts, which means the following areas are handled under the KIFEE umbrella:

- Process Engineering
- Advanced Biological Materials
- Advanced Inorganic Materials
- Electrolysis Systems
- Nanotechnology
- Education on Energy and Environment

On 6–9 September 2009, NTNU hosted the fourth “KIFEE Symposium on Environment, Energy, Materials and Education” in Trondheim. This successful symposium attracted 150 participants, of whom 53 were from Japan. A total of 130 lectures and posters were presented at the symposium, which also contained a final plenary session on “Sustainable Energy”.

As a direct result of this strategic cooperation, Doshisha University, which is a partner in KIFEE “Process Engineering”, has been recruited as an active partner in the large new Research Council of Norway programme on “Energy efficiency in industry” (CREATIVE). This programme starts in 2010 and is a part of the national Energy21 initiative.

KIFEE plays a very important role in Norway’s cooperation with Japan on energy and the environment, and the Research Council’s support is crucial.

## China

In close cooperation with Innovation Norway and the Research Council, systematic strategic efforts with China started in 2004. The following strategies have been developed concerning selected universities and areas for long-term cooperation:

- Xi’an University of Architecture and Technology
  - Sustainable Rural Development
- Tsinghua University, Beijing
  - Energy Conservation in Buildings; Energy and Society; Hydrogen/Fuel Cells; Renewable Energy (wind, solar, bio); Carbon Capture and Storage, Energy systems
- Shanghai Jiao Tong University (SJTU)
  - Gas Technology (LNG), Gas Engines, CO<sub>2</sub> as working fluid; Carbon Capture and Storage; Renewable Energy; Energy Systems
- Chongqing University
  - Gas technology

## Tsinghua University (THU)

The cooperative effort with Tsinghua University (THU) on Energy in Buildings has developed well and the university is now a partner in the NTNU CEER on “Zero Emission Buildings” (ZEB), as well as a partner in the new LinkS project on sustainable energy strategy, which is a part of CenSES.

Visits between the two universities have taken place since 2007. In 2008, THU’s Institute of Nuclear and New Energy Technology (INET) and NTNU decided to develop a “Joint Virtual Research Centre on Renewable and New Energy”, with a focus on Bio-energy and Bio-fuels, Carbon Capture and Storage (CCS), Hydrogen technology and Sustainable Energy Strategies.

A Memorandum of Understanding (MoU) between INET-THU and NTNU, with StatoilHydro (now Statoil) as an industrial co-partner, was signed in October 2008. On 30–31 March 2009, a Joint Seminar and Workshop on “New Energy” between INET-THU, NTNU-SINTEF and StatoilHydro was organized at Tsinghua campus in Beijing. The workshop was co-financed by the Research Council of Norway and approximately 40 people participated.

In December 2009, Professor Li Zheng from THU visited NTNU-SINTEF. He is head of the Tsinghua Low Carbon Technology Laboratory, which is interested in working with NTNU on CCS technology.





Participants at the workshop on "New Energy" at Tsinghua University Campus in Beijing

The goal of NTNU and the strategic area in 2010 will be to develop a Joint Research Centre with THU on Sustainable Energy, which will include all the areas mentioned above.

### Shanghai Jiao Tong University (SJTU)

The following research areas have been identified for cooperation:

1. LNG technology (including small-scale production and distribution)
2. Distributed energy systems - CCHP
3. Carbon dioxide capture and storage (CCS)
4. Carbon dioxide as working fluid
5. System analysis and optimization => Regional energy planning

The LNG technology cooperative effort has begun, but has been delayed and so far only one PhD has started. On 11-14 November, three LNG professors from SJTU visited Statoil's LNG plant in Hammerfest, and thereafter NTNU-SINTEF. Workshops were organized to bring forward plans for cooperation in teaching and research, so we foresee projects in 2010.

As a direct result of this strategic cooperation, SJTU is now involved as an active partner in the new large Research Council of Norway programme on "Energy efficiency in industry" (CREATIVE).

The goal of NTNU and the strategic area is to enter into a

contract on a Joint Research Centre on "Sustainable Energy" between SJTU and NTNU in 2010.

