

2007 Annual Report, the RENERGI programme (2004-2013)

The year 2007

2007 was a breakthrough year for the acknowledgement of anthropogenic climate change, leading to a dramatic increase in attention to research on environmentally sound energy. In 2007 the RENERGI programme focused on renewable sources of energy, including hydropower. The programme issued two main calls for proposals: one for Researcher Projects and Knowledge-building Projects with User Involvement (KMB) in June, and one for User-driven Innovation Projects (BIP) in October. In December, the programme board awarded NOK 52 million in funding for projects for 2008.

As part of the analyses prior to the calls for proposals, the programme prepared the report *Samfunnsforskning i RENERGI-programmet* (“Social science research under the RENERGI programme”, Norwegian only). Drawn up by the consultancy firm ECON, the report provided the board with a better basis on which to determine the role of the social sciences in the RENERGI programme. Foresight analyses were also conducted on solar cells, offshore wind power, bioenergy and biofuels.

Through a three-year development project funded under the RENERGI programme, the Research Council has contributed to solar cell company Elkem Solar’s development of a metallurgical process for the production of silicon that substantially reduces the consumption of electricity – a contribution to making solar cells even more environment-friendly.

Progress in the field of hydrogen has not matched expectations, despite great enthusiasm after the strategic Norwegian Hydrogen Council submitted its action plan for this field in December 2006.

The programme administration and the board contributed to the establishment of Energi21, a common forum for Norwegian energy stakeholders. The forum’s first phase was completed with the submission of its strategic recommendations to the Minister of Petroleum and Energy, on 5 February 2008. The RENERGI programme’s project portfolio already contains a number of projects that form a good basis for implementing the priorities of the Energi21 initiative regarding offshore wind power, bioenergy and cable technology as well as the development of policy, instruments and markets.

Objectives

Primary objective

The primary objective of the RENERGI programme is to develop knowledge and solutions as a basis for ensuring environment-friendly, economically efficient and effective management of the country’s energy resources, a highly reliable energy supply, and internationally competitive industrial development related to the energy sector.

Secondary objectives (5-10 year perspective)

- New technologies, systems and solutions that facilitate energy restructuring by improving the efficiency of energy production, transmission and use, making more energy available and improving system security and flexibility.
- Environment-friendly energy systems that reduce emissions of greenhouse gases and other air pollutants, improve land use, etc.

- New, internationally competitive goods and services related to the energy sector.
- Knowledge and analysis as the basis for the authorities' and industry's long-term energy strategies, public debate and design of public policy instruments.
- Internationally competitive research communities in high-priority fields that collaborate extensively with international researchers and various types of users.

Budget, projects and research fellowships

Budget and projects, 2007

Available funding in 2007:	NOK 202.5 million
Funding allocated in 2007:	NOK 158.2 million

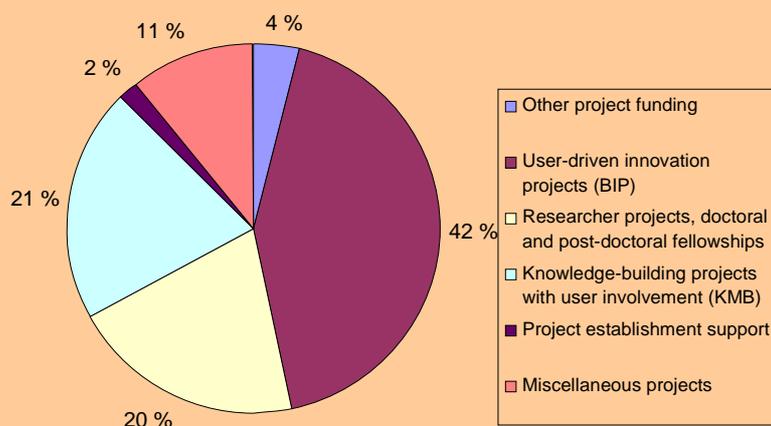
Programme's funding sources in 2007 (in NOK million):

