The Research Council of Norway

Clean Energy for the Future – from vision to true alternative!

Programme
Final report – RENERGI

Large-scale Programmes

The RCN initiative to meet national research priorities

CONTENTS

PREFACE

Research on environment-friendly and renewable energy has been of high national priority in recent years. Research activities in this field were consolidated under a single programme for the first time in 2004 with the establishment of the programme Clean Energy for the Future (RENERGI). For close to ten years the RENERGI programme has been a key channel for public funding for energy research, and it has helped to effectively structure competence-building in the field.

This final report provides an overview of the programme's activities and results from the entire programme period. In addition to illustrating the broad scientific scope of the research activities in the field, the report shows how the programme has delivered results of major significance to trade and industry, the research community and society at large.

Under the RENERGI programme, the Research Council has successfully integrated activities and established a common strategy for environment-friendly energy research, thereby achieving a higher profile programme and clear funding priorities. The RENERGI programme has been a driving force behind and has brought together players in a number of national scenario and strategy processes. Among other things, this has led to the launch of Energi21, Norway's national R&D strategy for the energy sector, and a new instrument, the Centres for Environment-friendly Energy Research (FME). There is no doubt that the major budget growth in the wake of the broad-based political agreement on climate policy achieved in the Storting in 2008 is, in part, the result of the focus on common strategies, which has provided politicians with clear input regarding targets, and thus the willingness to invest.

The external evaluation of the RENERGI programme concluded that the programme has been a success. The RENERGI programme has managed to give Norwegian research groups a significant boost, particularly through competence and network-building. This goes to the core of what the Research Council seeks to achieve. The evaluation report points out that most of the projects funded by the RENERGI programme would not have been implemented without this support, which documents just how important the programme has been for energy research in Norway. The evaluation report similarly identifies that those familiar with the RENERGI programme were satisfied with its practice and the way in which it was managed, and would like to see the model of a single, integrated programme continued.

The Ministry of Petroleum and Energy has been the largest source of funding for the RENERGI programme, although other ministries have allocated significant funding. The fact that the Research Council has had the latitude to administer allocations from the various ministries in a cross-sectoral manner has been a key success factor.

It gives me great pleasure to present this final report and state unequivocally that the RENERGI programme has delivered excellent results. I have great expectations for its successor, the Large-scale Programme for Energy Research (ENERGIX), which has already been launched and which will continue and refine the good work that has been done.

Arvid Hallen
Director General

1 THE RENERGI PROGRAMME – a research programme under changing framework conditions

The world needs new solutions

Launched in 2004, the programme Clean Energy for the Future (RENERGI) was one of seven programmes under the Research Council of Norway's Large-scale Programme Initiative. The point of departure for the new programme was the project portfolios of three previous programmes targeted towards industrial research, basic technological research and social science-related energy research, respectively.

The Large-scale Programme Initiative was established to better address national research priorities. The RENERGI programme was to have a long-term perspective, both with respect to its objectives and its duration, as well as a budget of sufficient size to make a difference. Moreover, the large-scale programme was to lay the foundation for a research strategy that extended to the entire field of environment-friendly energy research.

The launch of a large-scale programme for research on renewable energy reflects the importance of this topic. While the challenges relating to renewable energy have been – and still are – large and numerous, the field has opened up a corresponding number of promising opportunities.

The Kyoto Protocol dominated the scene at the time the RENERGI programme was started up, although no specific targets or action plans had been drawn up. In 2006–2007, a genuine change in awareness about climate challenges occurred, both in society at large and among the public authorities. This awareness was very evident in the broad-based political agreement on climate policy achieved in the Storting in 2008, which led to a significant increase in allocations to research on environment-friendly energy, among other things.

The white paper on Norwegian climate policy published in 2007 confirmed the objectives of the Kyoto Protocol: by 2020 Norway would contribute to reducing global greenhouse emissions by cutting the country's emissions by 30 % compared to 1990 levels.

The issue of energy restructuring gained an increasingly prominent role on the Norwegian agenda, and one of the responses to this was the establishment of Enova in 2002. Energy restructuring and raising energy efficiency have been one of the pillars of the RENERGI programme throughout its programme period. Now, as the programme draws to a close, there is much greater awareness of and commitment to raising energy efficiency among the various players – also internationally. There is widespread acknowledgment that efficient energy use is absolutely critical to reducing greenhouse gas emissions and satisfying the increasing demand for energy services.

The international market for renewable energy technology has grown, accompanied by optimism regarding the potential for Norwegian players to make a contribution. National and international research has been considered essential to devising the solutions the energy market will require. The Research Council has also recognised the need to start developing knowledge and solutions to enable the energy system to accommodate future energy demands.

Photo: Colourbox.com

From vision to true alternative

At the time the RENERGI programme started up, public opinion on climate challenges was much less evident than it is today and the belief in the potential of new energy technology was much more limited. The situation has changed dramatically during the course of the programme period. Ten years is a long time in this perspective.

In 2003

- Bioenergy, solar energy and wind power were identified as new renewable energy sources. During the Pentecost holiday weekend in 2012, Germany covered one-half of its electricity consumption with solar and wind power for a period.
- There were approximately 1 200 electric vehicles in Norway. In August 2011 there were 4 500. On 1 September 2012 there were 8 715, and every 20th car sold was an electric vehicle.
- The cost of a solar cell system was USD 4–6 per installed Watt. In 2012 this amount was reduced by more than half to USD 1–2 per installed Watt. In 2003 there were three or four solar cell companies in Norway, while today the country is home to a solar energy cluster.
- NOK 12 million in funding was awarded to social science-related energy research. In 2012 the Research Council awarded nearly NOK 75 million.

In strategy documents from the end of the 1990s it is obvious that renewable energy sources were considered "alternative" sources that might come to play a genuine role some day, but certainly not until well into the future, if ever. These new renewable energy sources – solar energy, wind power, bioenergy and wave power – were considered exotic and unlikely to be significant. Despite the understanding that advancements would take time, the level of investment and activity in the field of renewable energy was maintained and then stepped up. The results began to emerge, and industry players became involved on a wide scale. In the course of the programme period, the adjective "new" was dropped, and it has been years since wind power was described as "exotic". In the course of the RENERGI programme's ten-year programme period, public opinion on renewable energy sources and related technologies has been completely transformed.

Renewable energy technologies have now achieved:

- a maturity that makes them reliable enough to be incorporated into the planned energy supply;
- a market price that means they will soon be competitive with conventional solutions in many markets;
- a volume that makes them interesting for new industry players and new value creation.

This does not mean that the task is finished. New chapters still need to be written and major improvements will have to be made if industrialisation of these technologies is to be feasible. There is a formidable demand for renewable energy internationally, and new solutions must be developed to secure a sustainable energy supply in the face of growing global energy consumption.


Photo: Statkraft

HIGHLIGHTS

2

The RENERGI programme has in all ways been a large-scale research programme, with its broad scientific scope, sizeable budget and long-term perspective. Activities under the programme have helped to cultivate dynamic research groups that have participated in the international effort to develop new energy technologies that address global challenges. There has been increasing interest and commitment on the part of Norwegian industry players to seize the opportunities afforded by these technologies and seek a more active role in the international market. Research activities funded under the programme have resulted in a new crop of highly-skilled specialists who will help to develop sound solutions for the various stakeholders. This chapter highlights some examples of how the RENERGI programme has promoted progress on the clean energy front.

2.1 The energy system – decentralised production and more integration

In Norway and internationally, energy systems have traditionally been centralised, that is, produced at a few large-scale sites and then transmitted and distributed to consumers.

Over the past 10–15 years, a significantly different kind of energy supply has begun to take shape. Future solutions are likely to comprise a more differentiated energy supply that consists of many small-scale production units from a variety of sources. These solutions will be combined with centralised production solutions that also incorporate multiple sources, such as power generation from large-scale wind farms or vast areas of solar cells.

One related development is that new kinds of end-users within the grid appear to be gradually emerging. These new end-users, dubbed "prosumers", are customers who are consumers of energy one moment and producers of it the next. The rapid rise of electric vehicles is another area in which a growing range of customers will place new demands on the energy supply. For the conventional power grid to offer the increased flexibility and higher functionality that the future will demand, it must be integrated with an ICT network that can collect and exchange all the necessary information for monitoring and managing the grid while helping consumers.

In the past decade, the "smart" energy system has gradually become a common part of the energy sector, and the RENERGI programme has helped to develop the expertise required for future energy systems. This is the research area that has expanded the most dramatically under the RENERGI programme, and by its conclusion roughly NOK 140 million has been allocated to this field. This growth is based on an understanding of the challenges that the future energy system must deal with and the competencies that will be required. The Norwegian energy industry and related supplier industry have participated in these research activities, providing many players with insight into the kinds of development and challenges to expect.

Parallel to developing technical solutions, it is important to facilitate the development of market and regulation mechanisms that make it possible to implement emerging technologies. A broad assortment of social science-based research projects have been carried out to enhance knowledge about the relationship between future energy systems, the public authorities and consumers.

Integration with North Sea neighbours

In the Balance Management project, begun in 2007, SINTEF Energy Research collaborated with other stakeholders in Norway, the Netherlands and Belgium to develop designs for technology and a market model that exploit existing synergies between North Sea countries. By identifying the marginal costs for regulating European heating production and consumption, the project examined the possibilities of supplying Norwegian hydropower as a balancing resource, which would allow for the phasing in of additional intermittent renewable energy in Europe.


Photo: Statkraft


Photo: Conergy

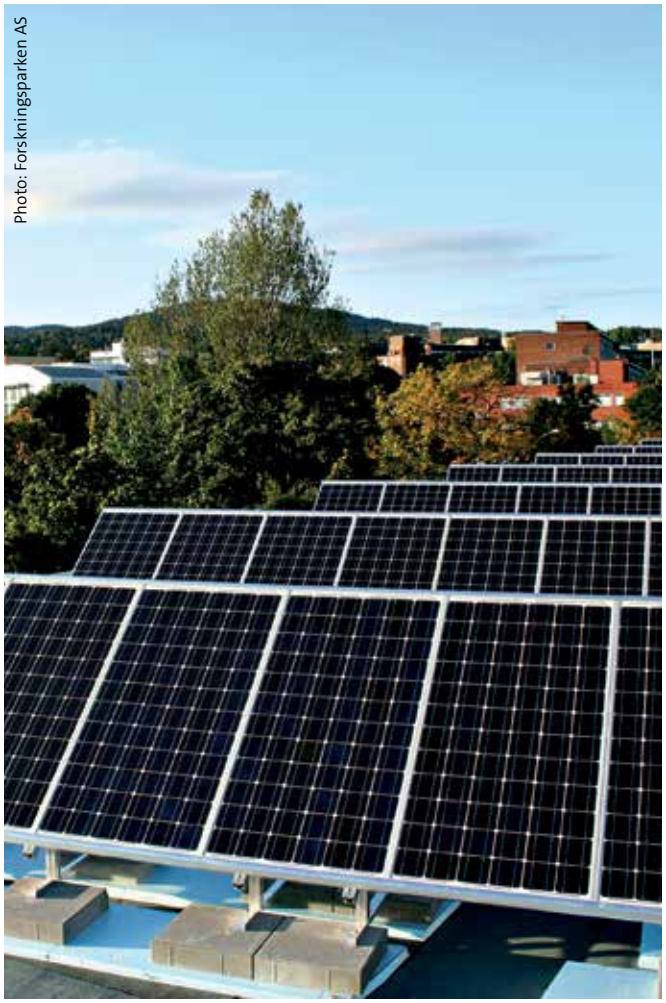


Photo: Forskningsparken AS


Photo: Småkraft as

2.2 Transport and energy – increased collaboration

At the outset, the RENERGI programme primarily targeted the stationary energy supply. In 2004, the Norwegian Hydrogen Committee submitted the Official Norwegian Report 2004: 11 identifying hydrogen as a future energy carrier with potential applications in both the stationary and transport sectors. The committee was appointed in collaboration between the Ministry of Petroleum and Energy and the Ministry of Transport and Communications, and the recommendations in the report were incorporated into a joint strategy drawn up by the ministries. The Ministry of Transport and Communications acted on the report's recommendations by moving its activities related to environment-friendly transport technology to the RENERGI programme. Hydrogen was to be the starting point, but the ministry and the programme also planned to intensify R&D activity involving biofuels. The clear synergies between hydrogen and biofuels, and the fact that the two are closely integrated in terms of technology for stationary energy supply, formed the starting point for close cooperation between the Ministry of Transport and Communications and the RENERGI programme. This also marked the beginning of what became a large portfolio of projects in the area of energy for transport. Initially, the Norwegian Hydrogen Highway project (HyNor) was a key component of the portfolio and knowledge development. Later, more projects on hydrogen and biofuels were started up. The ministry established the agency Transnova, under which the most market-oriented R&D activities were incorporated, while the RENERGI programme focused more on basic research.

Integrating this kind of transport-related project with the stationary energy portfolio has been productive; research groups have been developing new knowledge and solutions in both areas. In 2008 the programme was expanded to cover research on electric vehicles, and in the past few years the use of electric vehicles in Norway has risen sharply. In September 2012 there were 8 600 electric vehicles in use in Norway, with over 3 500 charging stations – evidence that the R&D efforts were well timed and made a significant impact.

Both the broad-based political agreement on climate policy achieved in 2008 and the white paper on Norwegian climate policy reflect the importance of these efforts, and indicate that a considerable portion of Norway's reductions in CO_2 emissions must come from the transport sector. User knowledge combined with research to find workable system solutions are essential for ensuring further growth in the use of electric vehicles.

The Norwegian Hydrogen Highway (HyNor)

The HyNor project was a trailblazing project to enhance knowledge about, and gain experience with, the use of hydrogen in the transport sector through specifically targeted projects and broad cooperation between many stakeholders: industry players, the research community and the public authorities. Through a geographically widespread series of nodes, the HyNor project generated valuable knowledge – as well as international interest. Even though some of the major industry players have since changed course, the knowledge and experience gained is being further developed by other players and research groups. This knowledge formed part of the basis for Oslo's current involvement in the EU's prestigious Clean Hydrogen in European Cities Project (CHIC) on demonstrating hydrogen-powered bus fleets.

The focus on hydrogen will continue in the years ahead. The solution will not solely depend on either biofuels, hydrogen or electric vehicles – these are all technologies that must be refined and utilised in parallel if Norway is to address the entire scope of future transport needs while minimising its CO_2 emissions

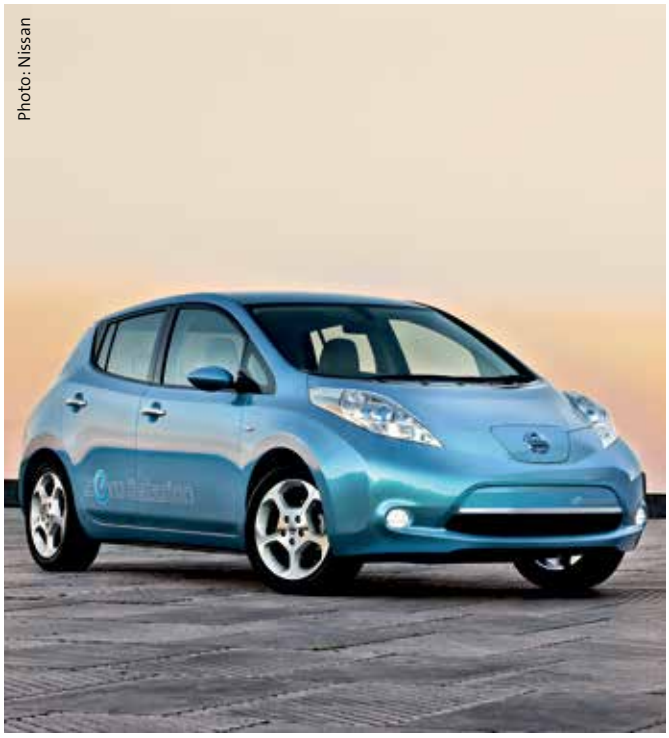


Photo: Nissan

Photo: Shutterstock

Photo: HyNor

A hydrogen filling station for Oslo buses.