### Other activities involving China in 2009:

- On 6-7 May, the Chinese ambassador in Norway visited NTNU and SINTEF to learn about our energy sector activities.
- On 3-6 June, the strategic area was represented at the Norwegian pavilion (under the leadership of Innovation Norway) on the China International Environmental Protection Exhibition & Conference (CIEPEC) 2009 in Beijing. Trond Kvilhaug also participated on the conference day (5 June) with a presentation of the strategic area with an emphasis on the framework of the CEER Zero Emission Buildings.
- A delegation from China Council visited our laboratories on 11 June, hosted by the Ministry of Environment.
- EPRM also participated in NTNU's Delegation to China 22-26 June with a visit to Fudan University in Shanghai and the University of Chongqing.
- On 24 November, our strategy for China Cooperation was presented at "China Meeting Place", organized by the University and College Council (UHR) in Oslo.

### India

On behalf of NTNU, representatives from the strategic area were invited to meet an Indian delegation from the Indian Ministry of Human Resource Development in Oslo on 13

August, regarding cooperation on energy research and education. We also participated in the launch of the government's new India strategy, "Opportunities in Diversity" in Oslo on 28 August. Arne Bredesen has been appointed by NTNU to the Working Group on educational cooperation on "Solar and Clean Energy".

## USA

In May 2004, the USA and Norway signed a MoU on research cooperation in the energy sector, with a special emphasis on CO<sub>2</sub> management, hydrogen fuel and new energy technology. NTNU has since developed strategic collaboratives with the Massachusetts Institute of Technology (MIT) and the University of Maryland.

### Massachusetts Institute of Technology (MIT)

The development of our strategic cooperation with MIT started in 2002 based on the personal networks of the former director of Norsk Hydro, Rolf Marstrander. In 2004 we were able to initiate the energy system project TRANSES (Alternatives for the Transition to Sustainable Energy Systems in Northern Europe), which involved Norsk Hydro, Statoil, Shell, Statsbygg, Enova, Statkraft and Statnett as sponsors; and MIT, Chalmers, NTNU and SINTEF as research partners. The TRANSES project was concluded in 2006 with a successful seminar.

In 2005 and 2006 we continued to expand our joint MIT-NTNU efforts, based on the model of paired professors developed by our strategic advisors Rolf Marstrander and Per-Erling Frivik. In the paired professor model, two professors and two PhD students or postdocs from MIT and NTNU work together on a common project. After a hectic preparation process, we were able to officially start up the "MIT-NTNU Gas Technology Program" with a signing ceremony at the Research Council of Norway in August 2006. This cooperation model has attracted a great deal of interest and attention, and is now used as a template in the development of NTNU's other international cooperative efforts.

The "Gas Technology Program" involved three PP projects in its first phase: "Gas transport systems", "CO<sub>2</sub> capture", and "Hydrogen production". This effort was financed by Statoil and RCN. In 2008, a new project on "LNG technology" was started.

The two universities also decided in 2008 to extend our cooperative efforts to an "Energy program", which would also include Renewable Energy, while in 2009, a new PP project on "Offshore Wind" was under preparation.

As a result of this relationship, MIT is now also involved in the CEERs on "Offshore Wind" and "Zero Emission Buildings".

The cooperative effort is headed by a Management Group with representatives from Statoil, MIT and NTNU. The contact person at MIT is the Deputy Director of MIT's Energy Initiative, Professor Robert Armstrong.

### University of Maryland (College Park)

Our cooperation with University of Maryland (UMCP) has progressed very well since the successful BILAT-financed Seminar on Energy and Environment at NTNU in November 2006, where 27 participants from UMCP's Joint Global Change Research Institute (JGCRI), the University of Oslo, IFE, SINTEF and NTNU agreed to cooperate on the following areas:

- Hydrogen/Fuel cells
- Combined Cooling Heating & Power
- Reliability and Safety
- Energy System Analysis (TRANSES II)

Activity has since begun in two areas, Hydrogen Technology and Energy System Analysis.

A proposal for a new large Energy System Analysis project, LinkS, has been made. LinkS was designed as a follow up to TRANSES and was funded in 2009 as a part of the Energy21 CEER process. LinkS will be a KMB, which will be an important part of CenSES and will also involve Tsinghua University in Beijing, in addition to the University of Maryland's Joint Global Change Research Institute.

