

STRATEGIC AREA
**Energy and Petroleum –
Resources and Environment**



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NorRen Summer School, class of 2012 (photo: Ida Fuchs)



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 gave priority in 2000 to six strategic areas where multi-disciplinary teamwork provides high-quality research with substantial long-term social impact. These are:

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

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About Energy and Petroleum–Resources and Environment

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

This is why NTNU placed energy on its main strategic agenda as early as 2000, and started to develop an organization based on goal-oriented multidisciplinary teamwork to handle the complex problems and challenges facing society.

Energy is essential to society because we need it to provide for fundamental human needs, such as food, clothing, housing/shelter, 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 greenhouse gases. During the same period several billion new world citizens will join us around the “global dinner table”. Providing sufficient energy and clean energy to ensure a peaceful and sustainable society for everyone in the future is one of the largest challenges facing global society today.

There will be an enormous demand for new knowledge, new technology, new solutions and new innovations to meet this global challenge. NTNU and our research partner SINTEF want to play an active role by supplying the scientific and technological knowledge and innovations needed to support the global transformation process towards a sustainable future.

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

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

Thanks to its hydropower and petroleum resources, and its favourable conditions for renewable energy, Norway may be considered as an “energy country”. For this reason, government and industry have invested in energy research and education in Trondheim for more than 100 years. By applying our teamwork strategy to identify the challenges and opportunities, and recruit multidisciplinary teams to handle them, NTNU and SINTEF have been successfully increasing

our energy-related research and education efforts since the strategic area was established in 2000. Today there are more than 1500 people at NTNU and SINTEF working to create new knowledge, new technology and new solutions to realize our common vision:

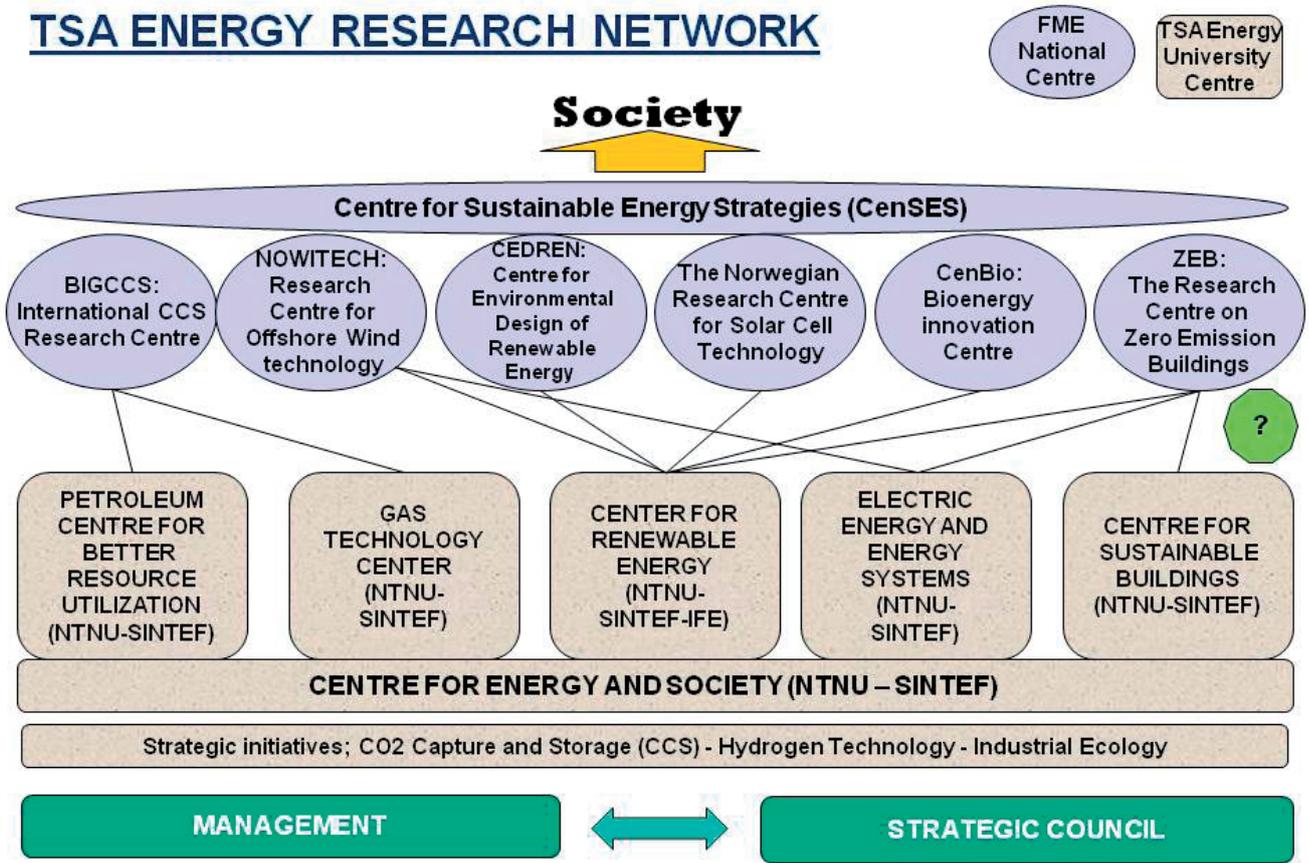
Sufficient and clean energy for a sustainable and peaceful society



The “Energy Team” includes around 350 professors and more than 750 PhD candidates and postdoctoral students working with basic energy-related research. In addition, NTNU graduates each year approximately 300 to 400 MSc candidates for the energy sector. Our combination of research and education constitutes a major advantage and added value, because these highly qualified candidates bring with them the newest and best knowledge and skills, which they utilize for the rest of their working lives to solve problems and create new “clean” solutions for the benefit of society.

The “Energy Team” has, since 2000, developed a substantial organization based on multidisciplinary activities:

TSA ENERGY RESEARCH NETWORK



Schematic sketch of TSA Energy's network

Six goal-oriented multidisciplinary research centres

1. Centre for Energy and Society (NTNU)
2. Centre for Sustainable Buildings (NTNU - SINTEF)
3. Centre for Renewable Energy (NTNU – SINTEF – IFE – UiO)
4. Gas Technology Centre (NTNU - SINTEF)
5. Petroleum Centre for Better Resource Utilization (NTNU - SINTEF)
6. Centre for Electric Energy and Energy Systems (NTNU - SINTEF)

In addition, we have developed strategic initiatives that involve multidisciplinary work between the centres:

1. CO₂ Capture and Storage (CCS)
2. Hydrogen Technology
3. Industrial Ecology

Our research teams are involved in the following national Centres of Excellence:

Four Centres for Research Based Innovation (CRI):

1. Integrated Operations
2. Multiphase Flow Assurance

3. Innovative Natural Gas Processes and Products
4. Drilling and Well Technology for Improved Recovery

Seven Centres for Environmentally friendly Energy Research (FME), which were started in 2009-2011:

1. Centre for Sustainable Energy Strategies (CenSES)
2. BIGCCS – International CCS Research Centre
3. Centre for Environmental Design of Renewable Energy (CEDREN)
4. Bioenergy Innovation Centre (CenBio)
5. Norwegian Research Centre for Offshore Wind Technology (NOWITECH)
6. The Norwegian Research Centre for Solar Cell Technology
7. The Research Centre for Zero Emission Buildings (ZEB)

These FMEs constitute a total research investment of more than NOK 2.5 billion over 8 years, and operate as a close cooperative effort between universities, research institutes and industry. The industrial partners provide 25% of the funding, while the remainder is provided by the Research Council of Norway (50%) and NTNU/SINTEF. Close to 200 PhDs and postdocs will be educated. This substantial

research effort provides a foundation for creating new solutions that may help handle the challenges facing the world, and it also makes us an interesting research partner for international cooperation.

Our main strategic partners are the Norwegian government, the Research Council of Norway and the Norwegian energy industry. The goal of this national team is to lay the foundation for a new environmentally friendly “energy revolution”. This will be our third energy revolution over the course of NTNU’s 100-year history:

1. The first was to develop hydropower as an energy source for Norway’s industrial development. Norway (mainland) had no coal, and we had to find other ways to provide energy for our industrial and societal development.
2. The second was to develop new technological solutions, among them drilling technology, subsea platforms, multiphase flow and LNG technology, which completely changed the way we produce oil and gas from offshore fields.

3. Now the aim is to bring forward new solutions to provide environmentally friendly energy, based on renewable energy, CCS and energy efficiency.

The Strategic Area Energy (hereafter TSA Energy) relies heavily on close cooperation and coordination with the different NTNU faculties and departments. The team is organized to involve 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, all of whom work in state-of-the-art laboratories. These research groups have been created by the faculties in collaboration with industry, through the allocation of personnel resources and laboratory investments. The development of new research groups to handle future new technology areas thus relies on good communication between the faculties and the “Energy team”. The Faculty-Centre-Matrix below shows how we have developed cooperative networks with almost all NTNU’s faculties.

FACULTY – CENTRE – MATRIX	Faculty of:	Contribution to Centres					
		CSB	EEES	SFFE	GTS	BRU	CES
	Architecture and Fine Art	X		X			
	Engineering Science and Technology	X	X	X	X	X	X
	Natural Sciences and Technology			X	X	X	
	Information Technology, Mathematics and Electrical Engineering		X	X	X	X	
	Social Sciences and Technology Management				X		X
	Humanities	X		X			X

Strategies for 2011–2015

To contribute to our vision and overall strategy, our Strategic Council has decided that TSA Energy will give priority to the following main areas and key technologies in the period from 2011 to 2015:

- Sustainable energy strategies – social sciences (CenSES)
- Efficient end use of energy (both in buildings and industry)
- Utilization of renewable energy sources (offshore wind, solar energy, bio energy, hydropower, ambient heat)
- Carbon Capture and Storage (CCS) to allow utilization of fossil fuels in future
- Smart energy systems (smart grids) that integrate sources and end users in an efficient way
- Utilization of natural gas in an environmentally friendly way
- Better resource utilization and energy from the arctic region
- Hydrogen technology

Our priorities are based on Norway's proximity to the North Sea and the Arctic Basin, which contain a large potential for extracting renewable energy, and considerable reserves of oil and natural gas. These are robust areas that coincide with the key technology areas published in an international prognosis (see IEA Energy Technology Perspectives 2010), as well as Norway's Energy21 national strategy. Nuclear energy is another key technology internationally, but is not a part of our energy strategy.

Our research in most of these areas is already strong, but there are subjects that need to be improved. Fostering teamwork between the social sciences and technology is of special concern. Under the different main areas/key technologies, we will give priority to the following strategic initiatives during the period of the plan:

- Create arenas for cooperation between CenSES and the different technology areas, to improve our understanding of how new energy solutions may be realized, and accepted and used by society.
- Strengthen our activity in smart grids (also called "Networks of the Future"), in cooperation with the ICT (Information and Communication Technology) Strategic Area.
- Utilize the results from the FMEs in our education and innovation.