2.3 Technology and social science – knowledge for formulating policy

In the 1990s Norway had organised its energy-related social science research activities under separate programmes. In launching the RENERGI programme, the Research Council and the Ministry of Petroleum and Energy recognised and addressed the need to tie this type of research more closely to energy research within technical fields and the natural sciences.

Research-based knowledge that is later included in reports often forms an integral part of the basis for political decisions in the energy sphere. When considering commitments such as entering new energy markets, investing heavily in technology development, and cooperating on international agreements on energy, climate and the environment, Norwegian decision-makers need more information about the ramifications for the national economy and society at large. Instruments to raise energy efficiency and agreements on participating in the emissions trading system have been important focus areas for social science-related research under the RENERGI programme, with the aim of achieving targets for a higher proportion of renewable energy.

The Norwegian energy system faces a different set of challenges compared to most countries in the EU and the Nordic countries. No other country in Europe has: over 60 % renewable energy production (not including the offshore petroleum industry); hydropower as its nearly exclusive source of electricity production; and, potential resources from river systems yet to be regulated. When taking decisions regarding new instruments and hydropower regulation schemes for the future energy system, it is critical to assess their impact on Norway's energy flexibility, its ability to manage peak loads, and the functioning of the energy market in Norway and the other Nordic countries. Norway is in need of research that addresses the potential of new technologies, while assessing their environmental impacts as well as their benefit to society and trade and industry.

In response to new national and international challenges, the RENERGI programme board has systematically, throughout the programme period, strengthened the project portfolio in energy policy, energy markets and interdisciplinary technology studies. In 2004 the portfolio for social science-related energy research totalled NOK 12 million. By the end of the programme in 2012 it had grown to encompass more than 35 projects with allocations totalling NOK 55 million. Research activities in this field are generating knowledge and providing highly trained specialists who are utilised by a wide range of stakeholders. In order to further increase the relevance of such research while maintaining its high international standard, three FME Centres for Social Science-related Energy Research (FME Samfunn) were launched during the RENERGI programme period.

The public authorities depend on this knowledge when formulating national policy for the energy sector. Knowledge is equally important to energy companies, consultancy firms and industry organisations when working on measures such as raising energy efficiency, green certificates markets, climate-friendly transport and the development of regulation mechanisms.

Climate Change Altering Nordic Energy Systems (CANES) at the Fridtjof Nansen Institute

The project has analysed key areas of EU policy such as:

- Climate gas emissions trading system
- Renewable energy
- The market for raising energy efficiency and regulations relating to state subsidy

What is the significance of these policy areas for Norwegian players and Norwegian-Swedish cooperation? One general insight gleaned from the project is that the development of European climate and energy policy is characterised by two questions:

- How much proportionate influence should the EU have compared to national policy?
- Should climate and energy policy be based on market instruments or choice of technology?

There has been extensive disagreement, and at times the differences between stakeholders have been irreconcilable. As a result, the EU's climate and energy policy consists of a complex mix of instruments, making the need for knowledge about the ramifications of such policy greater than ever. Knowledge about European policy development will give national actors greater influence.

Heads of state gathered at the UN Climate Change Conference in Copenhagen in 2009.

Norwegian Parliament – Stortinget.

2.4 Offshore wind power

Photo: Owec Tower

The foundation for an offshore wind turbine.

In the 1990s Denmark and Germany each established a strong industry in wind power, encouraged by effective support schemes. Other countries also chose to invest in wind power, but growth in Norway was very limited.

Ambitious players in research and industry circles then began to pursue wind power with funding from the RENERGI programme. Norway had the advantage of experience in the maritime sector and offshore petroleum industry, and offshore wind power emerged as a major field of development. When the RENERGI programme was launched in 2004, only one Norwegian player was developing technology to serve this new market.

The programme has since provided funding for the development of technologies based primarily on the experience and expertise of Norwegian players in marine operations, the maritime sector and the petroleum industry. The dominant technologies are seabed-based installations and solutions for related maritime operations, but floating solutions are also being developed. At the conclusion of the RENERGI programme, a number of players are positioning themselves to serve the market for offshore wind power – a market that is primarily located outside of Norway.

Statoil's floating wind turbine Hywind.

OWEC Tower

Founded in 2001, OWEC Tower designed a steel platform based on the jacket concept but using its own newly developed elements. The company's breakthrough came in 2005, when the energy company Talisman Energy chose OWEC Tower's foundation for the Beatrice Wind Farm Demonstrator Project. Two wind turbines were installed in 2006 on OWEC Tower foundations. The following year, the company was selected as one of two foundation suppliers (the other supplier was the Norwegian company Aker Solutions) for the alpha ventus wind farm off the coast of Germany.

Then new projects began to roll in: the Ormonde Offshore Wind Farm in England and the Thornton Bank Offshore Wind Farm off the coast of Belgium. In 2011 OWEC Tower also delivered the prototype for a land-based facility at St. Nazaire, France. In 2009 OWEC Tower received funding under the Research Council's RENERGI programme to develop calculation methods for analysing foundations for offshore wind turbines

2.5 Growth of a silicon-based solar cell industry in Norway

The sceptics were wrong when claiming that solar energy had no future in Norway's energy supply and that business development was impossible without a home market. The Norwegian solar cell industry has flourished against all odds. There are now more than a dozen companies in the Norwegian solar energy cluster, representing an entirely new industry built on expectations of a rapidly growing demand for access to environment-friendly energy.

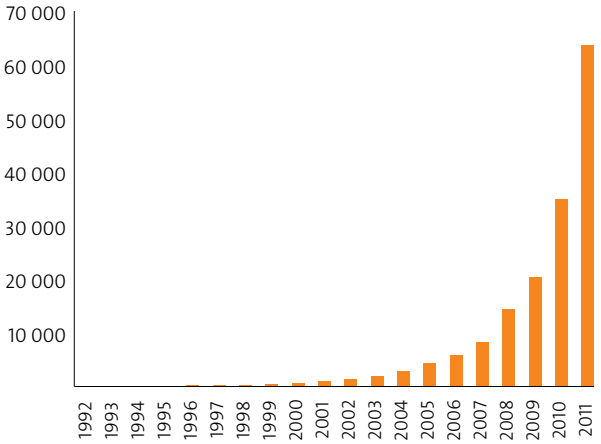
This success has built upon synergies between Norwegian cutting-edge expertise in materials and process technology, dynamic Norwegian research groups, and lengthy industrial experience with producing and refining silicon. Another vital ingredient has been local communities with a plentiful supply of energy and labour, along with a strong entrepreneurial spirit. The market consists of goal-oriented public authorities in other countries with forward-looking ambitions and the will to support this expanding technology.

The company REC was an early driving force in the growth of the Norwegian solar cell industry. Founded in 1994, REC, too, went on to become an influential leader in the international industry. In 2004 REC and Elkem Solar were two of just a handful of Norwegian companies with solar energy ambitions. In the years to follow, both companies grew on the merits of their own technologies, and with time a number of Norwegian companies emerged within the field, primarily to supply REC and Elkem Solar with services, technology and solutions. Some of the companies specialised in by-products in the value chain and began to deliver products to a wide array of Norwegian and international companies.

Solar cell production facilities are now being built on a scale never before seen, and the market is expected to grow. This coincides with a drop in the price of solar cells. In other words, targets set ten years ago have been reached, which is good news for the climate. In terms of the biggest driving force for developing solar energy – sustainable production of electricity that helps to ensure energy security and addresses climate change – this is an international success story. Regrettably, this success has caused the solar cell industry to struggle. Over the past year and a half, virtually the entire Western solar cell industry has been dealing with poor profitability, leading to temporary and permanent layoffs and production plant closures in Norway.

For certain industry players, this is a serious challenge that must be dealt with. The current situation requires companies to make the right choices ahead so that the Norwegian solar cell industry can grow and provide a footing for more green industry and environment-friendly energy production.

FIGURE 3.1 CUMULATIVE INSTALLED CAPACITY (IN MW) IN IEA MEMBER COUNTRIES



Norsun – high-efficiency solar cells

NorSun was founded in 2005. Alf Bjørseth, one of the founders, seized the opportunity to produce monochrystalline silicon wafers for the international solar cell market. NorSun wafers, which yield higher energy-conversion efficiency than multi-chrystalline silicon wafers, are in demand for applications requiring high performance, typically when space is limited, such as with solar roofing. Subsequently, NorSun does not face as much direct competition in this market segment from China as do companies producing standard solar cells based on multichrystalline silicon. NorSun has received NOK 10.5 million in funding under the RENERGI programme for the project Simultaneous Silicon Melting and Mono Ingot Solidification (SIMMIS)

Photo: fornybar.no

Photo: Shutterstock

2.6 Materials research – a source for new solutions in many areas

Along with ICT, materials technology is a fundamental generic technology for developing environment-friendly energy solutions. New materials or materials with special properties can be pivotal to solving many challenges; accordingly, materials research has been an important part of the RENERGI programme's portfolio.

The relevance of materials research is clearly demonstrated in projects on metal hydrides for storing hydrogen in solids. In order to utilise hydrogen as a fuel for vehicles, it is necessary to work out ways to transport sufficiently large amounts of hydrogen. For this purpose, researchers using advanced composite materials have developed tanks for hydrogen compressed at 700 bar. Norwegian industry players have actively participated in this development. Metal hydrides still do not have enough storage capacity, but there is growing interest in storing electric energy in the form of hydrogen, making metal hydrides highly relevant.

Metal hydrides also have potential for use in batteries; researchers are in constant search of new materials to increase the electrical storage capacity of batteries. Materials expertise is also valuable for better utilising the batteries already on the market. Enhanced understanding for advancing storage capacity, reducing degradation and improving safety has been a key focus of a number of projects funded under the RENERGI programme, including projects led by Norwegian battery producer Miljøbil Grenland.
Materials expertise has also played a critical role in the development of better, cheaper fuel cells with adequate product life. In this area, Norwegian researchers have contributed to major breakthroughs in the course of the RENERGI programme period.

The number of projects revolving around materials technology has been high under both the RENERGI programme and the programme on Nanotechnology and New Materials (NANOMAT), which has been important partner in this area.

Nordic Power Systems: more-efficient fuel cells for auxiliary power units (APUs)

Fuel cells are a valuable application area for materials technology. The company Nordic Power Systems (NPS), collaborating with the California Institute of Technology, has developed a solid acid fuel cell that can use diesel fuel as an energy source since it operates at higher temperatures than polymer electrolyte membrane (PEM) fuel cells. This feature gives the solid acid fuel cell major potential as an APU for lorries, boats and more.

Hotter operating temperatures make this fuel cell less sensitive to fuel impurities. Studies have shown that the fuel cell tolerates up to 10 % CO, so it can use energy sources that are less refined.

Tests show that the solid acid system has output equal to a PEM fuel cell, and a 1.2-kW unit can run on diesel fuel.
NPS has collaborated closely with US and German technology partners.

Collaboration has begun with the German partner on the final design of an industrial fuel cell as a component in improved power generators for use in vehicles and other applications. The project has received funding totalling NOK 5.9 million under the RENERGI programme.

Photo: NorSun

Photo: IFE, Kjeller

Photo: Prototech AS

Materials research is conducted at the Institute for Energy Technology (IFE) in Kjeller, Norway.

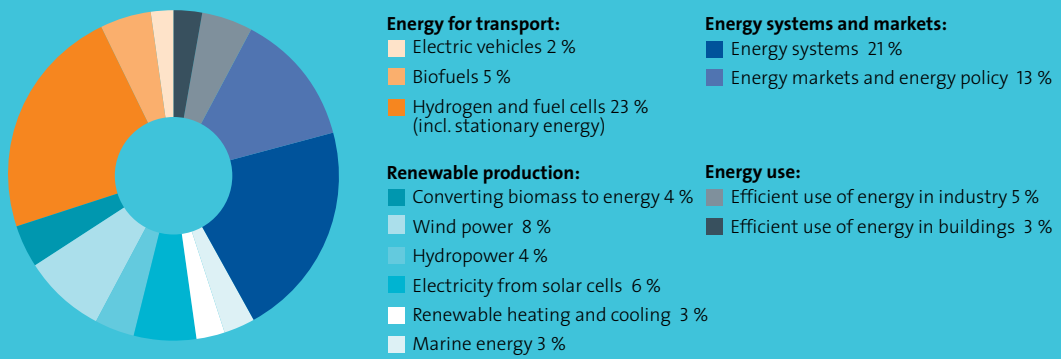
KEY ACTIVITIES

3

The RENERGI programme encompasses a very wide range of activities, with a project portfolio that reflects the challenges of developing a sustainable Norwegian and international energy system. Research under the programme has been organised into thematic priority areas. This final report presents the sub-areas of these priority areas together so that related research topics can be viewed in context with one another.

This chapter takes a closer look at the programme's 13 thematic sub-areas, describing their major activities and the players involved. The descriptions are not exhaustive but provide an overview of the challenges in each area and the programme's related activities. Descriptions of each technology area follow the same structure: global context, portfolio, key research players, and key results.

FIGURE 3.1 SHARE OF RENERGI ALLOCATIONS, 2005–2011



ENERGY USE

3.1 Efficient energy use in buildings

Photo: Morten Brakestad

Raising energy efficiency on the political agenda

Energy use and raising energy efficiency in buildings has not traditionally been a subject of major political ambition or targets. In the period 1990–1998, however, electricity consumption in Norway increased by 8.4 % per capita. This increase, combined with a standstill in hydropower development, put energy use in buildings on the political agenda. At the same time, climate awareness rose substantially in Norway and internationally.

In Report No. 29 (1998–1999) to the Storting on energy policy, national targets were set to significantly curtail energy use in buildings and to use 4 TWh of district heating more per year from new, renewable energy sources, heat pumps and waste heat by 2010. In 2001 the Storting established Enova, a state-owned enterprise, to promote the transition to environment-friendly energy production and consumption in Norway.


Photo: Morten Brakestad

When the RENERGI programme was launched in 2004 its project portfolio on energy use in buildings was relatively small and mostly technology-driven. In terms of topics, a number of projects focused on individual technical components in buildings. As the need for putting these new technological solutions into a larger context became apparent, projects were established to study their practical implementation. More attention was placed on end-users, particularly the ways in which their comfort and behaviour would be affected by changes in energy use.

Increased focus on energy use

The RENERGI programme has sought to increase the proportion of funding allocated to projects on energy use in buildings throughout the entire programme period. This has been difficult at times due to the low number of relevant grant applications submitted, but the situation improved after the establishment of the first Centres for Environment-friendly Energy Research (FME) in 2009, particularly the Research Centre on Zero Emission Buildings (ZEB), which is administered jointly by the Norwegian University of Science and Technology (NTNU) and SINTEF Building and Infrastructure. The FME scheme triggered an increase in industry activity in this area, which led to a greater number of high-quality grant applications in response to the programme's funding announcements. Projects tended to be larger-scale, and the portfolio for energy use in buildings comprised a steadily greater proportion of the overall portfolio. In the period 2007–2012 allocations to the area of energy use in buildings rose by roughly 50 %.