As can be seen from the Petroleum Centre report, the petroleum community has developed an impressive cooperative network with a wide range of international partners in the petroleum area. The current key countries are Angola, Bangladesh, Brazil, Canada, France, Italy, Mozambique, the Netherlands, Russia, Spain, Ukraine and the USA.

## What are the benefits of the Strategic Area arrangement?

- One of NTNU's greatest assets is that it is home to a wide range of disciplines in technology, society and the humanities. The strategic area is a tool to use this wide range of disciplines to be more useful to society.
  - The strategic area brings top-level research groups from different disciplines together in goal-oriented teamwork to solve complicated problems that are of great importance to society. These complicated problems can only be solved through multidisciplinary teamwork, and we have the resources needed "in-house".
  - By planning and carrying out things together successfully, we create better communication between disciplines. Walls between disciplines are disappearing, enabling the emergence of new multidisciplinary efforts. Because multidisciplinary research is critical to serving the future needs of industry and society, this approach attracts new partners and facilitates the commercialization of research results.
  - By working on larger problem areas as one team with a common strategy, we also improve our visibility and impact, both nationally and internationally.
  - The approach is also a benefit in winning funding from the Research Council of Norway, for the development of larger projects and programmes (it is easier for the Research Council to approve a ready-made project package than to try to put it together from individual pieces).
  - We may also have a competitive edge in the European Research Area and strategic international cooperation.
  - All this increases the opportunity for external funding of research projects, which has already been well demonstrated.
- Above all, it is a great asset to have a strategic area that acts "on behalf of NTNU", and that our Rector is available and supports us.

## Management in 2009

### Centres:

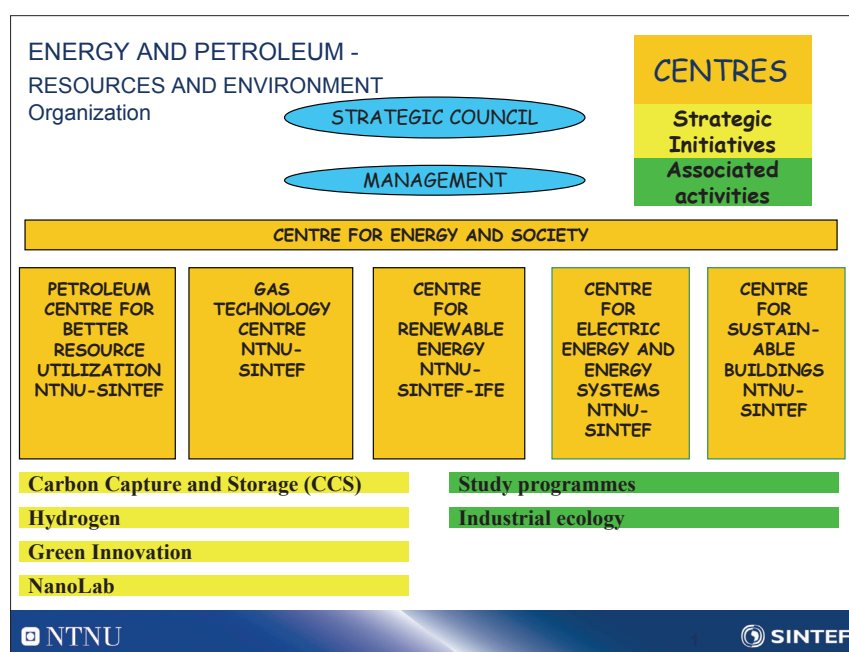
- Centre for Sustainable Buildings: Professor Emeritus Øyvind Aschehoug
- Centre for Renewable Energy:

Professor Johan E. Hustad (spring) / Associate Professor Ann Mari Svensson (autumn)

- Gas Technology Centre: Professor Olav

Bolland (spring) / Associate Professor Hilde Venvik (autumn)