Towards the end of the current period we will begin developing new initiatives as a continuation of our FMEs.

The strategic plan also contains strategies for the following areas:

- Strategic communication efforts with the Research Council of Norway, Energy21 and other funding agencies.
- Science dissemination and communication with the public, with the development of an "Energy Arena".
- Internationalization (EU, Japan, China, USA, India, South Africa, Russia and Brazil).
- Education – communication to young people.
 - International master's programmes
- Laboratory research infrastructures.
 - Road maps for "Sustainable Energy" laboratories

Energy21

The second phase of the work on the new national energy strategy "Energy21" was completed in 2011. Energy21 was established by the Ministry of Petroleum and Energy in 2007 with the goal to develop and implement a national strategy for research and development in the energy sector. The first strategy was delivered in February 2008 with the vision document "Norway: "Europe's energy and environment nation – from national balance to green delivery". This resulted in a strong growth in the energy research budgets from the Research Council of Norway, and in the establishment of the FMEs. Since then, Energy21 has been working on a new, more comprehensive goal-oriented strategy with respect to research. More than 140 people from the industry, research institutions and universities have been involved in creating more specific plans within 14 thematic areas.

Based on this material, the Energy21 Board carried out a strategic process, where emphasis was put on three main goals:

1. Increase value creation based on national energy resources and energy utilization.
2. A shift in energy sources, by the development of new technology, and efficient production of environmentally friendly energy.
3. Develop internationally competitive industry and competence for the energy sector.

Based on this, Energy21 delivered a new national strategy in 2011, giving priority to the following areas in the coming period:

- Offshore Wind Power – Industrial development and resource utilization.
- Value creation and value safeguarding through Carbon Capture Transport and Storage (CCS).
- Improved utilization of resources by balance power.
- Flexible energy systems – smart grids.
- Solar Power – strengthen industrial development.
- Energy utilization (efficiency) – converting low temperature heat to electricity.

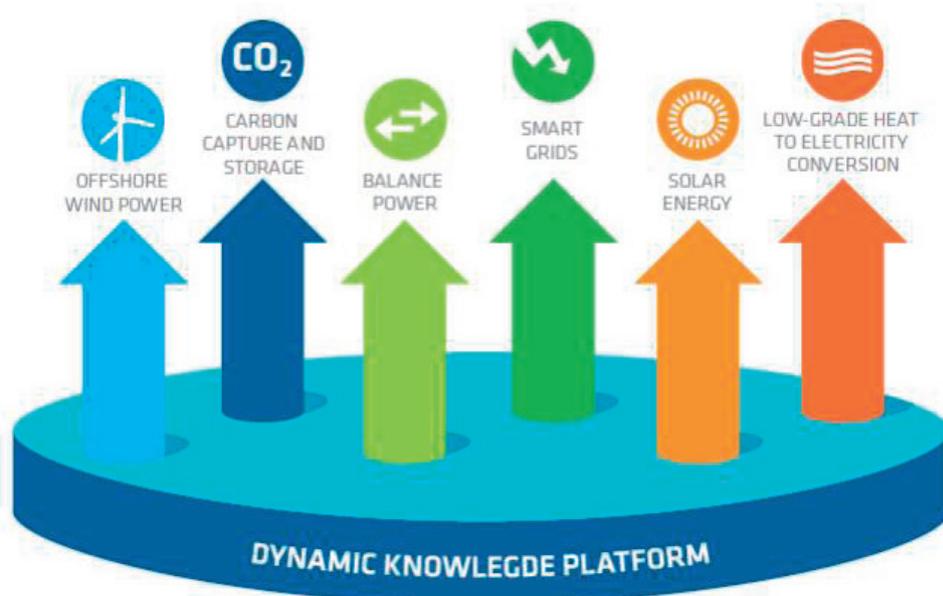
These areas coincide well with NTNU's key technology areas in the energy sector.

Researchers from NTNU and SINTEF participated actively in this process, and both NTNU and SINTEF were represented on the Energy21 Board.

In 2012 a new Energy21 Board was appointed, that shall contribute to the organization and implementation of the national strategy by strengthening the team-work between universities, research institutes, industry and society, so that the three main goals above can be successfully realized.

While the process will be based mainly upon the areas identified, new ones may also come up. Based on the results of research and proposals for improvement from the different partners, 2012 was used to develop a new, improved and more specific strategy to be finalized in 2014.

NTNU appreciates having a member in the new Energy21 Board, and we will recruit specialists from SINTEF and NTNU to participate actively and contribute in the work ahead.



The six main target areas for Energy21

Main events in 2012

- The first Preparatory Phase Project for the Pan-European Laboratory ECCSEL initiative has been completed, with a budget of NOK 15 million for the first two years. This phase finished on schedule by 2012, documenting a proposed legal structure, a governance model, a financial strategy, an infrastructure development plan and other elements of a general framework.
- The organization Technoport and the Renewable Energy Research Conference (RERC) decided to join forces in 2012 and organized *Technoport 2012 – Sharing possibilities* on April 16-18 in Trondheim. The highly successful international conference gathered 600 scientists, industrial leaders and politicians from 36 countries all over the world – the biggest event NTNU has organised thus far. Multidisciplinary teams totalling 800 students worked on problems related to UN's summit meeting in Rio de Janeiro (Rio+20), and a winning team was elected.



The winning team of the student competition at Technoport 2012

- The development of the activity within the Centres for Environmentally friendly Energy Research (FMEs) has been a major activity in 2012, both for the research groups involved and NTNU's administration. The FMEs have been successfully utilized by the Research Council, NTNU and SINTEF as target areas for developing strategic international cooperation on "Environmentally friendly energy".
 - Two successful seminars / workshops have been organized by the "Joint Research Centre (JRC) for Sustainable Energy" between Shanghai Jiao Tong University (SJTU) and NTNU; in Shanghai 4 - 6 June and in Trondheim 27 - 30 November, respectively. A new thematic group on "Offshore Wind & Smart Grids" was established.
 - Students from the Faculty of Architecture and Fine Art, together with ZEB-researchers, participated in the international competition Solar Decathlon Europe 2012 and were awarded a place among the 20 finalists.
 - The Centre for Sustainable Buildings participated in a workshop on "Green Buildings" with the Indian research unit TERI (The Energy and Resource Institute) in New Delhi to discuss and plan future R&D collaboration.
 - The new Erasmus Mundus funded MSc-programme on Wind Energy started in 2012. This programme is a collaboration between DTU, Denmark, TU Delft, Netherlands and University of Oldenburg, Germany.
 - The Norwegian Research School in Renewable Energy (NorRen), created by the Centre for Renewable Energy, is a new innovation which unites and coordinates the PhD education within renewable energy at five of the Norwegian universities; NTNU, UiB, UiO, UMB and UiT. The first NorRen Summer School was organized in Oslo in August 2012 with 74 participants from the whole country. The feedback from the participants was very positive, with regards to academic content, organization and social activities.
 - The official proceedings from the "2nd Trondheim Gas Technology Conference" (TGTC-2011) organized by GTS, were published in Energy Procedia Volume 26 in 2012.
 - In April 2012 BRU hosted the 8th international conference in the area of Rock Physics and Seismic (ROSE12) at NTNU. About 80 people participated in the conference, which was followed by a two-day short course on Geomechanics for Geophysicists.
 - BRU's Centre for Integrated Operations hosted the 9th international conference in the area of Smart Fields/ Integrated Operations in Trondheim. Mayor Rita Ottervik opened the conference. The conference attracted more than 300 participants (new record) and took place on 24-26 September.
- NTNU has joined and contributed to the establishment of the European Partnership for Sustainable Energy Education, Innovation and Technology (SEEIT), in cooperation with DTU, TU Delft, TU Munich, ALU Freiburg, Aalto University, Politecnico Torino, SINTEF, ENEA, and Fraunhofer ISE. SEEIT works on bio energy, wind energy, solar energy, energy efficiency and energy systems, and a SEEIT network has been developed at NTNU.
 - The new European Commission's SET plan for Education and Training Initiative has recruited expert groups within 13 technology areas to bring forward a Road Map for Education and Training. Seven professors from NTNU were selected, and we will act as the leading reporters for two areas: CCS and Electricity Grids.

- Professor Il Per Afseth was awarded the NPFs Geofysikerpris 2012 and Professor Martin Landrø was awarded the Conrad Schlumberger Prize 2012.
- The Centre for Energy and Society arranged a workshop and PhD course on "Innovation and learning in energy policy: New pathways to sustainability?". The response to the event was very good as approx. 30 researchers from Denmark, Finland, France, Ireland, Netherlands, Norway, Spain, Sweden and Austria met in Trondheim for three days (12–14 December).
- On 12-13 March CenSES arranged a seminar on "Energy Policy tools" with 20 participants from research groups and partners.
- "The Global Energy Assessment" (1800 pages) was presented at the Rio+20 summary in June 2012. Professor Edgar Hertwich contributed as lead analyst with sections on the total energy use of consumers, life cycle assessment of buildings, and the rebound effect. PhD student Kjartan Steen-Olsen and PostDoc Jan Weinzettel contributed an analysis of the energy embodied in trade to the Assessment's Energy Primer.

NTNU's activity in Northern Norway

The Arctic will be an important energy region in the future if we explore and develop its valuable energy sources (oil, gas and renewable energy) in an environmentally friendly and sustainable way. The Norwegian government has put the Arctic region on the agenda through the High North Initiative, and NTNU wants to contribute by making our skills and expertise available for the development of the competence needed to achieve the initiative's ambitious goals. New technologies from NTNU and SINTEF on LNG-production, multiphase flow, and CO₂-injection made it possible for Statoil to develop the Snøhvit (Snow White) field. This is only the beginning.

One decisive area is education and competence building, to meet the new challenges and create values from the vast resources. In the first phase starting in 2007, NTNU teamed up with the University of Tromsø and the University Colleges in Finnmark and Narvik to create Energy Campus North (ECN) in Hammerfest, which was and still is regarded as the

"Energy city" of northern Norway, with all the energy installations and companies that are present and active there.

In its first years, ECN worked on building cooperation between the partners to develop a new Energy Bachelor education offered in Hammerfest. For many reasons, this was not successful, and in 2011 the partners decided to end this cooperation. For NTNU, ECN was useful and important, because it gave us the opportunity to organize unique annual courses for our energy MSc students at the Statoil LNG installations at Melkøya.

Because the need for new competence still exists, NTNU has decided to carry on. Our new strategy, which will be offered in 2013, shall make existing energy expertise from NTNU directly available for the individual companies in Finnmark in the start-up phase by educating master students on relevant technology areas.