An ongoing challenge for the RENERGI programme has been to mobilise industry players. The construction industry is fragmented, with little focus on R&D. When establishing ZEB, the centre's management successfully engaged major players, which has led an even greater number of actors to see the value of investment in R&D activities. Towards the end of the programme period, energy use in buildings also became an issue of higher political priority. The topic has been raised in both the Government's recent energy report and the white paper on Norwegian climate policy. Report No. 28 (2011–2012) to the Storting on construction policy: *Good buildings for a better society* is the first of its kind and establishes specific guidelines for energy requirements for future buildings in addition to emphasising the importance of R&D and expertise. The white paper strengthens energy requirements to passive house standards in 2015 and nearly zero-energy standards in 2020. Research results from the RENERGI programme have helped to make these ambitious measures possible.

Competitive players with specialised expertise

The Norwegian University of Science and Technology (NTNU), SINTEF Energy Research and SINTEF Building and Infrastructure make up Norway's key research players in the field of energy use in buildings.

SINTEF Energy Research has earned recognition for its expertise in heat pump technology and various ventilation challenges. SINTEF Building and Infrastructure has been a partner in projects dealing with insulation, facades, window technology and rehabilitation solutions. NTNU has a great deal of experience with more interdisciplinary research activities involving architecture, the social sciences and technology. In addition, Norway's National Institute for Consumer Research (SIFO) has studied consumer-related aspects of energy use. The RENERGI programme has consistently sought to involve more players in research collaboration.

Awareness about R&D and innovation

Results generated under the RENERGI programme in the field of energy use have reflected growing awareness and new areas of prioritisation. Once a field afforded little attention, efforts to raise energy efficiency in buildings have now become an important target for decision-makers, with today's priorities being focused on end-users. This in turn has quickened the pace of innovation in the market.

Aided by the establishment of Enova and its support for environment-friendly energy sources, the use of heat pumps and district heating has been skyrocketing since 2004. Increased competence and R&D activity have been critical to growth in this area.

There has been significant growth in the awareness about R&D and innovation as two prime factors for value creation in this field. R&D and innovation have been essential for new developments such as passive housing and low-energy buildings, in addition to sound processes for raising energy efficiency in existing buildings. As a result, far more players currently take part in research collaboration in this area than when the RENERGI programme was launched.

ENERGY USE

3.2 Efficient energy use in industry

Photo: Sverre Jarild

Energy prices change industry

Of all the stationary energy consumed in Norway, land-based industry accounts for roughly one-third (80 TWh). Industrial energy consumption has remained fairly stable since the 1990s, while industrial production has increased. Nevertheless, there is still substantial potential for raising energy efficiency. In 2009 Enova estimated a potential savings of 12 TWh. The costs involved in comprehensive energy efficiency measures are high, and industry has balked at making such investments – although investments could lay the foundation for increased value creation and product quality as well as jobs. Furthermore, industry had traditionally enjoyed agreements with low power prices. For these reasons there were only a few, relatively small-scale projects on raising energy efficiency in industry under the RENERGI programme in its early years.

During the programme period, energy-intensive Norwegian industries experienced more and more energy price hikes; subsequently, energy began to comprise an increasing proportion of total production costs. Meanwhile, the terms for entering into long-term power agreements have changed, and a number of agreements are due to expire in the near future.


Photo: Hydro

These developments have motivated key industry players to focus more on the energy used in their own processes. Launched in 2009 as the largest project in the history of the RENERGI programme, the "Competence Project for Reduced Energy Use Through Advanced Technology InnoVations" (CREATIV) focused mainly on efficient heating and cooling processes and utilising waste heat. In one leap, the RENERGI portfolio for raising energy efficiency in industry expanded from a few small-scale projects for developing individual-component technology to multiple, much larger-scale, system-wide projects.

Complex, comprehensive projects

Under the programme, projects were launched targeting both industry-specific as well as pan-industrial challenges – projects addressing far more complex and comprehensive research questions to a far greater extent than previously. A key research topic has been efficient heating and cooling processes and utilisation of waste heat. The energy-intensive portion of Norwegian industry has demonstrated an impressive ability to mobilise R&D activities. The ferro-alloy and aluminium industries are now working on projects to raise the energy efficiency of their processes.

In June 2011 the Energi21 board presented Norway's National Strategy for Research, Development, Demonstration and Commercialisation of New Energy Technology. The ambitions in the strategy, chiselled out on behalf of industry, aim to reduce specific energy consumption while utilising more surplus heat in all land-based industry. Additionally, low-grade heat is to be better utilised for heating and for producing electricity. These aims were reflected in the RENERGI programme's funding announcements in the latter part of the programme period. Funding was also made available for projects targeted towards raising the efficiency of existing industrial processes by using optimal control systems, among other things.

Wide range of players

SSINTEF Energy Research and the Institute for Energy Technology (IFE) are key players when it comes to efficient technologies for heating and cooling, and for utilising surplus heat. They have carried out activities in collaboration with several relevant industry players such as the Norwegian Seafood Federation Service Office, REMA1000, Nortura, Norske Skog and Hydro Aluminium. The Norwegian start-up Single Phase Power is also very active in R&D on these technologies.

SINTEF Materials and Chemistry has been involved in several projects targeting the ferro-alloy and aluminium industries, in collaboration with Hydro Aluminium, the ferro-alloy research association *Ferrolegeringens Forskningsforening* and others. The company Goodtech Recovery Technology has been involved in research on waste heat utilisation in the aluminium industry.

Results of global importance

Raising energy efficiency in industry has a positive impact on value creation, competitiveness and job creation. Globalisation as well as shifts in Norwegian industry have led to major changes in framework conditions in connection with raising energy efficiency in industry, which has been particularly important for the energy-intensive aluminium industry. Research activities in this field have helped to make Norway's aluminium industry one of the world's most energy-friendly. Thanks to Norwegian hydropower, CO_2 emissions per tonne of Norwegian aluminium are a mere 10 % of those from smelteries powered by coal-fired power plants. The industry is working hard on boosting the energy efficiency of its processes to further reduce these emissions while also cutting its energy costs.

Another field in which great strides have been made in energy efficiency under the RENERGI programme is heat pump technology for refrigeration in the food industry. In this world of ever-greater distances between food production sites and population centres – not to mention more mouths to feed – these contributions towards energy-efficient refrigeration/preservation of food are very important.

ENERGY SYSTEMS AND MARKETS

3.3 Energy markets and energy policy

Photo: Shutterstock

Norwegian Stock Exchange – Oslo Børs.

Research on energy policy and energy markets is critical

Research-based knowledge on societal, economic and energy policy-related conditions that is later included in reports often forms an integral part of the basis for political decisions in the energy sphere. Prior to the RENERGI programme, social science-related energy research was organised in separate programmes with fairly small budgets. Once this research was integrated with technological research under a large-scale strategic programme, however, greater ambitions could be realised. Allocations to research projects within the thematic priority area "Energy markets and energy policy" under the RENERGI programme increased from NOK 12 million in 2004 to NOK 25 million in 2007 and then to roughly NOK 40 million in 2012. Including interdisciplinary projects, the funding awarded amounted to roughly NOK 55 million.

The RENERGI portfolio has been dominated by researcher projects throughout the programme period, as priority was given to basic knowledge-building in the field as well as the need for research on issues requiring independence from special interests. In the wake of the 2008 climate policy agreement, allocations to the RENERGI programme increased, and the programme board chose to place greater focus on research of relevance to players in the public and private sectors by funding a larger number of knowledge-building projects and similarly requiring user involvement in researcher projects.

New emphasis

In order to address the national and global challenges relating to energy, the environment and climate, greater priority needed to be placed on social science-related energy research.

Politicians, the public administration, trade and industry, and the general public all need more knowledge about the population's energy consumption habits and the energy market as well as public instruments to promote the development of renewable energy technology, raising energy efficiency and low-carbon transport. Research results generated under the RENERGI programme have revealed that the greatest limiting factor is not the availability of renewable energy, but rather the necessary restructuring of society towards more climate-friendly energy production and consumption.

In the initial work programme for the RENERGI programme, the main research focus was on energy markets. The aim was to develop Norwegian expertise in market schemes and regulatory mechanisms as a basis for further development of the Norwegian energy market, and to build knowledge that could provide a foundation for internationalising the energy markets for closer market integration with Europe. The bulk of this research was of a socio-economic nature. In 2007 the RENERGI programme board decided to shift priorities, based on an analysis of the role of the social sciences in the programme and the industry's and public administration's desired use of the research. The analysis was carried out in cooperation with relevant scientific communities and users. Its conclusions were threefold: 1) the social sciences should be given greater focus under the programme, 2) research on energy markets should be continued while opening up for research on other important topics, and 3) social science-related research should not only be carried out within the thematic priority area of energy markets but should also be integrated into the programme's other thematic priority areas such as renewable energy production, energy systems, energy use, etc. The growth in the programme budget from 2008 enabled the programme board to implement this reorientation. Towards the end of the programme period, research focused on an array of topics: energy markets, public policy and instruments for renewable energy and energy use, technology analysis, innovation and diffusion, and international climate and environmental agreements. In order to further increase the relevance of this research while maintaining its high international standard, three FME Centres for Social Science-related Energy Research (FME Samfunn) were established during the RENERGI programme period.

Broad-based support from the research community

A variety of research players have carried out research activities in the course of the programme. Among the major contributing institutions are the research department of Statistics Norway, the Frisch Centre at the University of Oslo, the Fridtjof Nansen Institute, the Center for International Climate and Environmental Research – Oslo (CICERO), and the Department of Industrial Economics and Technology Management and Department of Interdisciplinary Studies of Culture at NTNU. Other key research groups include the University of Oslo's Department of Economics, the Institute for Energy Technology, SINTEF Energy Research, the Norwegian University of Life Sciences (UMB), the Institute for Research in Economics and Business Administration in Bergen, the University of Oslo's Centre for Technology, Innovation and Culture, the Industrial Ecology Programme at NTNU, and SINTEF Technology and Society.

Research partners range from the public administration to industry players. Public sector project participants include the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Climate and Pollution Agency, and Enova. From industry, a number of companies have taken part in projects, including Agder Energi, SAE Vind, Hydro Aluminium, energy utility company Nord-Trøndelag Energiverk, BKK, Hafslund, Statkraft, Statnett, and Energy Norway.

Better equipped nationally and internationally

Research in this field generates knowledge and produces specialists for a wide array of stakeholders in society. The public authorities have depended on this kind of knowledge when designating national policy for the energy sector. Knowledge is equally important to energy companies, consultancy firms and industry organisations when working on measures such as raising energy efficiency, green certificates markets, climate-friendly transport and the development of regulatory regimes for energy companies.

To illustrate this point, the committee that prepared the Climate Cure 2020 report "Measures and instruments for achieving Norwegian climate targets by 2020" drew extensively upon the expertise at research institutions. For example, the research department of Statistics Norway was represented on the committee and contributed macroeconomic modelling calculations. Similarly, the preparation of the 2006 report by the Norwegian Commission on Low Emissions involved the use of models developed by the Institute for Energy Technology to analyse measures for cutting Norway's overall CO_2 emissions. This kind of model can also be a tool for calculating energy production in Norway.

By boosting knowledge development, the RENERGI programme has strengthened the country's research groups so that Norway is better equipped to participate actively in international fora for addressing climate and energy challenges.

ENERGY SYSTEMS AND MARKETS

3.4 Energy systems

Smart grids and balancing services

The European Strategic Energy Technology Plan (SET Plan), which targets a 20 % increase in the use of renewable energy and a 20 % improvement in energy efficiency by 2020, is leading to a transformation of the European energy system. The future will require a "smart grid" – a power grid that can accept energy from renewable sources and incorporate efficient new consumption patterns. Much of the knowledge needed is gradually becoming available, yet a substantial effort will be required before large-scale implementation can occur. In recent years the SET Plan initiative for power grids has been organising a collective EU-wide effort to fill the gaps in expertise and learn from the experience of local demonstration projects. These developments have also had an important influence on the RENERGI programme's priority-setting within the area of energy systems. The Energi21 RD&D strategy has identified balancing services for the energy system and smart grids as two of its six priority focus areas.

Norwegian suppliers of components and systems are advanced in key areas such as high-voltage cables and transformers, and R&D players have a high level of expertise in energy markets, grid analysis, and grid operations and management. The Norwegian grid owners, however, have lacked incentives for innovation and development. The RENERGI programme has assisted in efforts to improve the framework conditions for R&D in monopoly-regulated grid activities. In spring 2012 the Norwegian Water Resources and Energy Directorate (NVE) circulated a document for review on changes in Norwegian grid regulations which, if implemented, would make the framework conditions more attractive.

Need for system expertise – portfolio developments

In the early years of the RENERGI programme, research targeting energy systems was concentrated on a few priority topics, and projects tended to focus on solving specific problems. Over time the programme portfolio was developed in a direction in which projects were viewed in an overall context, and together represented efforts to generate the knowledge and solutions sought to resolve the challenges that are emerging. The programme board has directed the portfolio towards five areas: the environment, offshore grids, smart grids, grid management and system components, and framework conditions and market solutions.

Segments of the portfolio have targeted new system solutions that yield higher capacity yet minimise both environmental impact and conflicts between stakeholders concerning production and transmission systems. Offshore grids have also become more relevant. There has been much activity related to knowledge-building and innovation involving high-voltage cables. Smart grids have been given high priority across the board, which is reflected in the portfolio. Likewise, the increasing interest in balancing services has led to projects on framework conditions and market solutions, transformers, switchgear and controlgear.

Vulnerable research groups

Norwegian expertise in energy systems has been strengthened, and players such as SINTEF, NTNU, NCE Halden, the University of Oslo and the University of Bergen now hold a high international standard. Their standing in certain areas, however, is at risk due to low recruitment and significantly higher funding in other countries.

A number of Norwegian companies have demonstrated an impressive facility for innovation involving energy systems, including Doble TransiNor, Eltek Valere, NEXANS, ABB, Magtech, SmartMotor and Wärtsila Norway. In addition, Statnett has been a key driver of R&D, particularly on markets and transmission, and Energy Norway has been active on behalf of its members. Although innovation by grid owners has been declining since the deregulation of 1991, it has revived somewhat as a result of interest in balancing power and smart grids.

Leaders in transmission technology

The energy system is international, so international cooperation has been essential for achieving positive results. Growing international participation under the RENERGI programme has also led to greater demand for Norwegian expertise. The programme has helped SINTEF Energy Research to emerge as a leading European research institution, particularly in transmission, with key roles in several EU-funded projects. Statnett and ABB have achieved valuable results when it comes to improved control of transmission systems. Furthermore, a number of projects have contributed to the development of a coordinated Nordic power system and toward the vision of Norway's drawing on its hydropower resources to become a "green battery" for Europe.

Key results (in all five areas)

During the programme period, new system solutions have been developed to yield higher capacity while minimising environmental impact and conflicts between stakeholders concerning both production and transmission. Environmentally adapted design of hydropower and power grids has played an important role in these solutions.

Knowledge and new technology have been developed for offshore grids, involving the production, installation, operation and maintenance of subsea DC transmission systems. Principles have also been established for designing a future Northern European transmission grid providing Europe with greater access to environment-friendly energy.