Ministry of Agriculture and Food	3.50
Ministry of the Environment	8.35
Ministry of Trade and Industry	6.00
Ministry of Petroleum and Energy	99.80
Ministry of Transport and Communications	23.10
Fund for Research and Innovation	12.00
Miscellaneous revenues	14.69
Total	167.44

Number and type of projects in 2007: 184, of which 52 were new

User-driven innovation projects (BIP)	79
Researcher projects	37
Knowledge-building projects with user involvement (KMB)	38
Project establishment support	3
Other project funding	7
Miscellaneous projects	20

RENERGI programme projects, by project type
Total number in 2007: 184



Research fellowships, 2007

Doctoral fellows:	40 total man-years, including 9.5 by women (24%) 72 persons, including 25 women
Post-doctoral fellows:	9.6 total man-years, including 1.6 by women (17%) 19 persons, including 5 women

Comments on these figures:

There is good, wide-ranging involvement on the part of private enterprise in projects under the RENERGI programme. The programme contributes to researcher recruitment in the field of clean energy. This report period has been relatively stable with regard to budget, project portfolio and support for educational activities. There was greater focus in 2007 on the social sciences portfolio and use of resources for projects involving biofuels.

Performance indicators, 2007

Academic	
Scientific articles, peer-reviewed:	67 (38 in 2006)
Scientific articles, not peer-reviewed:	48 (51 in 2006)
Other publications/lectures:	389 (220 in 2006)
Number of books:	15
Measures targeted toward the general public:	68
Publicity in mass media:	638 (197 in 2006)
Industry-oriented	
Number of patents:	6
Number of licenses:	6
Number of new companies:	2
Number of new products/processes:	23
Number of new methods/models/prototypes:	49

Comments on these figures:

Comparing the 2006 and 2007 performance indicators, it is apparent that there was an increase in activity in the scientific fields encompassed by the RENERGI programme in 2007. Several figures for key indicators for dissemination of information, such as the number of scientific articles published, rose by over 50 per cent. Publicity in the mass media more than tripled, a clear indication of society's growing interest in issues related to climate change, renewable energy and energy consumption.

International collaboration

The EU

In the energy sphere, Norwegian research groups had a success rate of approximately 20 per cent in competing for funding under the EU Seventh Framework Programme. This is substantially lower than in 2006, but the number of applications grew from 27 in 2006 to 72 in 2007. Fifteen of these applications involved a Norwegian coordinating role. A total of 18 projects, four of which involved a Norwegian coordinating role, received a positive recommendation. Germany was Norway's most frequent project partner for joint applications, followed by France, the UK, the Netherlands and Italy.

One priority task has been to involve more small and medium-sized businesses (SMBs) in EU applications, but this has proven difficult to achieve in practice. Many SMBs do not have the resources, staying power or sufficient knowledge to fare well in the EU application process. With the aim of easing the introduction to the Brussels bureaucracy, greater effort has been directed toward getting institutions with extensive knowledge of such procedures, e.g. the Norwegian University of Science and Technology (NTNU) and SINTEF, to draw technology companies into participating in grant applications.

The IEA

Important activities associated with the International Energy Agency (IEA) include collaboration on research, development and market introduction of energy technology. This collaboration is organised into Implementing Agreements (IAs). At the end of 2007/beginning of 2008 there were 40 different IAs involving nearly 60 countries, organisations and companies. Each IA is organised under one of five focus areas, termed working parties (WPs): renewable energy, fossil fuels, end use, nuclear power, and cross-sectoral areas. Norway participated in over 20 IAs under all the WPs except nuclear power. Under renewable energy, Norway participated in eight IAs.

Major changes have occurred over time in framework conditions, international collaboration and conditions related to technology development within the research fields encompassed by the IAs. For instance, several international energy-related forums of cooperation have been established since the 1970s under the auspices of the EU, the Nordic Council of Ministers and others, and new thematic areas have been identified as the need has arisen. Against this background, the Research Council of Norway charged ECON/EXERGIA with conducting an evaluation of Norwegian participation in research-related collaboration under the IEA and the benefit thereof.