Centre for Sustainable Buildings (CSB)

This centre's main objective is to develop new knowledge, integrated solutions and technologies which may cover the energy demands in buildings with less negative consequences for the environment. Strategic goals for CSB are developed for these topics:

- Research and development
- Education
- International and outreach activities

A multidisciplinary approach is the main target for all CSB activities. The centre cooperates closely with the research centre Zero Emission Buildings (ZEB), which is a national Centre for Environmental Energy Research. There are, however, also NTNU and SINTEF units collaborating in CSB that are not participants in ZEB.

Main results 2012

Multidisciplinary centre research collaboration

In 2012, CBS has continued its collaboration with ZEB, other FME-units and researchers at non-CEER units at NTNU and SINTEF. Much of the work has a multidisciplinary character, integrating knowledge from engineering and social science fields. In 2012, the TSA Energy participants spent time preparing for the new organization of NTNU's energy activities.

The ZEB centre continues to add more PhD- and post.doc. candidates, totaling 24 at the end of this year, including those with funding from sources other than ZEB. Four of these are financed through TSA Energy. Some of the ZEB post.doc-candidates have obtained research positions at NTNU. A general trend is that the majority of the stipend holders are not Norwegian subjects; some are also from non-European countries.

Educational activities

The Faculty of Architecture and Fine Art began a new international Master-course in Sustainable Architecture in 2010. Students and faculty at this course, together with ZEB-researchers, participated in the international competition Solar Decathlon Europe 2012, and were awarded a place among the 20 finalists. Unfortunately, the main contractor for their proposed building project, the solar zero energy house "ZE+Hytte" (Zero Energy Cabin), was unable to produce the house in time for the Madrid exposition in 2012.



Celebrating the end of the India/Norway workshop with TERI in New Delhi December 2012 by doing "the wave". A follow-up of the photo in our 2011 report!

Nonetheless, the design will be useful for the construction of a "living lab" building at NTNU's technology campus.

International and outreach activities

In 2010, a Joint Research Centre was established between Shanghai Jiao Tong University and NTNU, and it was decided to finance and select four PhD energy students from each university. They will be educated at both institutions, and two of them are earmarked for building issues. In 2012, these PhD positions were announced and filled.

The European SEEIT-group (Sustainable Energy Education, Innovation and Technology), arranged a science seminar in Copenhagen in early 2012. The partners later discussed and developed a common EU FP7 application, which unfortunately was not accepted.

CBS has been active in 2012 in the development of new R&D roadmaps for important upcoming EU programmes, through the lobby organisations ECTP (European Construction Technology Platform), E2BA (Energy Efficiency in Buildings Association), and the new EERA (European Energy Research Alliance) initiative on Smart Cities. In 2011-2012, the Research Council of Norway (RCN) financed a project aimed at helping Norwegian companies and institutions in the construction sector to become involved in EU research. This project was awarded continuation to the end of 2013, and is now organizing a shadow group of participants representing Norwegian companies and institutions in the building sector. One of the strategic postdoc-positions of TSA Energy was awarded to support this activity.

In February 2011, NTNU's rector and a group of energy experts visited several R&D institutions in India, in order to register interest in collaboration. Then, in October 2011, NTNU staged an Indian week in Trondheim, and included in the arrangements a seminar on "Green Buildings" with visiting Indian participants. The main Indian institution for this collaboration is TERI, The Energy and Research Institute in New Delhi. The contacts established were followed up in 2012 with a workshop for planning future joint energy research in this field, held in December in New Delhi. Several researchers from NTNU and SINTEF participated in the TERI workshops, and this collaboration will be followed up in 2013.

Centre for Electric Energy and Energy Systems (EEES)

The research centre plays an active role in developing technology for the production, transportation and utilization of electric energy. The Gemini Centre unites the research activity at NTNU's Department of Electric Power Engineering and the Electric Power Technology and Energy Systems Departments at SINTEF Energy Research. 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 refurbishment
- 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

Education

The centre is involved in several programmes. The Energy and the Environment Study programme (5 years) 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 as well as the admission requirements has been high for several years. A total of 155 students are now enrolled, and the number of female students is stable at about 40%. The Electric power Engineering programme (2 years) is an international programme that has run for several years, while the programme Energy Use and Energy Planning started in 2010.

Research

The research centre participates actively in the NOWITECH (FME), an initiative where NTNU, SINTEF and IFE are partners 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 the technological and economical aspects.

The EEES is host of the SMARTGRID centre begun in 2011. This is an initiative with the participation of universities, research institutions and a wide involvement of industry. This is an interdisciplinary activity involving six of NTNU's seven faculties.

The centre participates in EU-funded projects where either NTNU or SINTEF is the main Norwegian partner.

Industrial collaboration

The centre works closely with the industry, particularly in energy conservation, where the direct interaction is quite strong. Two part-time professorships, one full 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.

Main results 2012

Education

- The evaluation and reconstruction of the future Energy and the Environment study programme (FREMS) in 2011; the new programme started in the autumn 2012.
- The Erasmus Mundus funded new MSc-programme on Wind Energy started in 2012. This programme is a collaboration between DTU, Denmark, TU Delft, the Netherlands and the University of Oldenburg, Germany.
- Continuing Education and professional development (EVU): The first SMARTGRID course was implemented.

Research

- Record number of PhD-thesis publicly defended (9).
- High number of publication points (5.7 on average, compared to permanent scientific staff).
- SMARTGRID:
 - Formal centre with six research partners and 37 members from industry.
 - Application for a new laboratory infra-structure prepared (currently in the phase II of the assessment).
- The EU funded project GARPUR granted.
- Our close cooperation with SINTEF Energy Research is carried out through the continuation of a GEMINI centre. Under this Gemini umbrella, a total of nine projects were started (Research Council of Norway or EU funded), 20 project applications were prepared (Research Council of Norway and industry participation) and 11 projects were granted.



Technical visit at the Smart grid/Renewable energy laboratory

Capacity building

- Professorship sponsored by Hafslund ASA within the field of SMARTGRID recruited.

Infrastructure

- New High Current Breaker Laboratory finished (Total of 5 mill. NOK invested).
- Upgrade and further development of SMARTGRID laboratory on NTNU premises.

International collaboration

- The scientific personnel at the centre actively participate in international research groups and technical committees, and are in the leadership of several groups (IEEE, CIGRE, IEA, IEC).
- Participation in Joint Research Centre with Shanghai Jiao Tong University.

Centre for Renewable Energy (SFFE)

The Centre for Renewable Energy's main objective is to increase the quality, efficiency and scope of education, research, development and innovation within the field of renewable energy in Norway. To achieve this, the Centre coordinates existing activities and establishes new activities at its member institutions to promote knowledge, development, and implementation and utilization of renewable energy sources and technologies.

The Centre for Renewable Energy (SFFE) was established in 2004 as a cooperative unit between the Norwegian University of Science and Technology (NTNU) and SINTEF. In December 2005 the Institute for Energy Technology (IFE) became an equal partner, and in January 2011 the University of Oslo (UiO) also joined the centre.

At NTNU, the Centre is placed under the strategic area of Energy and Petroleum - Resources and Environment. At SINTEF and IFE, the centre is incorporated into the management and at UiO it is affiliated with the Faculty of Mathematics and Natural Sciences. The internal networks of NTNU, SINTEF, IFE and UiO comprised more than 250 scientific researchers and 200 PhD students within the field of renewable energy in 2012.

The strategy of the Centre for Renewable Energy:

- **Influence:** The Centre participates in the public debate on renewable energy research, and innovation and their scientific framework in Norway.
- **Networking and coordination:** The Centre is a platform

for national and international cooperation, and coordinates the competence within renewable energy at the member institutions NTNU, SINTEF, IFE and UiO.

- **Dissemination and information:** The Centre is an information resource on renewable energy research in Norway, and works to increase the common knowledge on the subject.
- **Recruitment:** The Centre works to strengthen the educational facilities on renewable energy in Norway, and to recruit young people to renewable energy research and the industry.

Main results 2012

Consensus process for offshore wind

In January 2012 the report "Et hav av muligheter" ("An ocean of possibilities") was published, and was presented to Norwegian politicians at an event organized by the Federation of Norwegian Industries.

- The report was the result of a consensus process to discuss the framework necessary for establishing an offshore wind industry in Norway, carried out by SFFE and the Norwegian Climate Foundation.
- The project involved several actors from the research institutions and industry in Norway. Support was gathered from a number of prominent players in Norwegian research, trade unions, industry and environmental movements to make a claim against the political authorities that Norway should invest more strongly in offshore wind power.

UngEnergi initiative

In February 2012, a partnership agreement was signed by CenSES, SFFE, Skjetlein high school and Skjetlein Grønt Kompetansesenter. The partners will work together in the UngEnergi (YoungEnergy) initiative, where they will be collaborating on developing teaching materials on environmentally friendly energy for high school teachers, including educational material for class room teaching, educational material as well as for project work, and web resources for students and teachers.

- In 2012 the project has mainly focused on developing content for ungenergi.no, an online information resource for high school students, which will be launched in 2013.

Technoport 2012 & Renewable Energy Research Conference (RERC) 2012

RERC is a biennial conference organized by SFFE, and Technoport is an organization dedicated to sharing the possibilities of smart technology in the transition to a green economy. For the 2012 conference, SFFE and Technoport decided to join forces and RERC was thus organized as part of Technoport 2012 - Sharing Possibilities, an international conference on climate solutions.

- The successful conference gathered over 600 scientists, industry leaders and politicians from 36 different countries for lectures, discussions and debates.
- The 13 parallel RERC sessions featured several prominent keynote speakers from science and industry, and covered topics within renewable energy, transition technologies, innovation and environmental sustainability.

The Norwegian Research School in Renewable Energy (NorRen)

NorRen was established in 2011, and unites the PhD education within renewable energy at five of the Norwegian universities: NTNU, UiB, UiO, UMB and UiT. In addition, the research institutions SINTEF and IFE are associated partners within NorRen. The project is managed by SFFE.

- NorRen has catalogued relevant Master and PhD courses offered by the partner universities, and the resulting database is available at www.norren.no since 2012.
- The first NorRen Summer School took place in August 2012, aimed at PhD students and young researchers in Norway working with renewable energy and eager to see their own research placed in a cross-disciplinary perspective. The 74 participants represented a broad array of disciplines from engineering/technology, economics and social sciences. The summer school received overwhelmingly positive feedback, with regards to academic content, organization and social activities.

The “Green Phase” project

The “Green Phase” project was initiated by the former Minister of Petroleum and Energy, Terje Riis Johansen, at the start-up of the FMEs in 2009. He wanted to engage the PhDs and the young researchers working with environmentally friendly solutions within the FMEs, by bringing forward ideas and initiatives to the Ministry, and by contributing and participating in the official debate around “environmentally friendly energy” with a “young voice”.