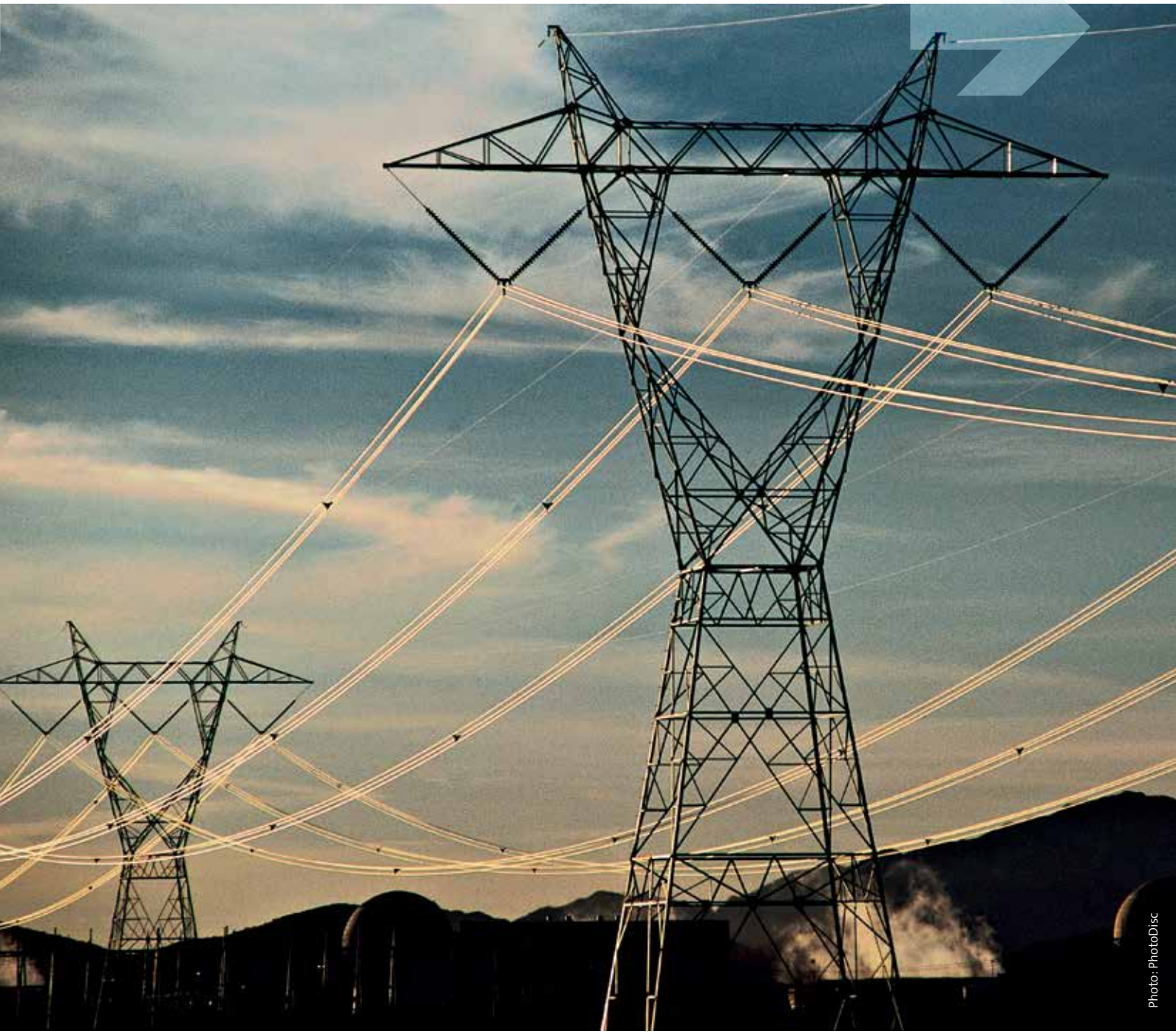


Photo: PhotoDisc

In the area of smart grids, principles for the optimal design of an interactive energy system have been established. New planning tools and new technology for grid control and protection have been developed, as well as for control of consumer appliances and coordination with district heating and gas. Expertise in smart meters has been gained, including an experience base for rolling them out in Norway. Research has provided enhanced knowledge about framework conditions and market solutions that can facilitate adequate access to balance power for unregulated renewable energy, as well as system solutions that support customers as both consumers and producers of energy.

In the area of grid management and system components, new expertise has been developed for ensuring supply quality and cost-effectiveness in an older, smarter, more heavily strained power grid. This expertise has been commercialised to some extent, and the Norwegian supplier industry has received funding for projects to improve generators, transformers, switchgear and controlgear.

RENEWABLE ENERGY PRODUCTION

3.5 Electricity from solar cells


Photo: Shutterstock


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Photo: Shutterstock

Photo: Shutterstock

Growth and consolidation

Under the RENERGI programme there has been a surge of research on solar energy and electricity from photovoltaic (solar) cells. Solar cells have become better and cheaper, which when combined with international funding schemes has led to dramatic growth exceeding all expectations. Electricity from solar cells is now competitively priced in many markets, even without subsidies, and this form of energy production is beginning to gain global significance. Prices have been driven down as a result of the increasing volume of solar electricity being produced, making profitability challenging for many solar players. The growth and subsequent price drop mean that many of the Western players are facing a demanding situation – and the next phase of this industry is expected to be one of consolidations.

Solar chain expands

The initial portfolio of the RENERGI programme contained little solar-related research. In 2004, for instance, there were only three solar projects, none of them originating in companies. Until 2008 there were only a few Norwegian companies in the solar field, then gradually, awareness began to grow and activities at research institutions increased. During this period, the RENERGI programme was similarly mobilising, and by 2007 the portfolio had grown to 10 projects involving four companies. In addition, the value chain for solar cells began to expand. An emerging Norwegian supplier industry entered the field. Spurred on by the broad-based political agreement on climate policy as well as the Energi21 strategy, solar research activities grew; larger projects were being launched and applicants were better equipped to carry them out. In the autumn calls for proposals in 2010 the Research Council received nine grant applications – from nine different companies. The programme's 2010 solar portfolio totalled NOK 25 million.

Dynamic players

The Norwegian companies REC and Elkem Solar have played key roles in developing knowledge and industrial activities in the field of electricity from solar cells. REC, by virtue of its size, has generated much activity for subcontractors and suppliers of specialised services. Entrepreneurs affiliated with REC have founded several new companies in the field. Elkem Solar has been involved in targeted, long-term development activities throughout the RENERGI programme period, with a number of projects focusing on the development of a clean metallurgical process for manufacturing high-purity silicon. The principal research players that have built up expertise during the programme period are the Institute for Energy Technology (IFE), the University of Oslo, NTNU and more recently SINTEF. IFE has also developed a solar cell laboratory where several projects have received funding under the RENERGI programme.

Efficient solar cells

Higher solar cell efficiency and cost reductions per unit produced have been the guiding objectives of solar research. This has been the focus of a number of projects carried out by players in both the research community and industry targeting various links in the production chain. Research results from RENERGI-funded projects have advanced progress on both fronts: lower cost and higher efficiency. One case in point is that Elkem Solar, with its portfolio of numerous research projects, did indeed succeed in creating its patented metallurgical process for solar-grade silicon. Norway and Norwegian players have contributed their share to the collective international effort that has made (and is continuing to make) solar cells progressively better, more efficient and lower-priced.

RENEWABLE ENERGY PRODUCTION

3.6 Wind power

Photo: OWEC Tower

Emerging political interest in offshore wind power

The development of Norway's first wind farms began in the early 1990s. The first wind turbines were erected at the beginning of 2000, and until 2005 there was major development, aided by support schemes at Enova and other sources. Then uncertainty about green electricity certificate schemes brought development to a halt for several years until large-scale wind farms were constructed starting in 2009. A common Norwegian-Swedish market for green electricity certificates was established in 2012 and much land-based wind power development is expected in the coming years.

Interest in offshore wind power began to take root in 2004 and Norway began considering floating wind turbines. In 2005 the RENERGI programme granted funding to the company Sway to develop its floating wind turbine concept. That same year Hydro tested its Hywind concept in a wave tank. Steady offshore winds and fewer conflicts over development were points in favour of far-offshore wind farms in Norway.

In 2007 Enova published a report estimating the potential for offshore wind energy in Norway to be 14 000 TWh. This report attracted great interest. The broad-based political agreement on climate policy achieved in the Storting in 2008 specified a large-scale increase in research allocations. An additional NOK 150 million in funding was to be set aside for a demonstration programme to develop offshore wind turbines and other immature energy technologies. Later reports concluded that seabed-based offshore wind would be more

Photo: Statkraft

costly in Norway than in other North Sea countries and that priority should be given to floating wind power.

Turbine prototypes

The RENERGI portfolio for wind power was initially very small, but during the programme period it has expanded in scope and there has been a substantial shift in research topics.

In its early days the programme mainly addressed land-based wind power and knowledge-building for developers. Most grant applications dealt with resource mapping, environmental and societal impact reports, and public acceptance of solutions.

Over time, more emphasis was placed on suppliers for production of turbines. In 2005 the first projects involving floating wind power concepts emerged, attracting considerable attention to offshore wind – a field on which the RENERGI programme board chose to place high priority.

The establishment in 2009 of two Centres for Environment-friendly Energy Research (FME) dedicated to offshore wind power ensured effective knowledge-building in this field. Furthermore, in the final years of the RENERGI programme period, the Ministry of Petroleum and Energy earmarked funding to step up the level of activity on offshore wind projects in phases between prototype and demonstration. Collaborative thinking across subject fields has led to unique solutions such as energy from the rotor being transferred hydraulically to a gearless generator on the ground. This lightens the top section of the wind turbine, allows for a slimmer tower and eases maintenance. The idea originated in 2006 at the company ChapDrive, which now has some 20 employees and has completed a hydraulic solution for a 5-MW turbine.

Major players in research and industry

SINTEF, NTNU and IFE have a long history of collaboration on R&D in the field of wind power; together they established the Norwegian Research Centre for Offshore Wind Technology (NOWITECH), an FME centre. The technology research institute Christian Michelsen Research (CMR), Uni Research, the University of Bergen, the University of Agder and the University of Stavanger have been working on related research areas and joined forces to establish the other FME centre for wind power, the Norwegian Centre for Offshore Wind Energy (NORCOWE). Collaboration between these two FME centres has grown in subsequent years, including through the Norwegian Offshore Wind Energy Research Infrastructure (NOWERI) initiative.

Norwegian energy companies such as Lyse, Nord-Trøndelag Elektrisitetsverk (NTE), Statkraft, Statnett, Agder Energi, Statoil and Vestavind Offshore are heading or participating in R&D projects as part of their development activity. Established players such as Aker Solutions, DNV, Fugro OCEANOR, Aibel and Nexans are using their experience and expertise to enter the wind power market. Newer players such as SmartMotor, Fedem Technology, StormGeo, Origo Solutions, OWEC Tower, Sway, Kjeller Vindteknikk, ChapDrive, Blaaster Wind Technologies, NorWind and STRAUM are all conducting R&D to establish themselves as suppliers to the wind energy industry.

Key results

During the RENERGI programme period, Norway has become a world leader in floating wind turbine installations. In 2005 Sway launched its innovation project to develop a floating wind power concept. Hydro (which later became Statoil) announced its Hywind project that same year. These, along with SINTEF's knowledge-building project "Deep sea offshore wind turbine technology" in 2007, marked the beginning of extensive activity targeting offshore wind power.

In the period 2009–2011 many suppliers to the offshore wind power industry received funding for their technologies, which has led to an array of products for sensing, wind resource mapping, foundations, installation, turbines and turbine components, and solutions for operations and maintenance. Currently there is a great deal of activity among Norway's potential suppliers to the industry in areas such as foundations, installation, operations and maintenance.

RENEWABLE ENERGY PRODUCTION

3.7 Hydropower

Photo: Shutterstock

World-class Norwegian hydropower expertise attracting international assignments

Norway has amassed so much know-how from developing hydropower at home that it is now a supplier of hydropower expertise internationally. Production of electromechanical equipment and turbines was established early in Norway, and both production and the final products were of high international calibre. Norway also has lengthy experience in building dams and waterways. The period 1960–1985 was the peak of hydropower development in Norway. For many years after that, hydropower was expanded very little, but in recent years activity has increased again, particularly for small-scale power plants.

Over the past decades the energy industry has been undergoing a major reorganisation process focused on operations, finances and restructuring. Low energy prices meant little incentive to develop hydropower within Norway, which in turn resulted in equipment suppliers such as NEBB and Asea (both merged into ABB) and Kvaerner scaling back their activities in Norway. Once new hydropower development stalled at home, much of the Norwegian expertise was maintained through projects abroad; several Norwegian consultancy firms have been quite active internationally.

Preserving and building expertise in hydropower

Energy prices have spiked in periods, increasing interest in new hydropower development projects and in optimising existing power plants. Previously the main concern was to ensure that Norway had a stable, reliable energy supply. Europe has a huge need for more energy, particularly during intervals of low wind-power production due to calm spells. This gives Norway an opportunity to revitalise its hydropower industry as an energy source to supplement Europe's wind power and marine energy. The rising demand for energy necessitates preserving Norway's existing know-how while also developing new expertise in areas such as environmental impacts of altered operational patterns. These needs have been highlighted during the RENERGI programme period.

In the programme's early days there were many projects on rehabilitation of ageing hydropower plants and on models for accessing water for hydropower plants. Climate change has affected hydropower production and created a need for updating and improving runoff models. Higher energy prices and green certificates markets have generated interest in small-scale hydropower production in recent years. The programme has allocated funding for the development of small-scale hydropower technology as well as to projects primarily aimed at maintaining Norwegian expertise in hydropower development.

Realising Norway's ambition to supply more balancing services from its hydroelectric plants will require alterations in operational patterns, from seasonal storage to hydropeaking – so it is essential to build up new expertise in operational issues as well as in environmental challenges. Hydropeaking entails frequent variations in water flow and reservoir levels, which can cause erosion and affect flora and fauna.

The RENERGI programme has provided funding to several projects within this subject area. During the programme period, the Centre for Environmental Design of Renewable Energy (CEDREN) was

Photo: Shutterstock

established. The primary focus of most of this FME centre's projects is on environmental impacts. Changes in flow patterns necessitate higher-resolution runoff models, and short-term prognoses have become increasingly important. RENERGI-funded projects have studied these issues.

When it comes to international efforts, hydropower is unlike most of the other areas under the RENERGI programme. Hydropower has not been an EU priority area and the hydropower industry has had to form its own international networks. Norway is represented in the International Energy Agency (IEA), which has attracted increasing interest in recent years. Brazil, Finland, Japan, the US and China are the other IEA members with hydropower research activities, and additional countries participate in certain related areas. Norwegian players have invested internationally and have taken part in projects receiving development cooperation funds.

Dynamic research collaboration on hydropower

NTNU is still home to the most prominent R&D community for hydropower. The major energy companies have largely conducted their own R&D activities in cooperation with Energy Norway, a non-profit industry organisation that plays a coordinating role. Companies such as Norconsult and Multiconsult also have dynamic research groups for hydropower. When it comes to production of components, particularly for small-scale hydropower projects, a number of new players have emerged. Rainpower is currently the largest of these, with some 350 employees and activities in several countries.

A new industry and strong environmental focus

The RENERGI programme has helped to facilitate a conversion of expertise in the hydropower industry and a stronger environmental focus on hydroelectric production. In the course of the programme period a generational shift has occurred in the industry, so it has been important to preserve the knowledge developed while also building new expertise during a time of low activity. Norway unquestionably remains an international leader in high-pressure hydroelectric plants. Production models have been improved and adapted to altered operational patterns and a changing climate. New drilling technology specially adapted for small-scale hydroelectric production has been developed, and a new industry has been founded for producing turbines and components for small-scale hydropower. In the course of the programme period, substantial expertise has been acquired in the environmental impacts of altered operational patterns for hydroelectricity production.