More information about Norwegian participation in IEA collaborations as well as a download of the evaluation are available at: www.iea.no (in Norwegian only).

Highlights and findings from selected projects in 2007

Low-energy buildings – from vision to reality?

Almost no one chooses to procure low-energy buildings, yet everyone would appreciate the offer to do so. The biggest challenge is in getting more contractors to choose energy-efficient solutions.

This is the main conclusion of the project “Low energy buildings – from vision to reality?”, conducted at the Norwegian University of Science and Technology (NTNU). “Attitudes will change, but mostly not until the building codes are tightened,” says project manager Knut Holtan Sørensen, a professor in the Department of Interdisciplinary Studies of Culture at NTNU. The objective of the project was to gain greater insight into the political, scientific, technological and practical processes associated with low-energy buildings.

The study dealt with the process of realising an energy-efficient building, from planning to construction and use. The project encompassed commercial buildings as well as residences. One problem the researchers encountered was the lack of clear criteria for what it means to construct a building that is energy-efficient and environmentally sound. The term “low-energy building” has a positive ring to it, but there is great dissimilarity in its actual interpretation by the players in the construction process. This was documented in most of the study’s six examples. The project focused its study on buildings that were expressly intended to be energy-efficient and/or energy- and environment-friendly.

Three critical factors affect the construction of low-energy buildings. The first is the motivation and financial situation of the contractor. The second is the expertise and interest of the architect and consulting engineer. The third is the availability of suppliers and installation personnel. Additional factors include the user's interest and willingness to exploit the energy-saving solutions. The project will lead to one doctoral thesis, now in its final phase.

Post-Kyoto climate agreements and technological innovation

In a research project funded under the RENERGI programme, Rolf Golombek of the Frisch Centre is studying types of technology agreements that may correct some weaknesses of the Kyoto Protocol. Dr Golombek believes that an international agreement on a research and development (R&D) initiative on climate-friendly technologies could yield additional gains if combined with an agreement focused on emissions, as the Kyoto Protocol is. The thinking goes that an agreement on developing new technology could make it cheaper to reduce emissions of greenhouse gases. An agreement that focuses on cuts in emissions typically affects a small number of groups, such as energy-intensive industry. A technology agreement normally distributes the costs evenly through tax assessment, so it is unlikely that specific groups would oppose it.

It is possible for countries to agree on different types of technology agreements. Dr Golombek's project indicates that it is most effective to have an agreement at the R&D level, since a joint subsidy initiative would typically be higher than the technology subsidy a nation would introduce without an international technology agreement. This would promote research on climate-friendly technology on a broader basis, beyond the narrow self-interests of any one country.

Another finding from this study shows that a technology agreement is more effective between fewer, large nations than between many small countries. According to Dr Golombek, this suggests that the initiative by the USA on a technology agreement between the highest-emitting countries could be a good alternative to the Kyoto Protocol, if it is binding for the parties.

Energy planning (the SEDS project)

The project "Sustainable energy distribution system planning methods and models" (SEDS) was a collaboration between NTNU, SINTEF Energy Research, the Norwegian Water Resources and Energy Directorate, several of the largest energy companies in Norway, and research groups in Denmark, Portugal, Switzerland, Finland and the USA. The objective of the SEDS project was to develop new methods and models for planning local energy systems that integrate new energy carriers (natural gas, district heating, etc.) using the existing power system optimally, and based on technological, economic and environmental criteria. Participants in the SEDS project worked closely with participants in the SINTEF Energy Research project "Analysis of transport systems with multiple energy carriers", concluded two years ago. More information on this project is available at:

<http://www.energy.sintef.no/Prosjekt/SEDS/>
<http://www.energy.sintef.no/prosjekt/energyplanningtoolbox/>

These two projects yielded four doctoral degrees in local energy planning. The projects also resulted in valuable new methods and models and a new "Energy and the Environment" educational curriculum at NTNU. In addition, the basis was established for a new energy planning tool, whose prototype was tested by the project participants and is now being further developed under the newly established "e-transport" project with Trønder Energi as a contractual partner.