“Green Phase” has been given the honour of handing out an annual “Green Phase Prize” to young people who bring forward new ideas, concepts, and projects within “environmentally friendly energy”. The prize of 50.000 NOK is given by the Ministry of Petroleum and Energy. In 2012 the prize was presented at “Technoport 2012” by the Minister of Petroleum and Energy, Ola Borten Moe.

The first phase of the project ended in 2012, and the Ministry and TSA Energy have agreed to prolong the project. SFFE will be responsible for the project, and a new project leader has been recruited.

SFFE lunch lectures

SFFE organized 12 public lunch lectures on topics related to renewable and environmentally friendly energy during 2012. Most of the lectures attracted an audience of 30-50 people. With more than 60 listeners, this year’s most popular lunch lecture was “Renewable energy – the financial crisis’ biggest loser?”, presented by Nito Simonsen from DnB NOR Miljøinvest.



NorRen Summer School, hydrogen car test drive (photo: Ida Fuchs, SFFE)

Gas Technology Centre (GTS)

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

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

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

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

Main results 2012

Technoport 2012 – Sharing Possibilities Conference

GTS participated actively in the session on Transition tech-

nologies-CCS, with a key-note lecture by Director Maria Barrio on "Natural gas as transition technology", and also supported the Public Drive in Trondheim, featuring 4 fuel cell electric vehicles.

Proceedings from 2nd Trondheim Gas Technology Conference (TGTC-2011)

TGTC-2011 (www.sintef.no/tgtc2011) was organized by GTS and took place 2-3 Nov. 2011. The proceedings from the conference were published in Energy Procedia Volume 26 on 18th of August 2012. Preparations for the 3rd Trondheim Gas Technology Conference to take place in June 2014 have begun, and the first announcement for the conference is on its way.

Participation at Barents Sea Conference April 2012 in Hammerfest

GTS was represented at BarentsExpo, and GTS-director Hilde Venvik participated as key-note speaker in the session "Gas and industry".

Student excursion to Statoil Tjeldbergodden

This year's student excursion, organized by GTS in cooperation with Statoil, was to the Tjeldbergodden methanol plant. 12 students from different NTNU MSc programmes were selected out of 31 applicants to follow an educational program during 1-5 October. GTS has received positive feedback from Statoil as well as the students, who demonstrated skills and enthusiasm in gas technology, adding value to the network between industry and academia.

GTS 2013-17 strategy and financing

The second GTS period came to an end in 2012, and considerable work was put into outlining a strategy for a 3rd period (2013-17), along with securing a continued financial basis between NTNU, SINTEF and the strategic partner Statoil. The new strategy puts the natural gas value chain at the centre, from gas resources and transport to processing and LNG, and eventually to conversion. Associated environmental topics such as emissions, efficiency, carbon capture and storage (CCS) and the introduction of renewables also have priority.

Internationalization activities

Visits to Qatar Gas Processing Centre and participation at the 11th Greenhouse Gas Technology Conference (GHGT-11), Japan, have been made. GTS has also been the host of delegations to NTNU from Tsinghua University, China, among others. Further details are available in the GTS Annual Report 2012 at www.ntnu.no/gass.



The GTS roll-up presented at the Barents Sea Conference 2012

Centre for Better Resource Utilization of Petroleum (BRU)

In September 2004 NTNU's Board of Directors included the upstream petroleum area (BRU) as a member of the strategic area Energy and Petroleum – Resources and Environment. The strategy plan for the upstream area was developed in 2004-2005, in close cooperation with oil and gas companies, service companies, governmental agencies, organizations, and the Research Council of Norway; see www.petroleum.ntnu.no/~kleppe/BRUreport.pdf. A new strategy plan was finalized in 2012.

Main results 2012

New strategy plan for research

In 2012, the new strategy has plans for research at the Faculty for Engineering Science and Technology. In the plan, the area "Methods for exploration and production of oil and gas" is defined as one of six Excellence Groups at the faculty. The plan outlines key research areas for discovering more oil and gas, and for increasing recovery from existing fields. The plan may be downloaded from www.ntnu.no/ivt/forskning.

Major research programs

- ROSE - the rock-seismic program
- 4D seismic - reservoir simulation program
- Improved oil recovery program
- Subsea program
- New drilling methods program
- Unconventional oil recovery program
- SFI-Smart Fields/Integrated Operations program (Host)
- FME-Subsurface storage of CO₂ (Partner)
- SFI-Center for Drilling and Wells for Improved Recovery (Partner)

International academic collaboration

NTNU has a wide range of international partners in the petroleum area. Key collaborating institutions in 2012 were: Agostinho Neto Universidade (Angola), Carnegie Mellon University (USA), Stanford University (USA), TU Delft (Netherlands), Pontifícia Universidade Católica do Rio de Janeiro (Brazil), CAMPINAS (Brazil), Universidade Federal da Santa Catarina (Brazil), University of Oklahoma (USA), University of Central Florida (USA) and Mines ParisTech (France). New university partners in 2012 are University of Texas in Austin, and Institut Teknologi Bandung (ITB), Indonesia.

International Conferences arranged in Trondheim

• The Rock Seismic Conference – ROSE12

During April 2012, the 8th international conference in the area of Rock Physics and Seismic was arranged at NTNU. The conference included sessions on Rock Physics, Modelling, Anisotropy and Signal Enhancement, Time Lapse and Reservoir Characterization, and Imaging and Inversion. About 80 people participated in the conference. The conference was followed by a two day short course on Geomechanics for Geophysicists, by Rune Martin Holt and Erling Fjær.

• The Integrated Operations Conference – IO12

During 24-26 September 2012, the 9th international conference in the area of Smart Fields/Integrated Operations was arranged by the Center for Integrated Operations (SFI) in Trondheim. The theme of the conference is Science and Practice, and presentations were held by academia and industry from all over the world. More than 300 persons participated, which is a record. Mayor Rita Ottervik opened the conference, and among the prominent speakers were Executive Vice President of Statoil, Øystein Michelsen. The conference is organized annually, and the next conference will be in September 2013.



Statoil, ITB and NTNU sign cooperation agreement in Djakarta, 27 November 2012

International educational programs

The Petroleum Department has established several programs for support of petroleum education in oil producing developing countries. Currently programs include Angola, Venezuela and Tanzania.

Graduated candidates

In 2012 86 MSc candidates graduated in the disciplines of Petroleum Engineering and Petroleum Geoscience. 35 of the graduates were non-Norwegian. Among the Norwegian students, around one-third spend a one year exchange period at a foreign university, primarily in the US, Canada, Brazil or Australia. A total of 10 PhD candidates defended their research in 2012.

Publications

A total of 141 titles, including refereed journal publications, conference presentations, posters, etc. were reported, of which 82 were in refereed journals or digital proceedings as extended abstracts or full papers. In the system of the Norwegian publication points, a total of 65 points were registered in 2012, as compared to 55 in 2011 and 50 in 2010.

International research prizes

Professor Il Per Afseth was awarded the NPFs Geofysikerpris 2012 and Professor Martin Landrø was awarded the Conrad Schlumberger Prize 2012.

SFI Integrated Operations

Phase II of the centre started in 2012, following the first 5 years of Phase I, and after a successful mid-term evaluation by the Research Council of Norway. All the existing partners of the centre decided to continue their membership. NTNU remains the Host Institution, and the research partners are SINTEF and IFE. The research activities may be found at www.iocenter.no.

Industrial collaboration

A close collaboration with industry insures the relevance of education and research, and provides the financial support for new facilities and research. Key industrial partners during 2012 were Aker Solutions, Bayerngas, BG Norge, Bridge Energy, BP, CGG Veritas, Chevron, ConocoPhillips, Det norske, DnV, E.ON Ruhrgas, ExxonMobil, ENI, FMC, Fugro-Jason, GdF Suez, IBM, Kongsberg, Lundin, Noreco, Petrobras, PGS Geophysical, Revus Energy, RockSource, Saudi Aramco, Schlumberger, Shell, SKF, Spring Energy, Statoil, TOTAL, Tullow, Wavefield Inseis, VNG, Wintershall.

Centre for Energy and Society (CES)

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
- Visions of the Hydrogen Society
- Energy markets and energy actors
- Climate change and climate knowledge: How it is understood and how it is acted upon

The strategic goals for the Centre for Energy and Society are focused on four areas that we see as particularly important in order to be excellent, relevant and visible in the years to come. In short, these strategies are about having a large portfolio of externally funded interdisciplinary projects, improving the dissemination and publication activities, enhancing our understanding of the needed knowledge, and recruiting and developing excellent students.

Main results 2012

New project: useTsmartly - Environmental peer-to-peer education for youth with a focus on the smart use of Information and Communication Technologies

The project is granted by the Intelligent Energy-Europe (IEE). IEE is EUs non-technological program within the energy area which shall contribute to realizing the EU 2020 goals on energy and climate through concrete projects. The partners in the project are Bergische Universität Wuppertal, Germany; Danish Building Research Institute, Denmark; Radboud Universiteit Nijmegen, Netherlands; Dune Works B.V., Netherlands; Smart Homes, Netherlands; Umwelt-Bildungs-Zentrum, Austria; Lokalenergi, Denmark. The Norwegian partner is Department of Interdisciplinary Studies of Culture (KULT), NTNU.

In this project they will take a look at the ways youth use and understand ICT. We know that information technology and multimedia play an important role in the everyday life of young people. We know less about the environmental consequences of the increasing use of ICT, and how youth engage with issues related to energy efficiency, ICT and the environmental consequences of their ICT use. This will be studied in this project, where we will specifically take a look at innovative energy and climate friendly solutions to increase the awareness of young people regarding a smarter use of ICT, as well as generating new ideas on how to create behavior

changes. Contact persons at KULT are Knut H. Sørensen and Robert Næss.

Joint Research Centre on Sustainable Energy with SJTU

The Centre for Energy and Society participates actively in NTNUs Joint Research Centre with Shanghai Jiao Tong University (SJTU), and Marius Korsnes has been employed as a PhD candidate to study the development of industry and technology for offshore wind in China, with a particular focus on the Norwegian presence in this market.

Workshop and PhD course: Innovation and learning in energy policy: New pathways to sustainability?

The response to the event was very good, and about 30 researchers from Denmark, Finland, France, Ireland, the Netherlands, Norway, Spain, Sweden and Austria met in Trondheim for three days (12 – 14 December) to discuss topics such as the use of knowledge in the formulation of energy policy, energy policy innovations, opportunities for sustainable restructuring of the energy sector, and the characteristics of innovations in energy policy.

Dr. Rob Raven from Eindhoven Technical University held an inspiring lecture on “transition policies for sustainable energy innovations” with concrete examples from the Netherlands and the United Kingdom. Professor Harald Rohrer from Linköping University gave an interesting insight into how civil society and NGOs have been seen as key in shaping energy policy through the ages, including the use of examples from the bioenergy area. In addition, two of CenSES own scientists, Henrik Karlstrøm and Sjur Kasa, featured good presentations on the economics of energy policy, with reference to a study of the liberalization of the electricity market and the economy, and the importance of knowledge for the development of Norwegian energy policy, respectively.