RENEWABLE ENERGY PRODUCTION

3.8 Marine energy

Photo: ANDRITZ HYDRO Hammerfest

A tidal energy turbine.


Photo: Thomas Bickhardt/Scanpix

Varying activity on marine energy

The level of interest in marine energy has varied since the 1980s. In the early 1980s there was a great deal of R&D activity at NTNU/SINTEF and several industrial pilot and demonstration projects were launched, but these were for the most part terminated in the 1990s. Favourable support schemes have renewed interest in Denmark, Portugal and the UK since the early 2000s.

Marine energy encompasses all energy production from ocean areas except offshore wind power. International studies on the potential of marine energy are highly optimistic for Norway and internationally. Enova performed a study that estimated the potential in Norway at 600 TWh for wave power and 1 TWh for tidal energy. Both wave and tidal power have advantages over wind power, but marine energy costs nearly twice as much as wind power, so the challenge lies in cutting costs. In Norway a number of different concepts have been developed for wave, tidal and osmotic power. Enova and Innovation Norway have supported the construction of prototypes, while the RENERGI programme has provided funding for development activities within these areas.

New support schemes promote research

New marine energy support schemes have boosted research activity, but no technology that satisfactorily exploits marine energy has fully crystallised yet. Statkraft is at the international forefront in the development of osmotic power and has established a testing facility at Tofte, 50 km from Oslo.

The marine energy portfolio totalled roughly NOK 2 million in the programme's early years. In the period from 2008 to 2010, allocations rose as a result of higher quality grant proposals.


Photo: Statkraft

An osmotic power plant.

Large and small players collaborating

The Norwegian Marine Technology Research Institute (MARINTEK) is Norway's strongest R&D environment in the private sector, but a number of industry players of various sizes are also active in the field of marine energy research, including Statkraft, Hammerfest Strøm, the offshore company NLI and Fred Olsen.

The RENERGI programme has awarded funding to projects involving industry players such as Statkraft Development, WAVEenergy, FOBOX, Siv.ing. Øystein Holm, E-CO Vannkraft, Hydra Tidal Energy Technology, Langlee Wave Power, Sørkomp, the Norwegian Wind Energy Association (NORWEA) and OWC, as well as research players such as the University of Oslo's Department of Biosciences, and NTNU's Faculty of Natural Sciences and Technology.

RENEWABLE ENERGY PRODUCTION

3.9 Renewable heating and cooling

High energy prices spur R&D on renewable heating and cooling

R&D efforts in the area of renewable heating and cooling have been inconsistent since the 1973 oil crisis, with little focus on energy policy and technology. Rising energy prices, however, have highlighted the need for research in this area. The establishment of the RENERGI programme has helped to direct more focus towards Norwegian R&D expertise and networks for renewable heating and cooling. The research community in this field is still fragmented but some valuable results have been achieved.

The development of infrastructure for district heating was begun in response to political targets for energy restructuring and increased energy recovery from waste. District heating using energy sources such as waste combustion, bioenergy and large-scale heat pumps has now been extensively developed throughout the country, in keeping with Enova's objectives. Norwegian know-how in district heating has been built up around a small environment at NTNU/SINTEF. District heating grids are widely considered a valuable element of the future energy system.

Norway has high-level R&D expertise in heat pumps; the research environment at NTNU, which centred around the former Department of Refrigeration and Air Conditioning, has long been at the forefront of this area. From the 1990s this expertise was disseminated to consultants and players in the energy and construction sectors. The use of heat pumps has grown, particularly in the construction industry, largely due to high energy prices.

In 2004 there was little development of solar heating, and R&D in this field was mainly conducted by small individual players in the research community and construction industry. The RENERGI programme has contributed to increased activity on solar heating.

The 2008 political agreement on climate policy brought about a paradigm shift in innovation for renewable heating and cooling solutions. Enova was allocated more resources for market deployment, the Research Council's R&D budget grew, and Innovation Norway received higher allocations for activities relating to environmental technology. The sum effect of these measures has been positive; dynamic groups for research and industry in this field are emerging. The IEA reported in its Energy Technology Perspectives of June 2012, however, that energy use for heating and cooling remains a neglected area of energy policy and technology. For this reason the forthcoming EU Framework Programme Horizon 2020 now has a clear-cut focus area: Renewable heating and cooling.

Enhanced knowledge base

Immediately after the political agreement on climate policy was achieved, the RENERGI programme revised its work programme to include renewable heating and cooling as a thematic priority area. The Research Council prepared several state-of-the-art reviews that formed the basis for the Government's bioenergy strategy, and together with the Research Programme on Nature-based Industry (NATUROGNAERING), the RENERGI programme helped to boost activity in this field, including the award of FME status to the Bioenergy Innovation Centre (CenBio). The Research Council's bioenergy-related activities were consolidated under the RENERGI programme in 2011. Overall, the RENERGI portfolio had positive growth in the areas of bioenergy, solar heating, geothermal heating, heat pumps, district heating and heat storage. A variety of players have driven R&D activity in the various areas: research groups, developers, entrepreneurs, the public administration/authorities, the industrial sector and environmental organisations have all taken part in this work.

Bioenergy

Early in the RENERGI programme period, primary focus was on increasing energy recovery from waste, in part due to pending requirements for waste disposal. In the wake of the 2008 climate policy agreement, the primary focus of programme activities on heating and cooling was directed towards bioenergy from forest-based biomass and agricultural waste. New, large-scale projects were launched on biogas, biofuels, combined heat and power (CHP), technologies for pre-treating biomass, and space heating (burning fuelwood) with heat storage. There is ongoing research collaboration with industry players in the waste management, energy, technology and agriculture sectors. In the waste management sector, SINTEF Energy Research has taken on leading roles in EU projects. The Norwegian University of Life Sciences (UMB) and the Norwegian Institute for Agricultural and Environmental Research (Bioforsk) are the country's leading research environments for biogas.


Photo: Sverre Jarild

Solar heating
The use of solar heating in Norway is still in an early phase. The University of Oslo's Department of Physics in particular has received project funding under the RENERGI programme and has been a driving force, helping to build a comprehensive network. Participation in IEA and EU projects has been a vital component of the competence-building process. Solar heating is gaining importance as an elemental energy source in the low-energy development concept.

Geothermal heating
The 26 000 ground heat systems in use in Norway in 2010 collected a total of 2.5 TWh of heat. The development of heat storage wells has primarily been driven by developers and consultants. Norway also has a few notable pilot fields of advanced-technology storage wells; the RENERGI programme has provided funding for the development of energy centres for such well fields. The development of deeper wells is being driven by research groups, petroleum companies, energy companies and smaller drilling companies. The key research institutions are NTNU/SINTEF, the University of Bergen, Christian Michelsen Research, the University of Stavanger, the Geological Survey of Norway, and the Norwegian Geotechnical Institute.

Heat pump technology
Heat pump technology is still an important research area at SINTEF/NTNU, which was a global leader in developing heat pumps with lower emissions of aggressive greenhouse gases in the 1980s. In the early 2000s the focus was still on improving this new technology, and with support from the RENERGI programme, refinements have been made. Key targets include higher temperature levels, higher efficiency and lower emissions. Heat pumps are now being used in many new application areas, such as industrial heat recovery.

District heating infrastructure
District heating infrastructure is being constructed in 19 of Norway's 20 largest cities as well as in a number of towns and built-up areas. Although new buildings consume substantially less energy, central heating infrastructure is still considered important. There will, for instance, still be local heat sources that would be difficult to exploit without such infrastructure, and there is a need for knowledge about local heating grids. Expertise in district heating infrastructure has been acquired and implemented, especially in the past decade, through international R&D cooperation via Nordic Energy Research and the IEA.

Close collaboration between scientific and technology disciplines
The research area of heating and cooling spans a broad range. The commercial side consists of many players: entrepreneurs, small companies and large companies in the primary industries, other industries, waste management and energy. The public administration stipulates requirements for environmental and climate footprint. Research is carried out mostly at the established institutions at or near UMB and NTNU/SINTEF. There is extensive collaboration between players and, importantly, particularly close cooperation between researchers in the natural science disciplines and the technology disciplines, where sustainability is an underlying principle. It is already apparent that demand for combined heating and cooling is growing – and more and more customers are seeking more integrated solutions with multiple energy sources and technologies. There will be a more pressing need for interdisciplinary approaches and collaboration in research, as well as more interaction between industry players and the research community. Smoothly-functioning value chains will be essential.

Dramatic emissions cuts and higher efficiency
In the 1990s SINTEF and the wood-burning stove industry successfully reduced Norwegian emissions from fuelwood burning, and cooperation in the 2000s succeeded in significantly raising stove efficiency. Norwegian fuelwood burning is now sustainable and knowledge-based, and comprises an important industry in outlying districts, with a sizeable export market. The RENERGI programme has provided funding to research projects in this field.

SINTEF, collaborating with the waste management sector, has developed concepts for burning more sewage sludge and wet organic waste, substantially reducing landfill needs.

The company Cambi has collaborated with UMB, Bioforsk and the Oslo Municipality Waste-to-Energy Agency to develop new processes for more efficient, cleaner biogas production. In 2012 the agency began constructing Europe's most modern biogas facility to supply fuel for the city's buses.

RENEWABLE ENERGY PRODUCTION

3.10 Converting biomass to energy

Photo: Shutterstock

Research on raw materials and their utilisation was strengthened under the NATUROGNAERING programme in the period 2009–2011. In January 2012 this portfolio was incorporated into the RENERGI portfolio for the purpose of achieving more integrated and value chain-oriented R&D activities.

Energy restructuring, security of supply and industrial development

Before the 2008 climate policy agreement achieved in the Storting, raw materials for bioenergy mainly related to fuelwood burning and utilising wood chips, a by-product of other forest-based and industrial production. The 2007 white paper on Norwegian climate policy recommended more activity to develop bioenergy. This was followed up by the Government's bioenergy strategy, presented in April 2008, which placed particular emphasis on utilising biomass – something Norway was not doing adequately. Key elements of the strategy included aims for achieving progress on climate change through restructuring the energy system, bolstering security of supply, and promoting industrial development. Increased allocations to Enova and more support for primary production helped to boost bioenergy market development. Published in 2009, the white paper entitled *Climate Challenges – Agriculture Part of the Solution* became a guiding document for increasing activities on biogas. In June 2012, the new white paper on Norwegian climate policy reiterated the intention to boost bioenergy efforts.

Interdisciplinary approach

Following the climate policy agreement, bioenergy-related activities were divided between the NATUROGNAERING programme (which assumed responsibility for upstream activities) and the RENERGI programme (downstream activities). Under the NATUROGNAERING programme, upstream activities were a new area of focus; a new state-of-the-art report on climate challenges and bioenergy was therefore drawn up, focusing mainly on land-based resources and, subsequently, marine resources as well. Naturally, forests were a key topic. Together with the Ministry of Agriculture and Food, the Research Council helped involved players at the Campus Ås research community to establish collaboration at the Norwegian Centre for Bioenergy Research (founded and jointly owned by UMB, the Norwegian Forest and Landscape Institute, and Bioforsk). The knowledge gleaned from the state-of-the-art review and the establishment of the Norwegian


Photo: Shutterstock


Photo: Shutterstock

Centre for Bioenergy Research put Campus Ås in a strong position with a sound, up-to-date, interdisciplinary knowledge base. Campus Ås then joined forces with SINTEF/NTNU to create CenBio, which was granted status as one of the eight Norwegian Centres for Environment-friendly Energy Research (FME). The collaboration between the Research Council programmes and CenBio would become very important.

Collaboration and pooling resources

Through close cooperation between the programme, industry, the public administration and the research community, Norway has succeeded in mobilising and structuring bioenergy research activities, particularly at Campus Ås and its collaboration with SINTEF/NTNU. The largest industry players in forestry and energy initially stated great interest, but the financial crisis of 2009 slowed progress at first. Locally, there was extensive involvement, and many small players were very willing to cooperate and pool their expertise in forestry and energy use. The starting phase of marine bioenergy research was aided by optimistic collaboration between the companies Statoil and Seaweed Energy Solutions and SINTEF Fisheries and Aquaculture. The RENERGI portfolio for R&D on bioenergy was eventually grouped into four areas: the environment and climate, harvesting and production from forests, biogas, and macro- and microalgae.

The environment and climate from a forestry perspective

More utilisation of bioenergy involves extracting more biomass from forests than by conventional harvesting. Specifically, this additional extraction will comprise logging residue, residual materials from clearing and thinning, and other low-value biomass. Research to determine the ecological and environmental impacts of such harvesting will therefore be critical for ensuring the sustainability of harvesting and bioenergy production. New research activities have also been initiated to generate better knowledge and new models for assessing the overall climate impact of increased utilisation of forest-based resources.

Harvesting and production from forests

Harvesting large volumes of low-value biomass is new in Norway. New research is providing a basis for new operations planning and better logistics and pre-treatment, but much work remains. Value chains must be able to direct resources to various applications: bioheating, combined heat and power, pellets, biofuels, paper and pressboard, and new applications for wood fibre.

Macroalgae (kelp) and microalgae for biofuel

The large technical potential for macroalgal biofuels has similarly attracted interest in the many possible uses of macroalgae; several R&D projects have been launched, involving SINTEF, UMB, Seaweed Energy Solutions, Statoil and aquaculture companies. R&D activities focus on large-scale cultivation and production, and efforts are underway to enhance international research cooperation on refining the raw materials. Research on microalgae is a smaller but important area for biogas production and as input for basic research on hydrogen production.

Closer international cooperation

Forestry and related research and management bodies are essential for increasing deliveries of sustainable biomass for profitable energy production. Close cooperation with suppliers and customers is crucial. Likewise on the marine side, it is vital that the aquaculture industry is able to continue cooperating on forming value chains that supply macroalgae for profitable energy production. For biogas, the effective collaboration must continue between waste management companies, industry in general and primary industries, technology companies and Campus Ås. International collaboration needs to be fortified in all three areas. Research on climate impacts and carbon balance will also be continued under the Research Programme on Sustainable Innovation in Food and Bio-based Industries (BIONAER).

New measures and the need for quality and relevance

Opportunities for profitable biomass production have been identified during the RENERGI programme period, and biogas processes and raw material mixtures that increase methane yield have been investigated. Research on climate impacts strengthens collaboration between the research community, the public administration and industry. The research environments surrounding SINTEF/NTNU and at Campus Ås have established four laboratories that are critical to maintaining the international calibre and national relevance of research in the field of converting biomass to energy, and have received funding from the Research Council.

ENERGY FOR TRANSPORT

3.11 Hydrogen and fuel cells

Photo: HyNor

A hydrogen filling station in Oslo, one of several along the Norwegian Hydrogen Highway (HyNor).

When the RENERGI programme started up, research on energy for transport was not part of its portfolio. The 2004 report submitted by the Norwegian Hydrogen Committee (Official Norwegian Report 2004: 11) on commission from the Ministry of Petroleum and Energy and the Ministry of Transport and Communications recommended establishing activities to develop hydrogen as an energy carrier. Based on the report's recommendations and its own experience from working on the report, the Ministry of Transport and Communications decided to channel its funding for R&D and the introduction of environment-friendly transport technology via the RENERGI programme. This was a conscious strategic move based on: 1) the scientific overlap between energy for transport and energy for stationary purposes (which was initially most clear in the case of hydrogen technology); 2) an awareness of the growing connection between transport and the energy supply; and 3) positive experience with the RENERGI programme from collaboration on the hydrogen report.