SINTEF Energy Research is now in negotiations to coordinate the SUSPLAN project, a larger-scale EU-funded project. The knowledge-building activities of the aforementioned projects have made it possible to take on such a role.

Supply-side security

Under the auspices of the project “Wide Area Monitoring and System Protection for Power System Security”, Statnett and ABB Norge have developed an entirely new monitoring system that considerably improves security of the main grid. This system now provides Statnett’s central grid operator with a far better overview of grid stability, and allows for the possibility of intervening to avert a large-scale shutdown in the event of a larger nationwide system error caused by e.g. increasing oscillation in the grid frequency. The project provides new opportunities for ABB’s Norwegian section, which is responsible for this business area in the international ABB corporation. The facility is the first of its kind in the world, and is to be further refined through the newly established project “Wide Area Control System for Control of FACTS/HVDC”.

Solar cell: Development of lower-cost, high-grade silicon for use in producing single crystals

Two more monocrystalline ingots have now been produced on an industrial scale using the Cz method. These ingots are made with 100 per cent Elkem Solar metallurgically purified silicon, designed for use in solar cells. Solar cells of wafers from the ingots have been produced at two locations – an industrial company and a research institute. The highest efficiency of the company’s solar cells was in the range of 15.3-15.6 per cent, while the highest achieved result for the research institute’s solar cells was 15.3 per cent. This is 0.7 per cent below the result for the reference cells. These were not, however, produced in the same oven, so there is some uncertainty in the comparison. The pulling of crystals on ES material was conducted using a low-cost method, so there is ample room for optimising the crystal extraction through further efforts.

Use of screw compressor in hybrid heat pump with ammonia/water as working medium

In the heat pump industry, a general trend is emerging toward the use of natural mediums – due to environmental concerns as well as the high cost of certain synthetic mediums. There is also a desire to produce heat pumps that can supply temperatures above 75-80°C. Although heat pump efficiency is better at lower temperatures, the overall economy and energy deliveries will be limited in many cases if heat pumps cannot deliver high enough temperatures. The hybrid heat pump developed at the Institute for Energy Technology (IFE) uses a mixed medium of water and ammonia, which theoretically could yield temperatures approaching 160°C at a system pressure of 20 bars.

Hybrid Energy AS is Norway’s sole national and international supplier of hybrid heat pumps, and IFE has the only research group in Norway that is working on compression/absorption-based heat pumps. Their heat pump, which generates hot water as well as refrigeration by recycling waste heat, is unique in its kind and has shown very good output and reliability at two installations in the food industry.

Many heating systems do not utilise waste heat sources due to a lack of effective, profitable technology for sufficiently raising the heat source temperature. In this context, there is a need to upgrade heat to a somewhat higher temperature in order to use it in existing systems.

Hybrid Energy’s aim in this R&D project is to refine the hybrid heat pump technology for use in larger-scale installations such as district heating facilities. Screw compressors are most suitable for use with heat pumps with a delivery output of over 1 MW. The primary objective

of the project is to develop a system for utilising a screw compressor in a single-phase hybrid heat pump with ammonia/water as the working medium. Screw compressors would be able to deliver greater output than piston compressors and would be cheaper for major output needs. The newest plate heat exchangers with higher thermal length will be used in the testing facility as well.

Production of hydrogen – from water

An important challenge in implementing hydrogen as a fuel is devising production solutions that are both efficient and environmentally sound. In the project “REELYPEM – Hydrogen Production from Renewable Energy Prototyping and Field Testing of a PEM Electrolyzer”, StatoilHydro’s Hydrogen Technologies has worked on developing an electrolyzer that generates hydrogen by “splitting” water. The project is a continuation of the decades-long activities of Hydro Electrolyzers. A new electrolyzer has been developed which uses a polymer electrolyte membrane (PEM) to provide higher energy efficiency; its prototype now generates a capacity of 1 Nm³/hour at atmospheric pressure. It has been tested under normal operating conditions for 1,100 hours. One advantage of the PEM electrolyzer over the most common (alkaline) type is its great flexibility with variable power supply, making it easier to utilise energy sources such as wind.