IEA Task “Social acceptance of Wind Energy”

Jøran Solli (NTNU) has participated in IEA Task 28 “Social Acceptance of Wind Energy” since 2009. Task 28 works as an interdisciplinary and cross-cultural exchange platform with the goal to support the successful development of wind energy in the participating countries. Task 28 involves experts from 10 countries, including the United States, Canada, seven European countries, and Japan. In 2012 the working group finalized a “good practice” recommendation report. These Good Practice Recommendations are aimed at planners, policymakers, and practitioners of wind power development. They present strategies from around the world that have been successfully used to improve wind

power projects, for the benefit of all, and to implement projects that are acceptable to the majority.

The reports and work in the IEA Task is a valuable contribution to the centre. More information can be found at www.socialacceptance.ch.

NORD-STAR

CenSES collaborate with NORD-STAR, the Nordic Centre of Excellence for Strategic Adaptation Research. NORD-STAR presents state-of-the-art climate visualisation techniques and policy-analysis tools to help bridge the gaps between adaptation science, practice and policy. And by linking climate adaptation with mitigation, NORD-STAR results will help public and private stakeholders at all levels to improve strategy development and decision-making.

Introduction of new colleagues, project presentations and group discussions were on the agenda when more than 30 researchers, PhD students and other NORD-STAR colleagues from the five Nordic countries met at NORD-STAR's Annual Meeting 2012 at Aalto University in Helsinki 23 – 25 May 2012. Project leader Jøran Solli, NTNU, and PostDoc Håkon Fyhn, NTNU, were among the researchers and project leaders that presented their progress one year after the inauguration of NORD-STAR.

ERA-net Smart Grid project

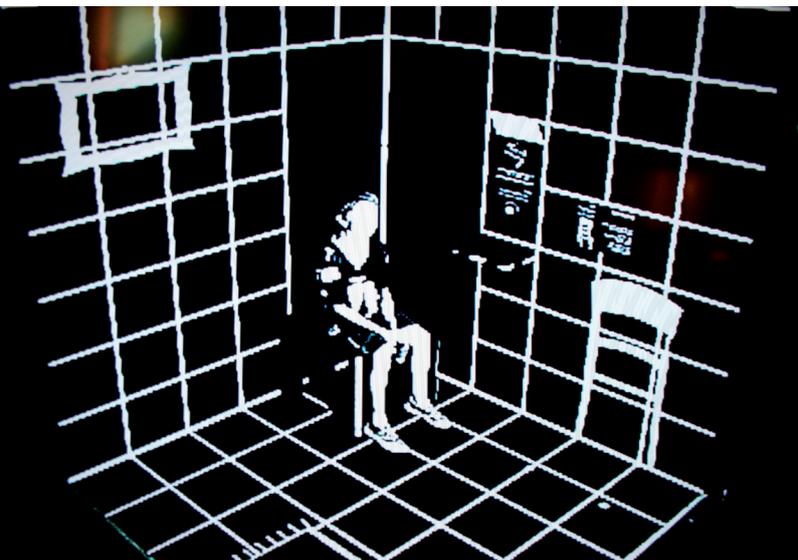
NTNU, SBi, Aalborg University and Technalia/Ziv Smart metering are partners in this ERA-net project, focusing on household smart grid solutions. Since the start up, NTNU has focused on studying the development processes of the

Norwegian Automated Metering Infrastructure, or smart meters. Participatory observation was conducted at a Norwegian network company and their AMI-project in the spring of 2012, and follow up interviews were conducted with project members. The aim was to uncover the relation between the developers of the technology, in this case the network companies, and the national regulatory body and the government. A study of policy development is also in the undertaking, looking at processes concerning the development and implementation of smart grid technology in Norway as they lead up to today. Similarly, the aim of this study is to uncover the political, regulatory and industry activities leading up to a national decision to install smart metering in every household by 2019. Particular interest is given to the role of future expectations for economy, technology, and users. Cost-benefit analyses have been central in the Norwegian discussion, but different actors have reached different conclusions about who will benefit, how, and when, from a mandatory implementation. Thomas M. Skjølvold was employed as a postdoc on this project. Other resource persons are PhD William Throndsen, Thomas Berker and Marianne Ryghaug.

Seminar on policy tools

On 12 - 13 March RA1 in CenSES arranged a seminar on energy policy tools with 30 participants from research and user partners in CenSES. The aim of the seminar was to discuss the research area based on presentations from researchers in CenSES. Different types of tools, from market to non-market based, were presented and discussed. The policy tools were discussed in relation to how households and central professions such as architects, engineers and economists understand and approach them. Other important issues presented and discussed were the status of political analysis in energy and environmental studies, and ways of reconciling environmental and energy political interests in renewable energy. 10 researchers presented, and user partners like Enova, Innovasjon Norge, Statnett and Transnova contributed valuable comments to the discussion.

Publications and dissemination of research results have been very good this year. A particularly great achievement was the fact that as many as three articles were published this year in the journal *Building Research and Information* ("Energy and buildings research: challenges from the new production of knowledge", published by Thomas Berker and Krishna Bharathi; "Municipal planning of a sustainable neighbourhood: action research and stakeholder dialogue" by Helen Jøsok Gansmo; and "Making energy visible in domestic property markets: the influence of advertisements").



Schematic smart grid information house

Industrial Ecology Programme

The Industrial Ecology Programme (IndEcol) is a multidisciplinary university programme. The research activities are focused on research collaboration in a multidisciplinary setting, but with an emphasis on research issues or methodologies that we believe have the potential for advancing the area of Industrial Ecology within our university. One of these areas is the environmental assessment of energy technologies. Climate change is one of the fundamental challenges facing our society today. The adoption of energy efficient technology and the shift to clean energy sources are indispensable for stabilizing greenhouse gas concentrations in the atmosphere, even though they are probably not sufficient. Substantial investments in new technology are required, and we have to make sure that these investments are directed to the right technologies, and that the generation of new problems is avoided. Our work contributes to IEA task forces, the IPCC and the UNEP Resource Panel.

The Global Energy Assessment, fully packed at 1800 pages and 5 kg, is on the way to becoming the new "energy bible". The assessment was presented at the Rio+20 summary in June 2012. Professor Edgar Hertwich contributed as lead analyst, with sections on the total energy use of consumers, the life cycle assessment of buildings, and the rebound

effect. PhD student Kjartan Steen-Olsen and PostDoc Jan Weinzettel contributed an analysis of energy embodied in trade to the Assessment's Energy Primer.

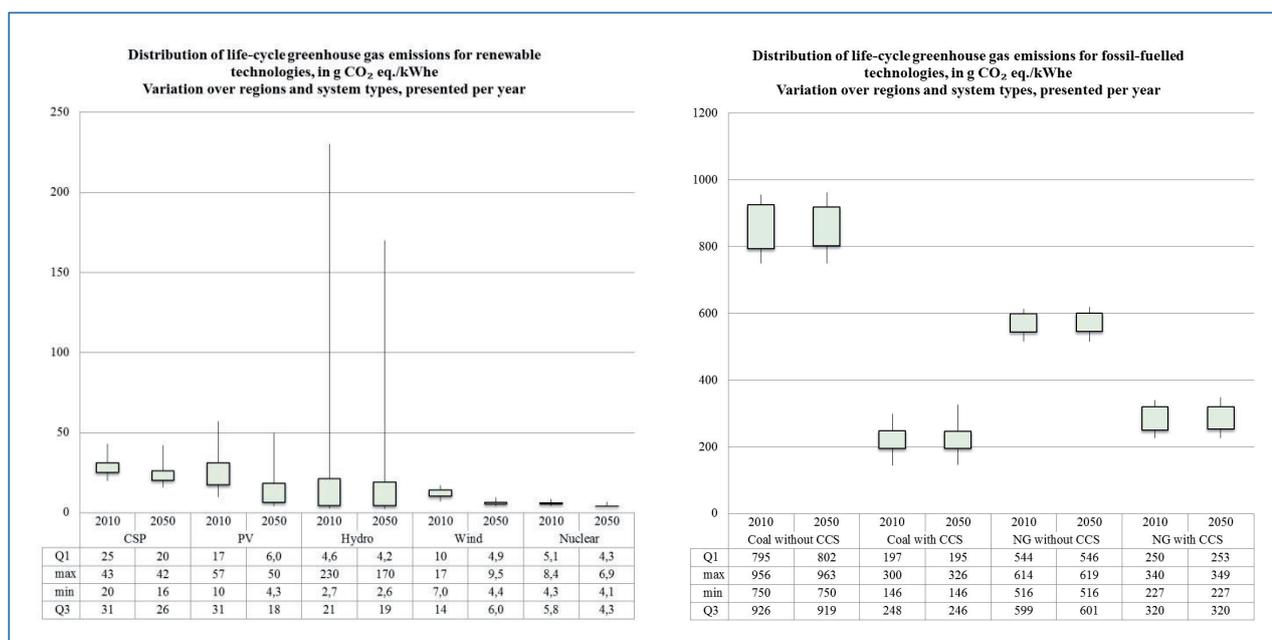
Main results 2012

In addition to the work on global energy assessments mentioned above, the main achievements in the area on energy from The Industrial Ecology Programme in 2012 are:

- An environmental sustainability benchmarking of low-carbon energy technologies
- New knowledge on environmental impacts from batteries used for transportation purposes

Environmental sustainability benchmarking of low-carbon energy technologies

Substantial changes in energy systems are required to meet the rising expectations of a growing population while addressing climate change, ecological and health issues and in the face of declining fossil resources; or - especially an end of easily accessible oil and gas. Becoming independent from these fossil resources and investing in the massive rollout of low-greenhouse gas electricity supply is of primary concern, as part of the solution to climate change



Life-cycle GHG emissions of different energy technologies. The presented range reflects the variation of the regional results among investigated technologies or cases within a single category. It does not represent the parameter uncertainty in technical or other input data.

and to the pressure on global fossil fuel reserves. The potential consequences of this large-scale deployment are poorly understood, or at least, in some cases, poorly quantified. A comprehensive assessment of the environmental and resource aspects of a wide range of *low-carbon* electricity supply technologies is carried out, based on IEA scenarios.

Aside from global warming, impacts on human health from electricity generation are mostly caused by combustion, through respiratory diseases. Toxicity plays an important role, but the quantification of toxic impacts is more uncertain. Ecosystems are affected by climate change through the destruction of habitats. Fossil fuel combustion mostly contributes to eutrophication and ecotoxicity impacts, whereas low-carbon technologies contribute to the impact on ecosystems through land use, water use, and the modification of physical habitats. Resource depletion is affected by the extraction of fossil resources for fossil fuel technologies, but also through the extraction related to the infrastructure intensity of renewable energy technologies: steel and cement constitute the most substantial share, with a second order contribution from specialty materials. Whether these specialty materials are critical has not been part of the scope, and will be the subject of further work.