Growing need for environment-friendly fuel

The RENERGI programme was established at a time when there was great international attention on hydrogen and a potential future hydrogen society. This interest had its basis in the heavy investments by the US and the EU in hydrogen, which were in part to satisfy the need for more environment-friendly fuel. In Norway, the Norwegian Hydrogen Council was established by the Ministry of Petroleum and Energy and the Ministry of Transport and Communications to follow up the abovementioned report, and hydrogen quickly became a high-priority area under the RENERGI programme. Interest waned after a few years, however, as activity slowed in the industry. Nevertheless, during the programme period there has been increasing activity to demonstrate the use of hydrogen for vehicles, and presently two large-scale demonstration projects are running in Oslo with support from the EU and Norwegian players. These projects received early funding from the Research Council, and on the initiative of the Hydrogen Council and with strong support from the Zero Emissions Resource Organisation (ZERO), the agency Transnova was established as a follow-up measure to the 2008 climate policy agreement. Transnova has largely assumed the RENERGI programme's activities relating to demonstration projects.

At the time the RENERGI programme was launched, there were still major technological challenges in connection with fuel cells and hydrogen storage for vehicles, which made it necessary to carry out comprehensive R&D and demonstration programmes. Today many of those basic challenges have been solved, particularly with respect to fuel cells' costs, lifetime limitations, functionality in cold weather, and vehicles' ability to carry adequate amounts of


Photo: HyNor


Photo: Hanne Aglen, Akershus Energi AS

A hydrogen filling station in a town near Oslo.

hydrogen. There remains a need to reduce costs and lengthen lifetime, but this appears feasible to achieve once serial production of hydrogen vehicles begins.

Electric vehicles are given political priority in Norway, but since the country offers the same favourable incentives for hydrogen, Norway may become an interesting early market for hydrogen vehicles in the same way that electric vehicles currently are.

Abundance of innovation projects

Overall, the hydrogen portfolio has grown from roughly NOK 45 million in 2006 to roughly NOK 60 million in 2011. Despite this, allocations to research on hydrogen and fuel cells ended up comprising a lower percentage of the RENERGI budget than in the early years. There have been disproportionately many innovation projects compared to knowledge-building projects and researcher projects.

The early portfolio consisted predominantly of projects headed by industry players in hydrogen production and demonstration projects in connection with the Norwegian Hydrogen Highway (HyNor) and the construction of filling stations.

From the outset, the major industry players involved in the RENERGI programme were Statoil, Hydro, Statkraft and DNV. After the Statoil-Hydro merger, activity related to hydrogen gradually tapered off, culminating in Statoil's decision in summer 2009 to curtail its hydrogen activities. Statkraft and DNV eventually phased out their activities as well. Other companies such as Elkem, NEL Hydrogen (formerly Norsk Hydro Electrolysers), Nordic Power Systems and some smaller companies have also headed projects in the portfolio. In general Norway has far fewer small and medium-sized enterprises involved in hydrogen and fuel cells than do Denmark and Sweden. Hydrogen production activity in Norway has dropped off since Statoil's withdrawal.

Significant international cooperation

Norwegian research groups have been very active internationally. SINTEF in particular has a key role in the EU's Fuel Cells and Hydrogen Joint Undertaking (FCH JU) and in this context works closely with the large European companies involved. SINTEF and NTNU are prominent in both PEM fuel cells for vehicles and hydrogen separation membranes. The University of Oslo, in collaboration with SINTEF, has in-depth experience in high-temperature ceramic proton conducting fuel cells. The Institute for Energy Technology (IFE) has world-class expertise in hydrogen storage solids (metal hydrides). On the industry side, the research groups at Hydro and Statoil have scaled back to a minimum. NEL Hydrogen still conducts a not-insubstantial amount of research, while R&D is underway at smaller companies such as Prototech.

Prototypes and ground-breaking technology

The objective of the RENERGI-funded project "Electrolysis-based hydrogen production using renewable energy sources", headed by NEL Hydrogen, is to develop electrolysis tubes based on electricity from renewable energy sources such as wind and solar power. Shorter response times and longer production windows are essential. A new cell design that allows for quicker response and a wider effective-capacity window has been developed and improved materials for electrodes have been identified. A prototype has been built and tested, and construction of a larger demonstration unit is planned. Commercialisation of this new technology is being planned and assessed.

In principle, high-temperature ceramic proton-conducting fuel cells are more efficient than other types of fuel cells for using hydrogen as fuel. Researchers under the project "Stack technology for ceramic proton conductors (StackPro)" at the University of Oslo have studied materials and stacking technologies for high-temperature proton ceramic (HTPC) fuel cells. Two Ph.D. candidates have been trained in materials science and technology for fuel cells, contributing to progress in HTPCs and ceramic materials at Norwegian companies and in Norwegian-coordinated EU projects.

Under its project "Development of ground-breaking fuel cell technology", Nordic Power Systems (NPS) collaborated with the California Institute of Technology to develop a solid acid fuel cell that operates at higher temperatures than PEMs can, so it can run on diesel, giving it potential as a separate power source for lorries, boats, etc. Hotter operating temperatures make this fuel cell less sensitive to fuel impurities. Studies have shown that the fuel cell tolerates up to 10 % CO, so it can use energy sources that are less refined. NPS also cooperated closely with US and German technology partners in the project.

ENERGY FOR TRANSPORT

3.12 Electric vehicles

Photo: Shutterstock

Norway, a leader in electric vehicles

For many years, Norway has led the way in the use of electric vehicles – thanks primarily to incentives such as express-lane privileges, free parking, and fee exemptions at purchase. This last consideration has made electric vehicles very competitive in Norway compared to other countries, since new-purchase fees in Norway far exceed those of other countries.

In the past two years a market shift has taken place for electric vehicles, which used to be either special designs or converted petrol-powered vehicles with limited application. Now the major automotive companies have introduced new electric vehicle models on the market, such as the Nissan Leaf, Mitsubishi i-MiEV and Citröen C-Zero, to name a few. For 2012–2013 plug-in hybrid vehicles are being launched as well – versions of hybrids powered by an internal combustion engine, a battery, and an electric motor, such as the Opel Ampera. The great majority of car trips are short enough to run on battery/electricity, but it is unproblematic for a plug-in hybrid if the trip is longer than the battery's range. This enables it to function as the family's primary vehicle – doing away with the need for one car for errands/commuting and another for driving to the family cabin.

There are roughly 8 000 rechargeable vehicles in Norway (as of August 2012), up from roughly 4 500 just a year earlier. Parallel to this sales growth in electric vehicles is the expansion of a substantial network of 3 500 recharging points, including some 50 quick chargers.

Innfasing av elektriske kjøretøy i RENERGI

The broad-based political agreement on climate policy achieved in the Storting in 2008 raised awareness about reducing carbon emissions in the transport sector. In 2008 the Ministry of Transport and Communications launched a campaign to speed up efforts to cut transport-related emissions; Liv Signe Navarsete, then Minister

Photo: Mathias Kübel

A Norwegian energy supplier's quick-charge station.

of Transport and Communications, took the initiative to promote the development of electric vehicles. A panel was appointed, and in May 2009 it submitted an action plan for electrifying the transport sector.

In 2009 the first R&D projects related to electric vehicles appeared in the RENERGI portfolio. The programme took an important step in this context by launching the large-scale TEMPO project on environment-friendly urban transport – based on an application for status as a Centre for Environment-friendly Energy Research (FME) – in order to accelerate research on how to actually implement environment-friendly transport technology. The portfolio was subsequently expanded, with two main branches: 1) materials, batteries and battery technology, and 2) system-wide challenges, user knowledge and the user experience, and knowledge for use of instruments.

From vehicle production to equipment supply

The Norwegian market has had players such as Think (formerly Pivco) and the smaller vehicle Kewet, now known as Buddy. Norway's electric vehicle fleet also included a small array of smaller, converted European vehicles. Currently there are fewer players looking to produce electric vehicles, but more with intentions to supply equipment, systems and services to the vehicle manufacturers. The entire recharging infrastructure is a vital part of this and represents major value.

The company Think, which carried out several projects under the RENERGI programme, was an important player in Norway, but now other players have taken the spotlight. The supply of electric vehicles is no longer the industry's bottleneck to growth. Now the challenges are user knowledge and the user experience. The biggest players addressing these issues in Norway are Grønn Bil and the Institute of Transport Economics (TØI).

Core challenges involve new materials and solutions to improve storage capacities, reduce recharging time, and extend battery lifetime. There are several dynamic Norwegian players in this area, both in the private sector and in research. Miljøbil Grenland, the University of Oslo and the Institute of Energy Technology are considered the leading Norwegian players in the field – and all three have been participating in various RENERGI-funded projects.

User behaviour and safety

The field's most important results are related to enhanced knowledge about user behaviour and systems for procurement and use of electric vehicles. Two key projects have produced results: the project eCar at SINTEF Energy Research and the TEMPO project, headed by TØI. New, critical technology to improve battery safety is currently being developed under projects headed by Miljøbil Grenland, which is also developing new methods for modelling, monitoring and controlling both the discharging and recharging of a battery's individual cells. This will enhance safety, provide good temperature control, extend vehicle range and reduce battery degradation.

ENERGY FOR TRANSPORT

3.13 Biofuels

Photo: Hans Otto Haaland

High oil prices trigger demand for biofuels

Only recently has the production of biofuels reached substantial volumes in some markets. Brazil launched initiatives for ethanol as a fuel in the 1970s in the wake of the international oil crisis. In the 1990s the US began to use ethanol as a substitute for petrol.

In the early 2000s biofuels were considered a renewable energy source with zero net emissions of greenhouse gases and lower emissions of particulates and other localised hazardous substances. Since 2007, however, biofuels have been criticised for contributing to rising food prices and for their disappointing environmental performance compared to the initial outlook.

At the time the RENERGI programme was launched in 2004, there was little research on biofuels being carried out in Norway. The most important measure taken in this field was the Ministry of Finance's tax exemption for using biodiesel for road transport, introduced in 1999. But not until a decade later, when mandated quotas were enacted, would biofuel sales skyrocket in Norway.

High oil prices and the desire for energy security based on Norwegian agriculture have been the prime drivers for biofuel development. More recently, cutting greenhouse gas emissions has also become a key motivation. In Norway and other countries with a large wood processing industry, development has also been encouraged by a downturn and restructuring of the markets for paperboard, cardboard and paper. Wood processing companies are also seeking new markets for wood pulp products.

The rise of second-generation biofuels

For years, Norwegian players have shown interest in research on biofuels, with focus on both conversion processes and issues of sustainability. The RENERGI programme has given highest priority to projects on second-generation biofuels based on timber and other biomass not used for food production.

This prioritisation has been influenced in part by the companies Borregaard and Norske Skog seeking new markets for wood pulp products. Companies that refine oil and gas also see potential in developing new, profitable processes that can be integrated into existing petroleum-based value chains.

Skilful Norwegian research community

Since the start-up of the RENERGI programme, significant research expertise in biofuels has been built up in the city of Trondheim at entities such as the Paper and Fibre Research Institute (PFI), SINTEF Energy Research, the Catalysis Group at SINTEF Materials and Chemistry, and NTNU. These key players are conducting research in biofuel-related areas such as pre-treatment and gasification as well as developing advanced processes for refining oil and gas for the

Photo: Istockphoto/shaunl

Photo: Shutterstock

conversion of wood and other vegetable material not used for food production into advanced, sustainable biofuels. Statoil has been a vital industrial supporter here.

At Campus Ås, researchers at the Norwegian University of Life Sciences (UMB) and other groups have carried out valuable studies on raw materials, environmental analyses and biochemical research. One example is UMB researcher Vincent Eijsink's work on enzymes and proteins for raising conversion efficiency from Norwegian wood to sugar, a key component in ethanol and other petrol substitutes, second-generation biodiesel, and biofuel for aviation.

Borregaard, which has been involved in many RENERGI-funded projects, has made major progress with its new BALI process. The process is flexible with regard to raw materials and efficiently converts wood and other vegetable material not used for food production into two products: very pure sugar, which in turn can be converted into biofuel, and water-soluble lignin, for conversion into high-value chemicals. Borregaard is now building a pilot facility for NOK 130 million for testing its BALI process. The company has received NOK 58 million in funding from Innovation Norway for constructing the facility.

The RENERGI programme has provided support through a number of projects to the start-ups Weyland and LTL Nor, both of which work on conversion processes for second-generation biofuels. Weyland, after receiving funding under the RENERGI programme for several projects, has also received funding from Innovation Norway's environmental technology support scheme to further develop its pilot facility.

Chaperone proteins and gasification processes

Perhaps the most sensational result from RENERGI-funded projects is Vincent Eijsink's discovery of a new type of chaperone protein that can greatly raise the efficiency of producing sugar from wood. He has published an article in the prestigious journal Science and sold patent rights to the Danish company Novozymes, a global leader in producing enzymes.

Other concrete findings have come from the knowledge-building project "GasBio" at SINTEF Energy Research, whose work with gasification processes for biofuel production has resulted in the construction of an innovative entrained flow gasification reactor with associated modelling tools. The project has led to Avinor, one of the partners, initiating a comprehensive feasibility study for producing biofuel for the aviation sector in Norway. Extensive expertise and knowledge have been acquired in this area in the course of the RENERGI programme period.

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OVERALL ASSESSMENT OF RESULTS

4

The primary objective of the RENERGI programme has been: "... to develop knowledge and solutions as a basis for ensuring environment-friendly, economically efficient and effective management of Norway's energy resources, a highly reliable energy supply and internationally competitive industrial development related to the energy sector. Research activities will also seek to find solutions to global energy and climate challenges as well as the political challenge inherent in Norway's role and responsibilities as a leading player in the global energy sphere." (Revised in 2008.)

4.1 Strategic results

New, collective research agenda

The launch of the RENERGI programme was accompanied by efforts to bring together relevant players, develop plausible future scenarios and draw up a national strategy for environment-friendly energy research.

Concluded in 2005, the Energy 2020+ foresight project involved several hundred representatives of relevant actors and stakeholders who collaborated on developing a wide range of scenarios, providing an important basis for future strategy development under the RENERGI programme. In 2007 the RENERGI programme conducted several smaller-scale scenario studies in cooperation with key research institutions in the areas of solar energy, bioenergy, biofuels and offshore wind power.

As a result of these processes, which were organised by the Research Council and the RENERGI programme, the Ministry of Petroleum and Energy decided to draw up a national strategy relating to environment-friendly energy. This culminated in the publication of the first Energi21 strategy report in 2008.

Competence-building

Building dynamic research groups has been an aim of the RENERGI programme board throughout the entire programme period. Thus, the portfolio has been managed in a long-term perspective with an overall focus on quality. The programme board has also strongly encouraged leading research groups to take advantage of funding opportunities. This has led to a significant boost in quality, as evidenced by the fact that many of these research groups have qualified for status as Centres for Environment-friendly Energy Research (FME). The objective of the FME scheme is to develop expertise and promote innovation through focus on long-term research in selected areas. The initial eight centres were launched in 2009 in the technology areas of electricity from solar cells, offshore wind power, bioenergy, environmental design, buildings, and carbon capture and storage (CCS). Three new FME Centres for Social Science-related Energy Research (FME Samfunn) were established in 2011.

Trade and industry mobilised

The RENERGI programme has sought to implement funding instruments that would encourage trade and industry to carry out more research. This has involved a variety of measures, including active use of various Research Council funding schemes targeting the business sector, meeting-places in the energy sphere such as *Teknologisk Møteplass* ("Technological Meeting-place"), and the above-mentioned joint strategy processes. In the final phase of the programme in particular, the programme board has focused attention on harvesting commercial results based on the competence-building that took place in the initial phase of the programme. The efforts have paid off; a significant portion of the large increases in the programme budget after 2008 were granted to trade and industry, and the number of companies participating in the projects rose dramatically.