- Petroleum Centre for Better Resource Utilization: Professor Jon Kleppe
- Centre for Electrical Energy and Energy Systems: Professor Robert Nilssen (spring) / Professor Olav B. Fosso (autumn)
- Centre for Energy and Society: Associate Professor Margrethe Aune
- Strategic Initiative "Green Innovation": Dr. Harald Gether
- Strategic Initiative "Carbon Capture and Storage": Professor Olav Bolland
- Strategic Initiative "Hydrogen Technology": Associate Professor Hilde Venvik
- Study programme Energy & Environment: Professor Vojislav Novakovic
- Research Infrastructures: Laboratory Director Morten Grønli



### Strategic area management:

- Leader: Professor Arne M. Bredeesen (arne.m.bredesen@ntnu.no)
- Associate leader: Dr. Trond Kvilhaug (trond.kvilhaug@ntnu.no)
- Secretariat: Anita Yttersian (anita.yttersian@ntnu.no)

## Selected Research Council of Norway projects at NTNU and SINTEF

- Engineering Science for a Sustainable Future - Institutionally Based Strategic Programme (ISP) from the Research Council of Norway – 16 PhDs and postdoc fellowships related to “Energy from the North” and “Renewable Energy”
- Renewable strategies? Implementation and commercializing new energy technologies
- Building markets, shaping policy? The role of economics in energy policy and energy use
- Participation in IEA PVPS Task 10 Leadership of Subtask 2: Urban Planning, Design and Development
- LifeTime Commissioning for Energy Efficient Operation of Buildings
- Financial Engineering Analysis of Investment and Operations in Electricity Markets
- A new concept for power quality and reliability measurement and management
- Balance Management in Multinational Power Markets
- Offshore Wind Energy in Norway: Setting the Basis
- Deep Sea Offshore Wind Turbine Technology
- Offshore Renewable Energy PhD Pool
- Nanomaterials for 3rd Generation Solar Cells
- NSF-European Materials Cooperative Activity, “Nanostructured oxide thin films for organic/inorganic solar cell applications”
- Advanced sample preparation and characterization of fuel cell materials for increased fuel cell durability
- High Temperature PEM Fuel Cells Operating with Organic Fuels
- Improved efficiency and durability of PEM water electrolyzers for hydrogen production
- Development of highly efficient nanostructured SOFCs integrating novel Ln(Nb,Ta)O<sub>4</sub>-based proton
- Optimal operation and control of chemical plants with natural gas feedstock (OPTGASS)
- BEEDIST - Basic energy efficient distillation technology
- Improved process design and operation of natural gas conversion technologies
- Advanced reactor modelling and simulation
- Recovery of CO<sub>2</sub> from high pressure gas with membranes
- Converting natural gas components to fuels and petrochemicals
- Fischer-Tropsch synthesis. Studies on the relation between catalyst properties and selectivity
- Development of CNF-polymer composites with high CNT loading
- Conversion of natural gas components in short contact time reactors
- New concepts in the catalytic dehydrogenation of propane
- Compact conversion of syngas to di-methyl-ether (DME)
- Large scale process for converting natural gas to hydrogen and high-value carbon
- Hydrogen production by Sorbent Enhanced Reforming
- Hydrogen production from natural gas in high temperature membrane reactors: Advanced catalysis from atoms to processes (MIT-NTNU)
- Carbon-supported core-shell electrocatalysts for oxidation of small organic molecules
- Template based synthesis of nanoporous metal-organic frameworks with high surface areas
- BIG CO<sub>2</sub>, Phase 2
- Evaluation Methodology for Power Production with CO<sub>2</sub> Capture (MIT-NTNU)
- CO<sub>2</sub> Capture, enabling research
- Parameter optimization in preparation of membranes for osmotic processes
- Just Catch
- Modelling of particle deposition phenomena in heat exchangers
- Resource Optimization and recovery in the Materials industry Ringdalen
- Public Acceptance of Post-Carbon Strategies
- Capturing light in solar modules (IFE)
- E-Car, A strategy for electrification of road transportation in Norway
- Towards carbon neutral settlements – processes, concept development and implementation
- Professionalism and pragmatism? The management of environmental knowledge and interdisciplinarity in consulting companies
- Active dynamic thermal storage for industrial processes
- “A Green Sea”, a 5-year project targeting new technologies and concepts for CO<sub>2</sub> and H<sub>2</sub>S removal from natural gas to avoid emissions and the use of harmful chemicals