Environmental implications of large-scale adoption of wind power

A scenario-based life-cycle assessment method is used to assess the environmental costs and benefits of wind power. The study estimates global emissions due to the act of building and operating wind power plants toward 2050, taking into account changes in the electricity mix. What is more, a set of life-cycle inventories for fossil fuel-based electricity is used to evaluate emissions savings from wind power. Results

indicate emissions of 2.3 gigatonnes CO₂e from wind power in 2007-50, in a scenario with a 12% share of wind in the electricity supply in 2050. The positive role of wind power in emission reduction, by displacing direct (in-plant) emissions of fossil electricity, grossly exceeds the total emissions from wind power (blue and purple lines in figure). Furthermore, indirect (fuel-chain) emissions of replaced fossil electricity (green line) also exceed the emissions from wind power. Hence, the study confirms the emission benefits of wind power.

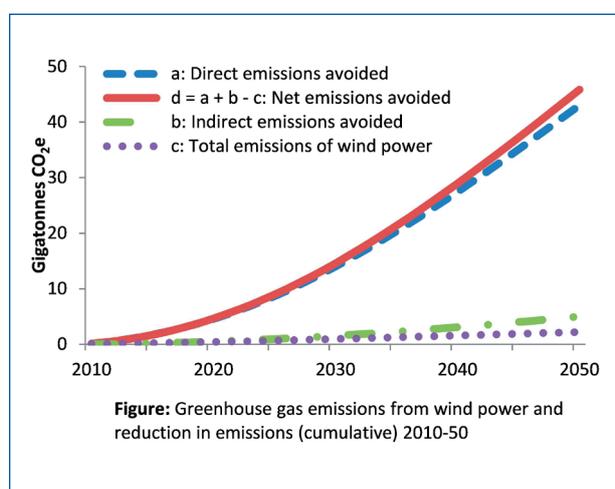
Environmental impacts of batteries for transportation purposes

The environmental impacts of producing, using and recycling three different kinds of traction batteries for electric transportation were assessed. For the same energy capacity, the new lithium ion (Li-ion) batteries outperformed nickel metal hydride (NiMH) for all the environmental impact categories considered. Nevertheless, the assessment demonstrates that the environmental consequences of battery production have been underestimated in previous life cycle assessment (LCA) studies. Producing a 25 kWh Li-ion battery indirectly causes greenhouse gas emissions in the order of 5 tonnes of CO₂-equivalent. These emissions are predominantly caused by the energy requirements for cathode production and cell assembly in cleanrooms. Furthermore, battery production is associated with various environmental impacts other than global warming potential. For example, the use of copper as it is currently extracted is responsible for important toxic emissions from mining activities.

In a subsequent study, the life cycle of a complete electric car was assessed. Producing an electric vehicle indirectly causes 65% more global warming potential than the production of a conventional car, with the manufacture of the battery largely accounting for the difference. To make up for this initial environmental burden, an electric vehicle must last 150,000 km and run on an electricity mix at least as clean as electricity from natural gas combustion. An electric vehicle running on an average European electricity mix will cause 26-30% less global warming over its life cycle than a comparable gasoline vehicle.

The role of aluminium stocks for climate change mitigation

A 50% reduction in greenhouse gas emissions by 2050, which would bring levels to below 2000 levels, cannot be reached if developing countries' patterns of aluminium stock follow those of industrialized economies, reports a study published in Nature Climate Change. The future global aluminium cycle was simulated, and its associated emission pathways and mitigation potentials were explored. The 50% reduction target can only be reached if future global per-capita aluminium stocks saturate at 200 kg, a level much lower than



Greenhouse gas emissions from wind power and reduction in emissions (cumulative) 2010-2050

that present in major industrialized countries, which ranges between 400 and 600 kg. This indicates that traditional mitigation strategies focusing on emission-intensity reduction in primary production, such as carbon capture and storage, should be complemented with innovative approaches aiming to reach the same or higher level of service with smaller stocks of material in use; for example, lightweight design and the optimization of components.

Climate change mitigation in the materials sector faces a twin challenge: satisfying rapidly rising global demand for materials while significantly curbing greenhouse-gas emissions. Process efficiency improvement and recycling

can contribute to reducing emissions per material output. However, long-term material demand and scrap availability for recycling depend fundamentally on the dynamics of societies' stocks of products in use, an issue that has been largely neglected in climate science. Aluminium in-use stock patterns set the essential boundary conditions for future emission pathways, which has significant implications for mitigation priority setting. If developing countries follow industrialized countries in their aluminium stock patterns, a 50% emission reduction by 2050, to below 2000 levels, cannot be reached even under very optimistic recycling and technology assumptions.

International Cooperation

All of the strategic area's centres 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 expand its industrial cooperation, particularly the European Union, Asia (Japan, China and 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 the professors and an organization have been established.

The strategic area Energy enjoys an excellent collaborative relationship with the Research Council of Norway, which has co-financed most of our strategic network development. Our strategy of employing the FME research areas as target areas in the development of our international cooperation has been very successful. We now have substantial research activity in these selected areas, which makes us an interesting partner to universities and research institutions worldwide.

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 6th and 7th Framework Programmes. Thus, we are involved in a substantial number of projects (27, see separate list at the end of this report) under the topics of Energy and Society, Energy in Buildings, Renew-

able Energy, Heating and Cooling, Hydrogen and Fuel Cells, and Carbon Capture and Storage (CCS). NTNU/SINTEF's share of these EU projects amounts to approximately NOK 140 millions.

ECCSEL – ESFRI

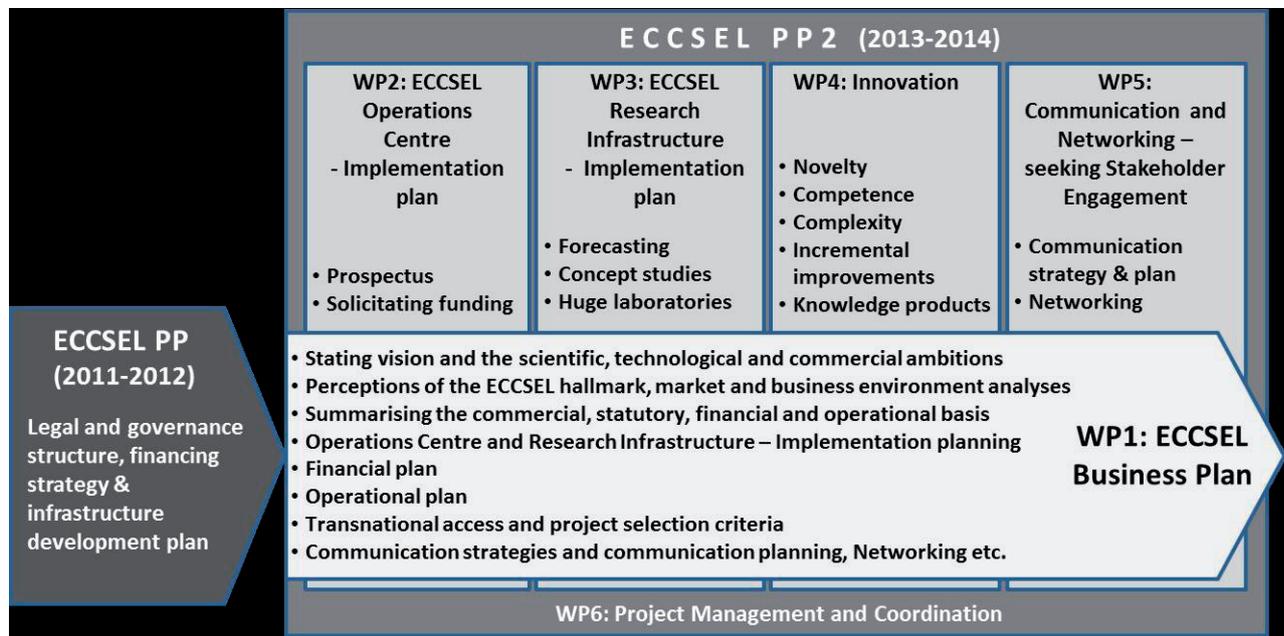
As described in the 2008 and 2009 Annual Reports, Norway was successful in getting our ECCSEL initiative included in ESFRI's new Road Map for 2008. (ECCSEL = "European Carbon Capture and Storage Laboratory Infrastructure", ESFRI = "European Strategic Forum for Research Infrastructure").

In January 2011, the EU - funded and NTNU - lead ECCSEL Preparatory Phase project was started. The first phase (PP1) finished on schedule by 2012, documenting a proposed legal structure, a governance model, a financial strategy, an Infrastructure development plan and other elements of a general framework.

In the second phase (PP2 from 2013 to 2014), the prerequisites for forming the ECCSEL research infrastructure and Operations Centre will be established. The outcome will be used to form an agreed upon ECCSEL Business Plan, so ECCSEL can be in full operation as a pan-European distributed RI from 2015.

The PP2 project is divided in 6 work packages as seen in the figure on next page.

The ECCSEL PP2 consortium has 15 partners from 10 countries across Europe. In the operation phase, ECCSEL could also involve partners and facilities outside the current preparatory phase project.



ECCSEL PP2 project work packages

Timeline:

- Preparatory phase: 2011-2014
- Operation phase: From 2015

Estimated costs:

- Preparatory phase: Approx. 4.0 M€
- Construction costs (until 2030): Approx. 150-250 M€ (to be updated during the preparatory phase)

For more information, visit www.eccsel.org

SEEIT – Strategic Partnership for Sustainable Energy Education, Innovation and Technology

As described in earlier annual reports, the SEEIT Consortium, which reached the final round in the competition for a Knowledge and Innovation Community (KIC) in Energy, decided to form a new consortium to carry out its original plans to work together and take initiatives on energy research programmes and education.

This SEEIT organization, developed in 2010, consists of the following partners:

- **Universities:** Aalto University, Albert-Ludwigs-Universität Freiburg, Copenhagen Business School (CBS), Delft University of Technology (TU Delft), NTNU, Politecnico di Torino (Polito), Technical University of Denmark (DTU), Technische Universität München (TUM).
- **Research Institutes:** ENEA (Italy), Fraunhofer Institute for Solar Energy (Germany) and SINTEF.

See also www.seeit-alliance.eu/SEEIT

The main areas of interest for SEEIT are bio energy, wind energy, solar energy, energy in buildings, energy efficiency and energy systems, i.e. a strong team on sustainable energy.