Internationalisation of Norwegian energy research

International energy research has been a key focus of the RENERGI programme board. One aim has been to ensure that international cooperation was primarily established in response to the needs identified in the grant proposals submitted to the programme. The most important arenas for such cooperation have been the EU, the International Energy Agency (IEA) and the Nordic countries. In recent years funding was awarded for bilateral research projects with China and India, respectively. Activities under the programme also included participation in a wide array of international events, such as Transatlantic Science Week in the US and EXPO 2010 in Shanghai, China. One-half of the active projects in 2010 incorporated international cooperation and one-fourth of the programme budget was associated with international research cooperation activities. The most important partner countries have been the US, Sweden and Germany.

Norwegian players in every fourth EU-funded project

The number of projects receiving funding under the EU Seventh Framework Programme (FP7) is a good measure of the degree of internationalisation of Norwegian energy research. One-third of all Norwegian energy research project proposals were approved for funding under FP7. Norway participates in 24 % of all projects recommended for funding, totalling of 56 projects at the end of 2011. These projects involve some 260 Norwegian energy researchers, with EU funding totalling NOK 300 million. Norway's most important partner countries in this context are Germany, the UK, France and The Netherlands. The RENERGI programme also participated in joint calls for proposals with other countries under the EU's ERA-NET scheme.

The role of the RENERGI programme has been to design strategies for funding Norway's participation in these arenas in order to promote Norwegian interests and players. The programme therefore provided support to projects that have influenced the shaping of EU strategies and participation in the IEA.

Photo: Statkraft

Photo: Shutterstock

4.2 Overall results

Photo: Sverre Jarild

500 projects and NOK 4 billion in funding

The RENERGI programme provided support to some 500 R&D projects in the course of the programme period, with an average grant of NOK 4 million per project. Funding allocated by the programme totalled NOK 1.7 billion for the 2004–2011 period. If allocations in 2012 are included, the programme has awarded over NOK 2 billion to Norwegian R&D activities in the area of environment-friendly energy. In addition, the research groups themselves invested a comparable amount of their own resources. This means that research activities have been conducted for roughly NOK 4.2 billion. This does not include the currently active portfolio of the RENERGI programme, which will be taken over in its entirety in 2013 by the ENERGIX programme.

Comprehensive results in the long term

Documenting the results of research and development is not always an easy task, not least when summing up the activities of an entire research programme. Key findings and breakthroughs may be the result of targeted R&D activity, external factors and economic conditions, or fortunate or unfortunate circumstances. In addition, as a general rule, the most important results do not emerge until some time after research activities have been concluded and final reports have been submitted. It is therefore important to view research results in a long-term perspective. In the course of the programme period, Norwegian energy research groups have made great strides in a number of research areas and helped to develop a smoothly-functioning, future-oriented energy system.

There are a variety of indicators that demonstrate how well research activities are advancing the achievement of the programme objectives. For trade and industry, the number of patent applications, product licences, new companies, and new products and processes say something about the potential for industrial development generated by the projects. In addition, the success of Norwegian R&D groups in competing with researchers from the rest of Europe for funding under the EU framework programmes is an important indicator of the quality of Norwegian energy research. The external evaluation of the RENERGI programme concluded that the programme has played an essential role in building up central competency in the field. The quantitative results reveal a similar picture.

FIGURE 4.1 SCIENTIFIC RESULTS

TYPE OF PUBLICATION	NUMBER, UP TO 2010
Scientific articles, peer-reviewed	216
Scientific articles, not peer-reviewed	176
Reports and lectures	1500
Dissemination measures and news items in the mass media	Several thousand

Scientific publication

In the period up to 2010, projects under the RENERGI programme reported the publication of 216 articles in peer-reviewed scientific journals and 176 articles in other scientific journals. The projects also reported nearly 1 500 reports and lectures as well as several thousand dissemination measures and news items in the mass media. In 2010 the Research Council restructured its system for registering scientific publication and dissemination activities, so it is difficult to compare the figures from before and after 2010. However, in 2011 alone the projects reported the publication of 173 scientific articles (including monographs and chapters in anthologies) and 273 articles in other types of publications (including periodicals and series). For the majority of knowledge-building and researcher projects, publication has been a key channel for dissemination of research results; however, publication often takes place after the project has been concluded. For innovation projects, other types of dissemination activities and other ways of implementing results have been more relevant.

International success indicates high quality

An additional and at least equally important indicator that research holds a high standard is the performance of Norwegian research groups in international competitive arenas. At present Norwegian projects are significantly more successful than the European average, and energy is one of the areas in which Norwegian players excel. The fact that many project proposals fronted by Norwegian energy researchers have received EU funding demonstrates the high calibre of the research and its relevance for addressing societal challenges.

Doctoral training boosted

The RENERGI programme has contributed to a major increase in the number of younger students pursuing a Ph.D. in energy research. In 2012 alone, more than 120 doctoral candidates were receiving funding under the programme. In addition there were 50 post-doctoral candidates. Approximately the same number are receiving funding via the FME centres. There is no doubt that this large pool of highly-trained specialists will be a tremendous resource for the energy sector and related sectors once they embark upon their careers in the research community and trade and industry.

The proportion of women fellowship-holders in projects funded under the RENERGI programme has risen. Looking at the entire programme period, approximately of 35 % of doctoral fellowship-holders and just over 30 % of post-doctoral fellowship-holders were women. Looking at 2011 alone, the proportion of women is much higher: 42 % of doctoral fellowship-holders and about 36 % of post-doctoral fellowship-holders.

Significant participation on the part of trade and industry

R&D is an important investment that generates economic value within the community. Norwegian trade and industry has been very eager to take part in the large-scale mobilisation of R&D efforts in the area of energy research triggered by the broad-based political agreement on climate policy achieved in the Storting in 2008. This is reflected in the increase in requests for RENERGI funding. The

FIGURE 4.2 NUMBER OF FELLOWSHIP-HOLDERS RECEIVING FUNDING UNDER RENERGI

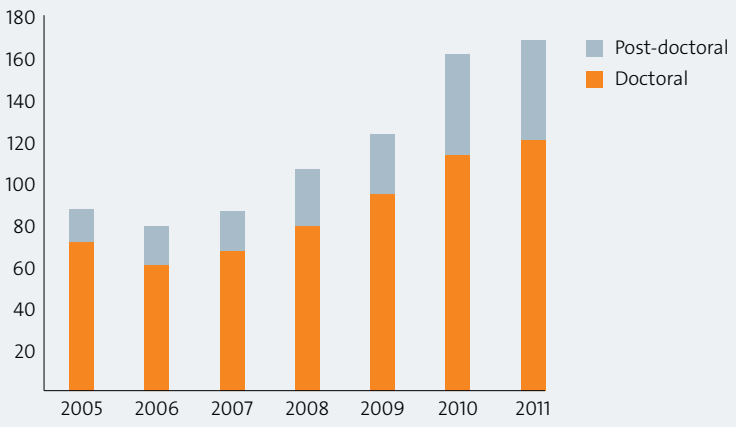


Photo: Sverre Jarild

Project manager Berta Matas Güell and programme board chair Elizabeth Baumann Ofstad.

FIGURE 4.3 a DOCTORAL FELLOWSHIP-HOLDERS – GENDER DISTRIBUTION

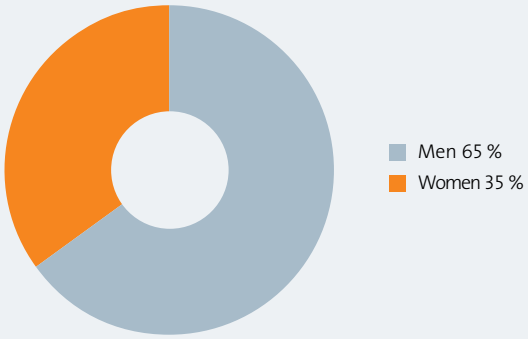
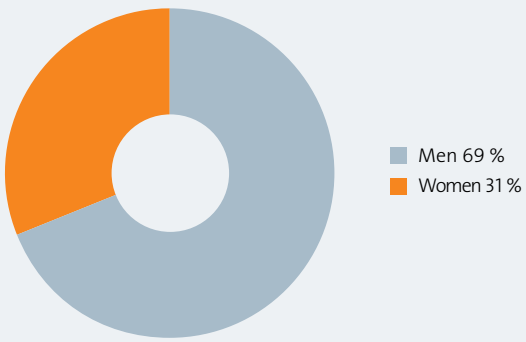


FIGURE 4.3 b POST-DOCTORAL FELLOWSHIP-HOLDERS – GENDER DISTRIBUTION



programme received a large number of applications for new projects in response to every funding announcement, and recipients were selected from among a multitude of very high-quality projects. Trade and industry has taken part in these activities both in a wide range of innovation projects led and managed by private companies and through investment in knowledge-building projects that benefit the companies themselves as well as other stakeholders.

Results – trade and industry

More than 140 companies have been the Project Owners of RENERGI-funded projects. In addition, a number of companies have participated as partners in one or more projects. The large number of participants illustrates the broad range of the R&D activities and the degree of mobilisation achieved in recent years.

For companies, the primary objective of R&D activity is to generate results that can be commercialised and provide a foundation for new development. These types of results are difficult to identify as direct project results. For example, it may be hard to ascertain whether a new product is genuinely new and which factors have been critical to achieving this result. Companies have reported a wide array of results of significance for further development in the energy sphere.

Photo: Sverre Jarild

FIGURE 4.4 NUMBER OF INDUSTRIAL PARTNERS IN RENERGI PROJECTS, DEVELOPMENT IN 2006, 2008 AND 2010

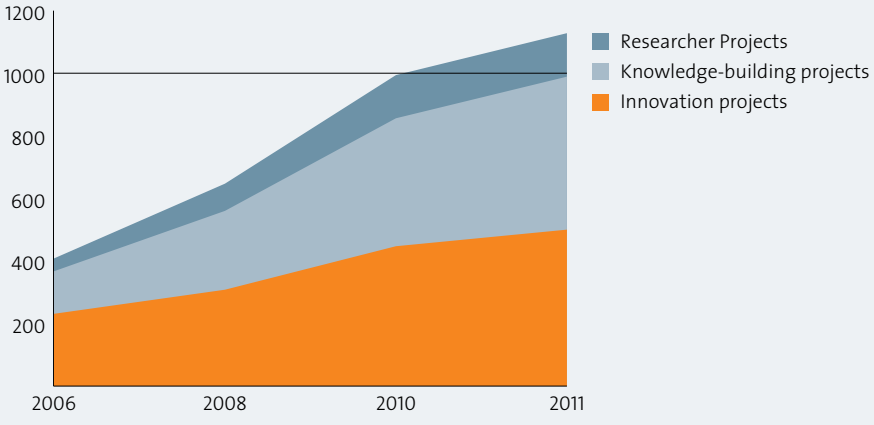


FIGURE 4.5 RESULTS, TRADE AND INDUSTRY

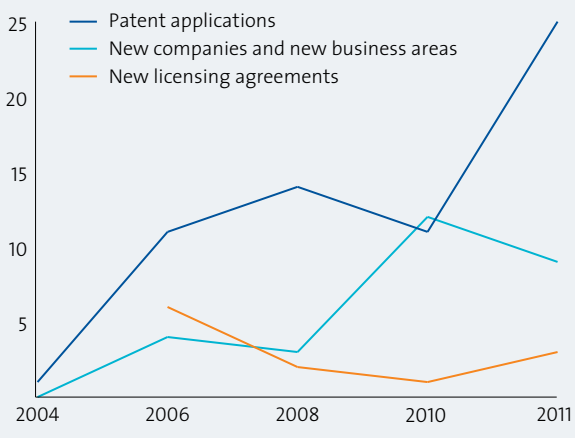
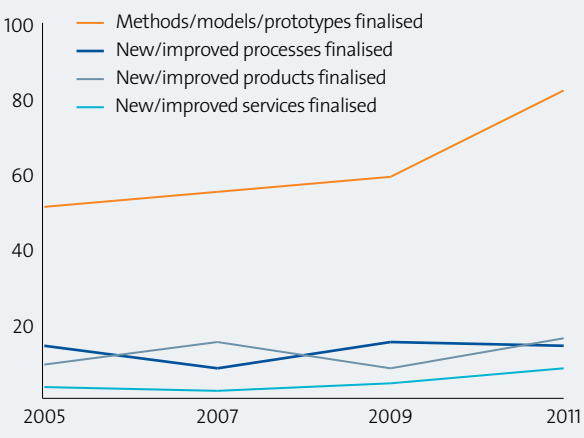


FIGURE 4.6 RESULTS, TRADE AND INDUSTRY



4.3 External evaluation

Photo: Sverre Jarild

The Research Council conducts systematic evaluations of programme activities. In 2011 the RENERGI programme was evaluated together with the programme Optimal Management of Petroleum Resources (PETROMAKS) by the consulting firm Rambøll, which presented its report on 29 February 2012. The evaluation was conducted during the final phase of the programme period; thus the report could not address all of the programme results.

The RENERGI programme is achieving its objectives

The evaluation report states that the programme is on target to achieve its objectives. In particular, funding has led to extensive cooperation with international specialist environments and various types of users. Many of the projects have resulted in – or are expected to result in – new technologies, systems and solutions for energy restructuring.

The report therefore concludes that the RENERGI programme appears to be well on its way to contributing to attaining national policy goals and to achieving the purpose and objectives of the programme.

The programme's annual report for 2011, which is the last complete year for which a report has been submitted, shows a large increase in the number of concrete results, which confirms the findings of the evaluation. It is worth noting that a number of market-oriented

results have also emerged from more basic research projects and knowledge-building projects.

Players have been mobilised

The evaluation report concludes that the RENERGI programme has helped to mobilise relevant national research groups and has had a structuring effect, thereby enhancing the international competitiveness of the groups. These research groups have regular, established cooperation with trade and industry and the research community. Consistent prioritisation in a long-term perspective, based on analyses of strong Norwegian niche areas, scientific merit and innovation capacity, has been at the core of the RENERGI programme's research funding awards.

The report points out that certain specialist environments at SINTEF and the Norwegian University of Science and Technology (NTNU) have dominated the field, and a number of industrial players have also been regular project participants. This is a reflection of both the stringent quality requirements and the structure of Norwegian research in this field. Nevertheless, in 2011, there were approximately 1 000 participants in the ongoing projects.

The report also notes a lack of interest among the energy companies, especially the grid companies, in participating in research projects. This may be due in part to the fact that framework conditions for R&D are not particularly attractive.

Good reputation

According to the evaluation, those familiar with the RENERGI programme have been highly satisfied with its practice as well as the way in which new priorities were incorporated into the funding announcements. The programme is also perceived as flexible and accommodating, for example with regard to project follow-up and reporting. However, certain players would like to see greater consistency in terms of giving greater focus in the funding announcements to the thematic areas being given priority over longer periods.

Funding has been crucial

The evaluation report points out that the programme has given a major boost to participating research groups with high additionality. Of the projects awarded funding, 71 % would not have been carried out without the funding, and only 2 % would have been implemented without adaptation. Of the projects that were not awarded funding, 74 % were not started up at all, and only 2 % were implemented without adaptation. This clearly demonstrates the trigger effect provided by support under the programme. In addition, funding has significantly enhanced cooperation with international research groups and promoted the development of new technologies, systems and solutions to facilitate energy restructuring.