## Selected EU Framework projects at NTNU and SINTEF

- PRIME Policies for Research and Innovation in the Move towards the European Research Area (Network of Excellence), <http://www.prime-noe.org/>
- PEP - Promotion of European Passive Houses, [www.europeanpassivehouses.org](http://www.europeanpassivehouses.org)
- ECO-CITY: Joint Eco-City Developments in Scandinavia and Spain, <http://www.ecocity-project.eu/>
- BRITA in PUBs: Bringing Retrofit Innovation to Application in Public Buildings, <http://www.brita-in-pubs.eu/>
- TREES: Training for Renovated Energy Efficient Social Housing, <http://www.cenrg.ensmp.fr/trees/>
- 3-NITY: 3-fold Initiative for Energy Planning and Sustainable Development at the Local Level.
- EMINENT: Early Market Introduction of New Energy Technologies.
- FOXY: Development of solar-grade silicon feedstock for X wafers and cells.
- FCTEDI: Fuel Cell Test and Dissemination Network, SSA-Strategic Support Action.
- GreenNet-EU27: Guiding a Least-Cost Grid Integration of RES-Electricity in an Extended Europe.
- NextGenBioWaste: Innovative Demonstrations for the Next Generation of Biomass and Waste Combustion Plants.
- SEEWEC: Sustainable Economically Efficient Wave Energy Converter.
- SISI: Silicon for Solar Cells at Low Costs on an Intermediate Scale.
- ThermalNet: European Network for biomass pyrolysis, gasification and combustion.
- WAVESSG: Full-scale demonstration of robust and high-efficiency wave energy converter.
- WILMAR: Wind Power Integration in Liberalized Electricity Markets.
- DYNAMIS: Towards Hydrogen and Electricity Production with CO<sub>2</sub> Capture and Storage (Coordinator)
- ENGAS: Environmental Gas Management Research Infrastructure (Coordinator)
- ENCAP: Enhanced Capture of CO<sub>2</sub> (Project manager)
- CO<sub>2</sub>Remove: Geological storage of CO<sub>2</sub>
- COACH: Co-operation Action within CCS EU-China
- CASTOR: CO<sub>2</sub> from Capture to Storage
- ULCOS: Ultra Low CO<sub>2</sub> Steelmaking
- INCACO2: International Co-operation Actions on CO<sub>2</sub> Capture and Storage
- CO<sub>2</sub>GeoNet: Network of Excellence in Geological Storage of CO<sub>2</sub>
- NATURALHY: Preparing for the hydrogen economy by using the existing natural gas system as a catalyst
- ZEP: The Technology Platform for Zero Emission Fossil Fuel Power Plants (two members)
- DECARBit: ("Decarbonize it") Focus on precombustion gas separation and hydrogen combustion
- CESAR: (Postcombustion solvents and testing in demo plants)
- CAESAR: (SEWGS processes and materials testing)
- ECCO: European value chain for CO<sub>2</sub>
- CO<sub>2</sub>-net: Thematic Network
- ECCSEL: European Carbon Dioxide Capture and Storage Laboratory Infrastructure
- iCap – innovative CO<sub>2</sub> capture – EU FP7

## Other international projects at NTNU and SINTEF

### IEA – International Energy Agency

The Centre for Sustainable Buildings is participating in the following projects and programmes at the IEA:

- IEA ECBCS Annex 44: Integrating Environmentally Responsive Elements in Buildings <http://www.ecbcs.org/annexes/annex44.htm>
- IEA ECBCS Annex 47: Cost-effective Commissioning, <http://www.ecbcs.org/annexes/annex47.htm>
- IEA PVPS Task 10: Urban Scale PV, <http://www.iea-pvps-task10.org/>
- IEA Heat Pump Programme Annex 29: Ground-Source Heat Pumps Overcoming Technical and Market Barriers, <http://www.energy.sintef.no/prosjekt/Annex29/>



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**NTNU – Trondheim**  
Norwegian University of  
Science and Technology



## **NTNU**

The Norwegian University of Science and Technology (NTNU) in Trondheim represents academic eminence in technology and the natural sciences as well as in other academic disciplines ranging from the social sciences, the arts, medicine, architecture and the fine arts. Cross-disciplinary cooperation results in ideas no one else has thought of, and creative solutions that change our daily lives.

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