In 2012 we have worked further to establish the organization and start up the following new initiatives:

- In 2011 Erasmus Mundus application EWEM – “European Wind Energy MSc” was awarded, with Delft University of Technology, Technical University of Denmark, Carl von Ossietzky Universität Oldenburg and NTNU as partners. EWEM aims to educate 120 -150 MSc graduates per year, with a specialization in wind physics, rotor design, electric power systems and offshore engineering. The study programme was launched in September 2012.
- The SEEIT consortium also brought forward an application for EU FP7 Energy 2012.8.1.1: “Next Generation heat pump technologies based on natural working fluids”. The application was awarded and activity started up in 2012.
- SEEIT organized two workshops in 2012: on “Buildings and their Future Energy Solutions” at DTU 15-16 March and on “Energy Education (&Training)” at TU Delft 25-26 October. On both occasions Steering Group Meetings were arranged.
- SEEIT submitted a joint response to EU’s Green Paper “From Challenges to Opportunities: Towards a Common Strategic Framework for EU Research and Innovation Funding”.

- SEEIT was invited to nominate candidates to the Expert Group that was established to develop the SET-Plan Education and Training Initiative (see below).

SET-Plan Education and Training Initiative

The European Commission has put education and training on the strategic map, realizing that the education of sufficiently many specialists in the most important new technology areas will be of utmost importance to realize the goals of the SET-plan. Expert groups have been set up for 13 areas: Bioenergy, Carbon Capture and Storage (CCS), Concentrated Solar Power, Electricity Grids, Energy Efficient Buildings, Energy Storage, Fuel Cells and Hydrogen, Nuclear Energy, Photovoltaic Energy and Wind and Ocean Energy.

By using our connections in EUA-EPUE and SEEIT, NTNU was able to recruit members to seven of these areas, and act as reporter on CCS and Electricity Grids.

Strategy for further work

NTNU will work more systematically in 2013 to participate actively in the joint initiatives being developed by EERA (European Energy Research Arena), EPUE (European Platform of Universities Engaged in Energy research, Education and Training) and SEEIT.

One main activity will be to participate in the process of realizing the SET-PLAN Road Map for Education and Training that will be launched in 2013.

Japan

Kyoto International Forum for Environment and Energy (KIFEE)

KIFEE, which was founded by Professor Yasuhiko Ito, was originally created for the universities in the Kyoto region to develop an international arena for strategic cooperation between universities working to develop a sustainable society, inspired by the Kyoto Protocol.

When the Bilateral Agreement on Technological Cooperation between Japan and Norway was signed in Tokyo in May 2003, there was a desire to build up a long-term research partnership that could serve as a basis for industrial cooperation.

Norwegian universities were invited to participate in KIFEE because of the long-lasting and good relations between the universities in the Kyoto region and NTNU, initiated by Professor Signe Kjelstrup. Since the bilateral agreement involved interactive research between energy and materials to provide new solutions to build a sustainable future, it was decided to employ KIFEE as a platform and arena for

the strategic research cooperation. The Research Council of Norway allocated funds for the development of this area, and Innovation Norway made their invaluable network available for the project.



The first KIFEE Symposium was arranged in Kyoto in October 2004

The first KIFEE Symposium was arranged in Kyoto in October 2004. Since then, one workshop and four more symposia have been successfully organised in Japan and Norway. The response in both countries has been exceptionally good. The presence of more than 40 Japanese participants at the previous KIFEE meetings in Norway, and a similar attendance from Norway at the previous symposia in Japan, reflect the substantial commitment from both countries.

It may be concluded that KIFEE has developed into a platform and arena for strategic research cooperation that targets process engineering, electrochemistry and advanced inorganic materials, advanced biological materials, education in energy and environment, and advanced sciences and technologies for environment and energy.

The 6th KIFEE Symposium was organized in Trondheim in September 2012 with 191 participants (56 from Japan). The symposium also included a plenary strategic session on Sustainability Science, a topic that was introduced by Professor Hiroyuki Yoshikawa in an excellent and inspir-



Participants at KIFEE 2012

ing presentation during the previous KIFEE Symposium in Kyoto in 2011. In addition, workshops were arranged in process engineering, electrochemistry and advanced inorganic materials, advanced biological materials, and education in environment and energy.

In 2012 NTNU decided to invite University of Oslo, University of Bergen, SINTEF and the Institute for Energy Technology (IFE) as permanent partners. In Japan the Institute of Advanced Industrial Science and Technology (AIST) will join KIFEE as full member. The first "Board Meeting" was organised on 1 November in Tokyo during Prime Minister Stoltenberg's visit to Japan.

We will cooperate closely with the Research Council of Norway to develop an official role for KIFEE as a strategic institutional cooperation between Japan and Norway in the area of energy and environment.

China

The development of long-term strategic cooperation with China in the energy sector started in 2004 in close cooperation with Innovation Norway and the Research Council of Norway. At that time, Professor Harald Høyem from the Department of Architectural Design, History and Technology had already developed a long-term partnership with Xi'an University of Architecture and Technology. The following strategy for the further development of the relationship was adopted for selected universities and areas for cooperation:

- 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
 - Gas Technology (LNG), Gas Engines, CO₂ as a Working Fluid, Carbon Capture and Storage, Renewable Energy, Energy Systems
- Chongqing University
 - Renewable Energy

Tsinghua University (THU)

The cooperation with Tsinghua University has already started within the "Energy in Buildings" discipline, since THU is a partner in the NTNU-led FME on "Zero Emission Buildings" (ZEB). They are also a partner in the LinkS project on sustainable energy strategy, which is a part of CenSES.

During our successful meeting at Tsinghua University right after EXPO 2010, THU and NTNU agreed to develop a Joint Research Centre, with an emphasis on "Renewable Energy", "Carbon Capture and Storage", "Hydrogen Energy Technology" and "Energy System Analysis and Sustainable Energy Studies". The development of the JRC Agreement has been delayed, but in October 2012 a high-ranking delegation, headed by the THU Vice-President visited NTNU on short notice. During the successful visit we decided to start up a joint research cooperation between THU and NTNU, and we identified the following topics of mutual interest:



From the JRC official opening ceremony

- Bio energy (Renewable Energy)
- Carbon Capture and Storage; CCS
- Hydrogen Energy Technology
- Energy System Analysis and Sustainable Energy Studies

Further progress in cooperation as well as identification of common projects is expected during a workshop at THU in the autumn of 2013. The financing of this workshop has long been granted by the Research Council of Norway, and they have been willing to wait, so this grant will now become useful.

Shanghai Jiao Tong University (SJTU)

Thanks to efficient cooperation and preparations by both SJTU and NTNU's top management, an agreement on a Joint Research Centre (JRC) on Sustainable Energy between SJTU and NTNU was signed in May 2010 by SJTU President Jie Zhang and NTNU Rector Torbjørn Digernes. The main areas addressed by the JRC are:

- Gas technology to support the utilization of natural gas to substitute for coal (LNG technology – Distributed CCHP)
- Carbon Capture and Storage (CCS) to reduce CO₂ and other greenhouse gases – Use of CO₂ as the working fluid
- Renewable energy (solar energy, wind energy, ambient)
- Energy use in Buildings / Zero Emission Buildings (energy efficiency)
- Energy System Analysis and Sustainable Energy Studies
- Catalysis in New Energy Technologies

In 2012 two workshops were organized to follow up and give input in the development of the different projects and activities:

Workshop 1 in Shanghai 4 – 6 June 2012

This workshop was very eventful! The highlight was the memorable signing ceremony on the agreement of the unique Double Degree MSc Program by SJTU President Jie Zhang and NTNU Rector Torbjørn Digernes, who afterwards opened the JRC officially by unveiling together a JRC Centre Official Plate.

Before this official opening of the Joint Research Centre, a plenary strategic session was arranged at the Green Energy Laboratory at the Minhang campus of SJTU, where the audience enjoyed strategy speeches from the top management of SJTU (Dean Lifeng Xi) and NTNU (Rector Torbjørn Digernes), from the Research Council of Norway (Executive Director Fridtjof Unander) and from invited industrial companies (Shanghai Electric by Hugo Yu and Statoil China by Vice President Jens-Petter Kvarstein), all of them underlining that the plans for what we want to achieve within the JRC are really important.

The 2nd official JRC Board meeting was organized in Shanghai on 5 June right after the plenary part of the workshop ended. Offshore Wind / Smart Grids have been on the agenda since the first workshop in Shanghai in May 2011. The Board appreciated that the preparations have come so far, and decided to start up a project within this area. This project comes in addition to the four projects that were approved and begun in the autumn of 2010, and the status of these projects was presented in parallel workshops.

On June 6 parallel workshops were organized within the projects already started, including a Double Degree Master education, to present the progress in their work. The reports, with plans for the work ahead, were presented at a summing up plenary session, and constitute the total plans for further development of our JRC.

Workshop 2 in Trondheim 27 – 30 November 2012

This workshop was attended by altogether 36 participants (11 from SJTU and 25 from NTNU). Workshops within the scientific areas “Energy Use in Buildings” and “Offshore Wind & Smart Grids”, as well as “Education” and “Administration” were arranged. The “Energy in Buildings” group carried out a comprehensive programme with more than 20 participants, including representatives of two Norwegian industrial partners (Hydro Aluminium and YIT).

This workshop also made it possible to organize the first workshop and start up activity within the new fundamental research area of “Offshore Wind & Smart Grids”. This is a very positive development on an area with large potential both in China and Norway.

During the “Education workshop” we were able to reach a final agreement on the curriculum for the Double Degree Master education.

The programme also allowed for laboratory visits, a “Summing Up - Session” and meeting with NTNU’s Rector, Torbjørn Digernes, to present the status and plans for the work ahead.

The economic situation for the JRC is very positive, thanks to a grant from the Research Council of Norway (RCN), who have awarded our application with 1.85 million NOK for three years of operation (2013-2015).

More information is available at www.ntnu.edu/jrc/jrc

India

In 2011, NTNU’s leadership put cooperation with India on the strategic map and a large delegation visited India in February. TSA Energy organized a multidisciplinary “Energy group”, and with help and support from Innovation Norway we visited eight selected research and education institutions, three in Chennai and five in Delhi. The main objective of the visits was to exchange information about ongoing research and education, and identify potential areas where cooperation could be developed.

During NTNU’s multicultural event “India Week” in October 2011 we were able to organize a successful one-day energy seminar on “Green Buildings”, with participants from NTNU, TERI (The Energy and Research Institute in New Delhi) and MCRC (Murugappa Chettiar Research Centre).

As described in the Centre for Sustainable Buildings section, the contact established with TERI was followed up in 2012 with a workshop for planning future joint energy research in this field in December in New Delhi. The workshop included a visit to “Departure for TERI Retreat” in Gurgaon, where considerable TERI research facilities are located. The TERI collaboration will be followed up in 2013 on the topics “Green Buildings” and “Smart Grids”. TERI, with its “Centre for Research on Sustainable Building Science (CRSBS), and NTNU, with its FME on “Zero Emission Buildings”, are excellent partners for planning specific projects. However, one possible challenge will be to find funding for the activities.