From the project “REELYPEM – Hydrogen Production from Renewable Energy Prototyping and Field Testing of a PEM Electrolyzer”

Production of hydrogen – from natural gas

Natural gas is currently the most important source for the production of hydrogen. Any future regime using hydrogen in the transport sector must feature an entire value chain that is environmentally sound – so if hydrogen is to come from natural gas, the process must not emit CO₂ during production.

The SINTEF Group in Trondheim is collaborating with several petroleum companies with the aim of developing compact, flexible and energy-efficient reactor concepts for producing hydrogen from natural gas, which entails accumulation of CO₂. Key challenges involve catalysers, membranes and O₂ adsorbents – and progress has been made within all three of these areas under the project.

The properties of **new catalyser materials** have been tested in H₂ production of dry feeds, i.e. with methane and air under mild conditions (< 650°C). Low temperatures mean great benefits in terms of material stability and life span, and will subsequently allow the use of cheaper materials. The reaction is self-sufficient with the heat of reaction, in contrast to conventional technologies that operate by injecting steam into the feed at critical temperatures approaching 1,000°C, requiring externally added energy. With dry feed the system can be simplified to avoid energy lost in, for example, producing steam. One ensuing challenge, however, is to establish material properties in order to avoid coke formation and deactivation.

New knowledge has been generated about requirements for catalyser materials and the interplay between materials and reactor design in terms of the ability to maintain efficient production of hydrogen at low gas temperatures. Promising catalyser systems, which include noble metals on a suitable carrier, have been identified and will be further investigated.

The objective of developing new **membrane materials** is to find materials that can be used to separate the hydrogen from the natural gas and carbon dioxide, most preferably directly from the reaction mixture at a practical temperature. Currently, separation is done at low temperatures with polymer membranes, and at up to 500°C with palladium membranes. At higher temperature the Pd membranes lose their strength, but this can be solved by adding a

composite of metal oxide and ceramic. Trials are underway to devise such membranes, and tests conducted in the USA indicate that these can be used at temperatures up to 900°C. Cermet (ceramic-metallic) membranes, with an effective range from 400 to 900°C, satisfy the temperature range the industry wishes to operate within (approximately 400 to 650°C). Several designs are under development. The first design, which has also been tested, provides a good hydrogen flux even without being optimised.

New energy-efficient methods are being investigated using **O₂ adsorbents** to separate oxygen and nitrogen from air at high temperature (400°C) and high pressure. Various candidate materials are being examined for the possibility of designing material properties (capacity, pore size, adsorption strength, etc.) that make it possible to achieve kinetic or thermodynamic separation. Promising materials have been identified and the separation effect has been confirmed in principle through experimental measurement.

From project 164621, “New process technology for production of hydrogen from natural gas”

Risk to birds from wind turbines in coastal Norway

In spring 2006 several sea eagles were found dead in connection with the wind farm at Smøla. A project has been established to acquire an improved information base and develop a tool that enables the wind power industry and the authorities to identify locations for new wind power projects with reduced potential for disturbance to birds. The project has the ambitious objective of determining the biological, species-specific and external factors that make the birds vulnerable to wind turbines. These may include manoeuvrability, hunting techniques, age of bird, nesting, local movement patterns, topography, weather, and location of the wind turbine in relation to migration routes. The project is also intended to determine the mortality rate's impact on the bird population.

To estimate the risk of collision between bird and wind turbine, a statistical model will be established for various wind farm scenarios. For especially susceptible species such as sea eagles, a theoretical model will be devised to describe population development. The project is being carried out in collaboration with Denmark's National Environmental Research Institute (a leading institution for studies of birds in areas with wind turbines), Uppsala University in Sweden, the SINTEF Group, and Statkraft.