USA

In May 2004, the USA and Norway signed a MoU on research cooperation in the energy sector, with a special emphasis on CO₂ management, hydrogen fuel and new energy technology. NTNU has since then developed a strategic collaboration 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 Marstrand. In 2004 we were able to start up 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 concluded in 2006 with a successful seminar.

Later in 2006 we were able to launch a “MIT-NTNU Gas Technology Program”, based on the PPP model (PPP = Paired Professors and PhD students). This programme involved three projects: “Gas transport systems”, “CO₂ capture” and “Hydrogen Production”, and was financed by Statoil and RCN. In 2008 and 2009, two new projects were started: “LNG Technology” and “Offshore Wind”.

As a result of our close relationship, MIT is now also involved in the FMEs related to “Offshore Wind” and “Zero Emission Buildings”.

The cooperation was 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.

Since the last PhDs have finished their work successfully, and all the partners are highly satisfied with the mutual achievements, Statoil wants to enhance their engagement in the MIT-NTNU-Statoil-cooperation, and planning of a new activity began in autumn 2012. The partners have agreed to start two projects, one within "Offshore Wind" and one within "Use of Optimization and Thermodynamics along the Natural Gas Value Chain". The cooperation will be financed by Statoil and NTNU with some involvement of RCN.

University of Maryland (College Park)

Our long-term 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

We have cooperative projects with the university in two areas, hydrogen technology and energy system analysis. A large KMB project, LinkS – "Linking Global and Regional Energy Strategies", was begun in 2009. This project involves NTNU/SINTEF, University of Maryland and the Joint Global Change Research Institute (JGCRI) in the USA, as well as Tsinghua University in China. Today the results from the LinkS project provide an important part of the scientific platform for the advanced energy analysis, now being carried out by CenSES.

South Africa

A delegation of 11 from South African government departments, academia, research institutes, industry and media made a "Norway Carbon Capture and Storage Capacity Building Visit" in May 2010. The South African delegation expressed a strong interest in working with NTNU on CCS at a post-graduate level. Thus, an application for a pilot project was made and approved, leading to a visit by NTNU representatives to the University of the Witwatersrand (WITS) in December 2010. The pilot project ran successfully and formed the basis for an application for a 2-year master's programme project approved in spring 2011. This project consists of four different types of activities:

- 1) Development of MSc programmes by including CCS specific courses
- 2) PhD programme
- 3) Industry course on CCS
- 4) Exchange of personnel

The EnPE (NORAD) programme with NTNU and WITS within the area of CO₂ capture started in 2012. Two PhD students were hired in 2012, and these two are working on the same topic but from two different angles. In October 2012 a five day CO₂ Capture and Storage course was held in Johannesburg, with participation both from industry and master students at WITS.

The Balkans

Over the years, NTNU has been developing cooperative networks on energy education with universities in the Balkan countries. In 2010, NTNU was able to launch a large new collaborative project, "HERD Energy", aimed at developing and establishing internationally recognized MSc study programmes in "Sustainable Energy and Environment", with the following participating institutions: The University of Belgrade, Belgrade, Serbia; the University of East Sarajevo, Lukavica, Bosnia and Herzegovina; the University of Sarajevo, Sarajevo, Bosnia and Herzegovina; the University of Tuzla, Tuzla, Bosnia and Herzegovina; the University of Zagreb, Zagreb, Republic of Croatia; Sør-Trøndelag University College, Trondheim; and New Energy Performance AS, Kjeller.

The project consists of three main activities: Development of MSc programmes, implementation of MSc programmes and dissemination directly to the energy sector in the western Balkans. The project has reached all its ambitious goals beyond expectation in 2012.

International cooperation on petroleum (BRU)

As can be seen from the report from the Centre for Better Resource Utilization of Petroleum (BRU), this community has developed an impressive cooperative network with a wide range of international partners that work with hydrocarbon issues. The current key countries are Angola, Bangladesh, Brazil, Canada, France, Indonesia, Italy, Mozambique, the Netherlands, Nigeria, Russia, Spain, Tanzania, Ukraine and the USA.

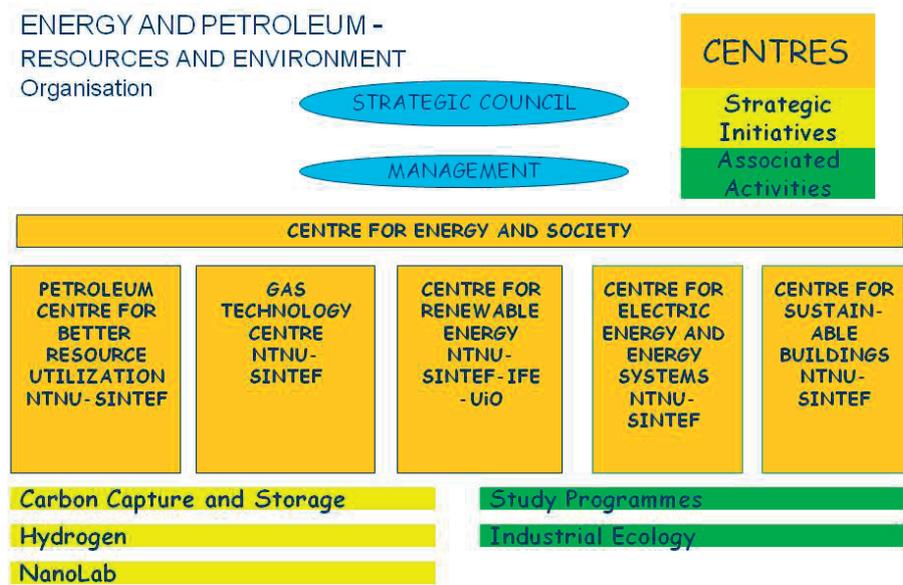
What are the benefits of the Strategic Area arrangement?

- 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 that enables 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 teams 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 successfully planning and carrying out efforts together, we create better communication between disciplines. Walls between disciplines disappear, 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 package of projects than to try to put it together from individual pieces).
- We may also have a competitive edge in the European Research Area with our 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 be a strategic area and act "on behalf of NTNU", with a Rector who is available, and supports us.

Management in 2012

The figure below shows a schematic diagram of the strategic area's organization.



NTNU

SINTEF

Centres:

- Centre for Sustainable Buildings: Professor Emeritus Øyvind Aschehoug
- Centre for Renewable Energy: Associate Professor Gabriella Tranell
- Gas Technology Centre: Professor Hilde Venvik
- Petroleum Centre for Better Resource Utilization: Professor Jon Kleppe
- Centre for Electrical Energy and Energy Systems: Professor Olav Bjarte Fosso
- Centre for Energy and Society: Professor Marianne Ryghaug

Strategic Initiatives:

- Industrial Ecology Programme (IndEcol): Professor Edgar Hertwich
- Carbon Capture and Storage: Professor Olav Bolland
- Hydrogen Technology: Professor Hilde Venvik
- Study programme Energy & Environment: Professor Hans Martin Mathisen
- Research Infrastructures: Laboratory Director Dr. Morten Grønli

Strategic area management:

- Director: Professor Arne M. Bredesen
- Associate Director: Dr. Trond Kvilhaug
- Secretariat: Anita Yttersian / Gunhild Valsø Engdal

Strategic Council:

- Ingvald Strømmen, NTNU (leader)
 - Anne Kathrine Slungård, Ungt Entreprenørskap Norge
 - Arve Holt, IFE
 - Eli Aamot, Statoil
 - Hans Jørgen Roven, NTNU
 - Snorre Valen, Stortinget
 - Nils Kristian Nakstad, Enova
 - Per Ola Ulseth, Skanska Norge AS
 - Steinar Asbjørnsen, Statkraft
- May Britt Myhr, SINTEF Petroleumsforskning AS
 - Sverre Aam, SINTEF Energiforskning AS

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)O₄-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 CO₂ 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 electro catalysts for oxidation of small organic molecules
- Template based synthesis of nanoporous metal-organic frameworks with high surface areas
- BIG CO₂, Phase 2
- Evaluation Methodology for Power Production with CO₂ Capture (MIT-NTNU)
- CO₂ 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 CO₂ and H₂S removal from natural gas to avoid emissions and the use of harmful chemicals
- Conversion of natural gas and biomass to liquid fuels (Renergi + Statoil Vista + GTS)
- Environmental Sustainability (Renergi)
- Tailoring Intervention Instruments to Promote Emission Reduction in Norway (Norklima)
- Developing policy and politics for environmentally friendly energy: Practice, innovation, learning and knowledge

EU FP7 Energy projects at NTNU and SINTEF

PROJECT NAME	RESPONSIBLE	ROLE	TOPIC
CCS			
ICAP	Svendsen	Coordinator	Energy
DECARBIT	Svendsen/ Hågg/ Bolland	Partner	Energy
CESAR	Svendsen/ Hågg	Partner	Energy
OCTAVIUS	Hillestad	Partner	Energy
ECCO	Tomasgaard	Partner	Energy
Carboncap	Hertwich	Partner	Energy
Nanosim	Bolland	Partner	NMP
ECCEL	Bolland	Coordinator	RI
ECCSEL PP2	Bolland	Coordinator	RI
Hydrogen			
WELTEMP	Sunde	Partner	Energy
SUSHGEN	Sunde	Partner	People/ITN
Bio Energy			
GREENSYNGAS	Blekkan	Partner	Energy
BRISK	Grønli	Partner	RI
Offshore Wind			
MARINA PLATFORM	Moan	Partner	Energy
WAWETRAN	Moan	Partner	People/ITN
Mare-Wint	Moan	Partner	People/ITN
ORECCA	Muskulus	Partner	Energy
HIPRWIND	Muskulus	Partner	Energy
IRPWIND	Muskulus	Partner	Energy
MARINET	Sætran	Partner	RI
Refrigeration			
NXTHPG	Eikevik	Partner	Energy
Energy Efficiency			
ZenN	Wyckmans	Partner	Energy
RAMSES	Wyckmans	Partner	Env
EFFESUS	Grytli	Partner	Energy
Smart Grids			
GARPUR	Uhlen		
Solar / Materials			
Cosmic	Tranell	Partner	NMP
Recover	Tranell	Coordinator	NMP

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
www.ecbcs.org/annexes/annex44.htm
- IEA ECBCS Annex 47: Cost-effective Commissioning, www.ecbcs.org/annexes/annex47.htm
- IEA PVPS Task 10: Urban Scale PV, www.iea-pvps-task10.org
- IEA Heat Pump Programme Annex 29: Ground-Source Heat Pumps Overcoming Technical and Market Barriers,
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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