The high figures for additionality show that Research Council funding has been crucial to the implementation of projects within trade and industry that would not otherwise have been carried out. These figures confirm that the programme, with its effective application review process, has had the capability to select and prioritise high-quality projects with a risk level that is too high for the players to have carried them out without co-funding.

Meets the needs of target groups

The evaluation report points out that the RENERGI programme has been primarily oriented towards meeting research needs and the needs of society at large. Focus on trade and industry has grown in the course of the programme period through the constructive prioritisation of innovation projects, which in turn has generated more interest on the part of the industry. The funding instruments employed by the programme are seen as appropriate for addressing the needs of the target groups, particularly in conjunction with the FME centre scheme.

The programme board's recommendations for the new ENERGIX programme

The evaluation report raises issues relating to the organisation and management of the RENERGI programme that the Research Council administration has incorporated into further planning. The RENERGI programme board has summarised the findings of the evaluation and formulated six recommendations for the programme's successor, the Large-scale Programme for Energy Research (ENERGIX):

- Clarify the objectives of the programme and make them more specific. This will be helpful when setting difficult priorities in a very broad area of responsibility.
- Continue the strategy of setting long-term priorities to enable leading Norwegian research groups to become internationally renowned and more competitive.
- Design funding instruments that enable research institutes and research groups to build and enhance expertise so they can obtain a position on the international research front.
- Further integrate industry priorities by cultivating closer cooperation with the Energi21 secretariat. At the same time the areas that are not covered by the Energi21 RD&D strategy should be clarified.
- Increase focus on effective follow-up and publication and dissemination of project results on an ongoing basis during the programme period.

Photo: istockphoto/shaunl

ORGANISATION AND IMPLEMENTATION

5 Organisation and implementation

Coordination between six ministries

The Ministry of Petroleum and Energy has channelled most of its funding for research on environment-friendly energy via the RENERGI programme. These funds have comprised the largest share of the overall funding for the entire programme period. The programme has also received substantial funding from other sectoral ministries and the yield of the former Fund for Research and Innovation (which was replaced in 2012 by allocations over the separate budget item from the Ministry of Education and Research). Allocations from the sectoral ministries are critical to ensuring that research is carried out in specific areas, such as, for example, energy use in transport (Ministry of Transport and Communications), converting biomass to energy (Ministry of Agriculture and Food), environmental disturbances relating to energy solutions (Ministry of the Environment), basic research and international cooperation (Ministry of Education and Research), and innovation and industrial development (Ministry of Trade and Industry). All of the ministries have allowed the Research Council the freedom to administer the allocations as it sees fit, enabling the RENERGI programme to apply this funding towards integrated, wide-ranging activities in all of the fields within the energy sphere. This approach has been vital, and the latitude given by the various ministries has helped to make the programme a cross-sectoral initiative.

The energy sector shares an interface with other key sectors, and interaction between these is important. Solutions chosen for use in the transport sector, for instance, will affect the national energy supply and energy system. Conversely, the future national energy mix and overall access to energy may play a role in determining the sustainability of various transport systems. There are similar energy-related areas of interface in many fields. The RENERGI programme has therefore worked closely with a variety of other research programmes.

Significance of the broad-based political agreement on climate policy

The RENERGI programme was launched with an annual budget of roughly NOK 100 million. Funding for research on environment-friendly energy has grown in the wake of the broad-based political agreement on climate policy achieved in the Storting in 2008. Much of this increase has been allocated to the RENERGI programme and the Centres for Environment-friendly Energy Research (FME) scheme.

FIGURE 5.1 RENERGI'S BUDGET, 2005–2011

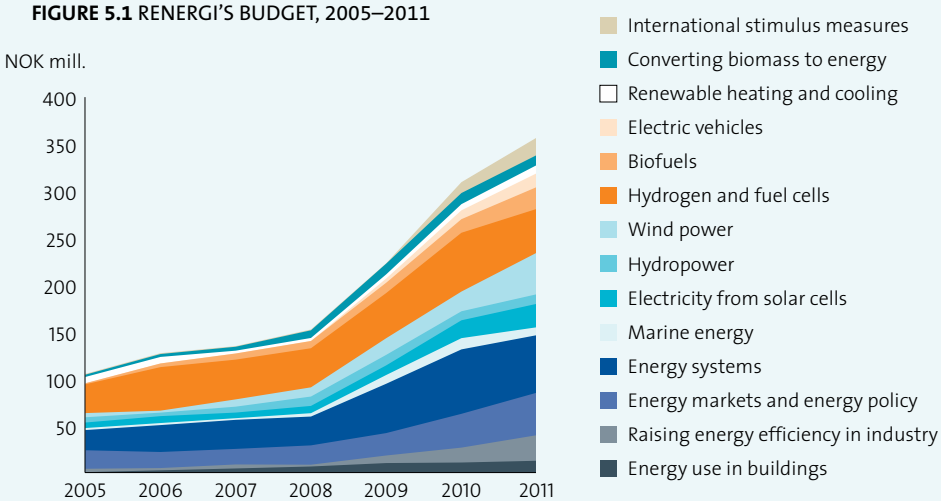
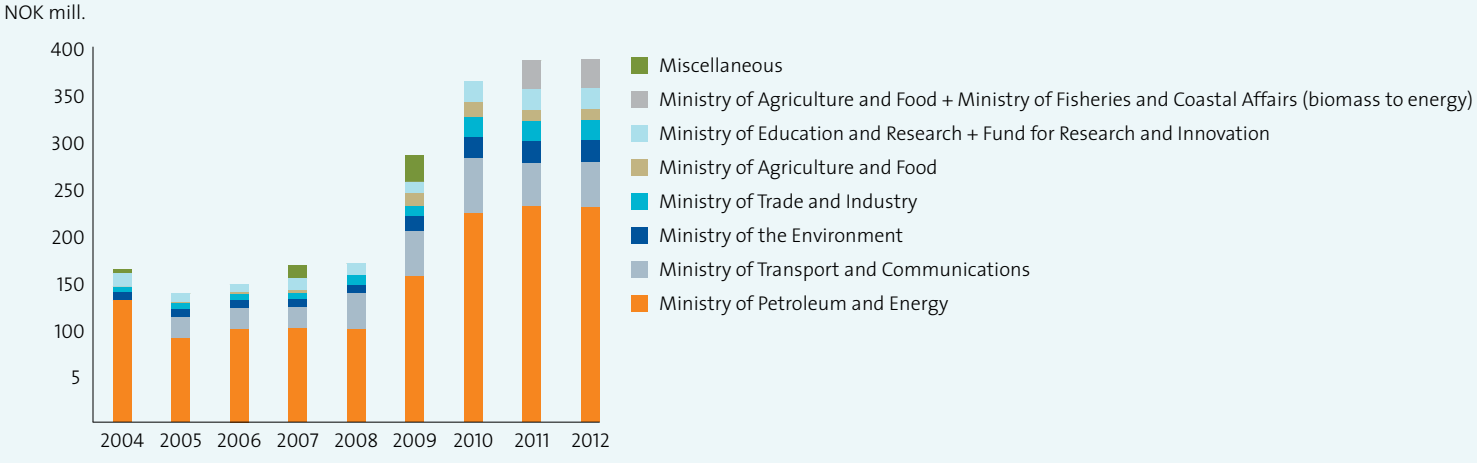


Photo: Terje Akerhaug/Dagsavisen/Samfoto

The signing of the climate policy agreement 2008.

FIGURE 5.2 ALLOCATIONS TO RENERGI



The RENERGI programme's budget nearly doubled in the period from 2008 to 2010, giving the programme essential latitude for action. The annual budget grew to nearly NOK 400 million in the last few years of the programme period.

The 2008 climate policy agreement laid out a concrete plan for increasing investment in research, and this plan was followed up by the Storting and the Government. While much of the growth in funding has been channelled via the RENERGI programme and the FME scheme, allocations were also augmented in a number of other programmes and funding instruments in related areas. The clear line taken by the Storting in 2008 made it possible for all types of research environments to incorporate an increase in funding into their planning, and is in all likelihood one reason why trade and industry and R&D groups have been able to rapidly step up their level of activity and expand their capacity.

The role of the Research Council

The Research Council and the RENERGI programme have attached importance to ensuring that the processes whereby funding is awarded have remained transparent, which has generated confidence in the decisions taken. The establishment of meeting-places for the many players in the energy sphere has also been a key task.

In 2011 projects under the programme involved more than 1 000 research and funding partners.

The programme has played an active advisory role vis-à-vis the ministries and the authorities, providing input prior to the Energi21 strategy processes and in connection with the operationalisation of the broad-based political agreement on climate policy, among other things. The launching of the FME centre scheme has made it possible to procure equipment and testing facilities that could otherwise not have been obtained within the framework of ordinary R&D projects. The programme has also assisted the ministries and the Norwegian Water Resources and Energy Directorate (NVE) in connection with a review of framework conditions for R&D in grid companies.

Communication and dissemination activities

The programme's main target groups have been trade and industry, the research community and the public authorities. The Research Council has been the hub for communication activities targeting the general public.

Annual energy research conferences have provided an important meeting-place for members of trade and industry and the research community, and have been organised and carried out by the programme in close cooperation with Enova, Innovation Norway and,

FIGURE 5.3 DISTRIBUTION AMONG PROJECT TYPES, BY YEAR

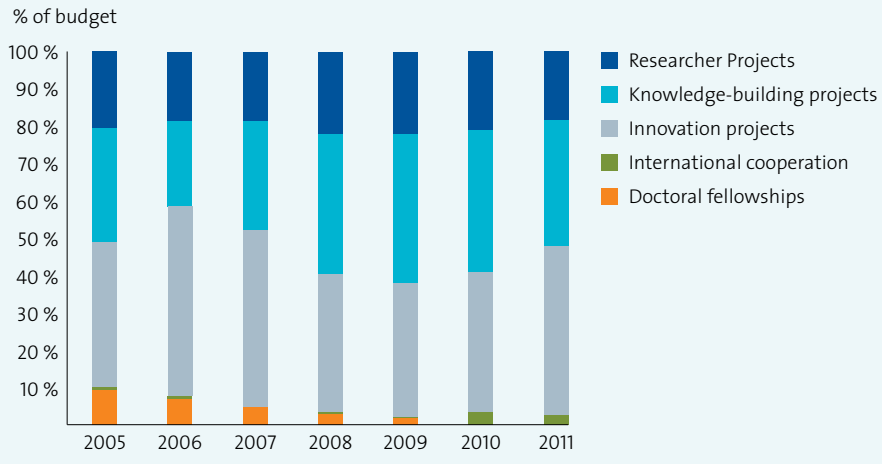
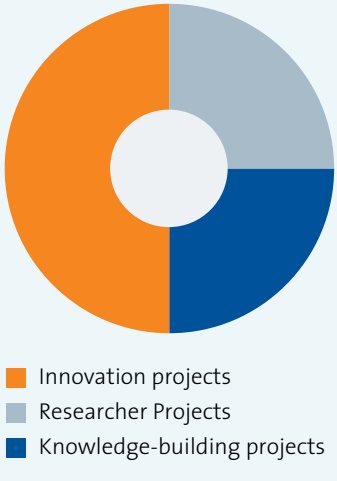


FIGURE 5.4 OVERALL DISTRIBUTION



subsequently, Transnova. The conferences have served as an important arena for dissemination of research results in addition to their function as meeting-places.

The RENERGI programme established the *Teknologisk Møteplass* ("Technological Meeting-place") in cooperation with the Federation of Norwegian Industries and Energy Norway early on in the programme period.

From 2010 the annual "Status på Stratos" conference has provided an excellent venue for meeting representatives of the allocating ministries. The most important tasks in this context have been to disseminate research results from the programme, present examples of good projects, and, not least, communicate the added value of funding research via a large-scale programme such as this. To reach out to students, the programme has cooperated with other players involved in the annual EFIKS conferences on energy, research, innovation, creativity and students held at NTNU.

Portfolio management

Increased allocations have resulted in growth in important initiatives in all of the thematic priority areas, concentrated in particular in the areas of energy systems, energy use in transport (electricity, biofuels and hydrogen), wind power and social science-based research on environment-friendly use of energy. Increased attention was given to raising energy efficiency in buildings and in industry as the programme period progressed.

All of these initiatives have encompassed basic research, competence-building to strengthen R&D groups at independent research institutes and universities, and innovation projects in trade and industry. This has led to a steady rise in the capacity of the R&D groups and the interest shown by trade and industry throughout the programme period. The number of grant proposals submitted in response to each of the funding announcements was large, and the challenge has been to select the best projects and put together the best possible portfolio based on national priorities and input from trade and industry to promote further growth.

The development of the overall portfolio has been dependent on the ample access to projects and players provided in connection with each funding announcement. The portfolio is also the result of strategic choices and priority-setting on the part of the programme board when allocating grant awards. The scientific merit and relevance of the grant proposals have been key criteria in the application review process. Steering a portfolio in the desired direction is a process that involves many variables, and that can never lose sight of the requirements pertaining to project quality and adequate implementation capacity on the part of the applicants.

Photo: Sverre Jarild

THE ROAD AHEAD

6 | THE ENERGIX PROGRAMME – A NEW LARGE-SCALE PROGRAMME

In early 2011 the Research Council launched a strategic planning process, dubbed *NyREN* ("New RENERGI"), to chart out the course for continued energy research activities after the conclusion of the existing RENERGI programme. By starting the process at such an early stage, the Research Council gave itself and its stakeholders ample time and opportunity to find solutions that would adequately incorporate important considerations and objectives into the successor to the RENERGI programme. The process was broad-based and open. The results of the evaluation of the RENERGI programme were published underway, and were also integrated into this process. In the evaluation the users stated clearly that they would like to see activities continued under a single programme and with the same overall focus of the RENERGI programme. A work programme committee was appointed in winter 2012 to draw up the framework for a new research programme along these lines. The energy research conference in May 2012 served as an arena in which all interested parties were invited to provide input towards the finalisation of the new work programme. In June 2012 the Research Board of the Division for Energy, Resources and the Environment at the Research Council approved the establishment of the new Large-scale Programme for Energy Research (ENERGIX), which issued its first funding announcement with a deadline of 17 October 2012. Thus the successor to the RENERGI programme is already forging ahead.





www.forskningsradet.no/energix

Attachment: Members of the RENERGI programme board and RENERGI programme coordinator

Interim programme board, 1 January 2004 – 31 January 2005
Elizabeth Baumann Ofstad, Hydro (Chair)
Jon Brandsar, Statkraft
Einar Hope, NHH – the Norwegian School of Economics
Margrethe Aune, Norwegian University of Science and Technology (NTNU)
Finn Ingebretsen, University of Oslo
Peter Lund, Helsinki University of Technology
Monica Havskjold, Norwegian Water Resources and Energy Directorate (NVE)
Petter Støa, SINTEF
Trude Sundset, Statoil
Jon Einar Værnes, Powel

Programme board, 1 February 2005 – 31 January 2008
Hanne Lekva, Statoil (Chair, 1 February 2005 – 30 June 2006)
Trond Mellingsæter, Fokus Bank (Chair, 1 July 2006 – 31 January 2008)
Unni Olsbye, University of Oslo (board member, 1 February 2005 – 31 December 2008)
Arne Sveen, ABB
Hans Terje Ylvisåker, BKK
Helle Mostad, Hydro
Ingrid Bjotveit, Norwegian Pollution Control Authority (SFT)
Lennart Hjalmarsson, University of Gothenberg
Margrethe Aune, NTNU
Peter Lund, Helsinki University of Technology
Petter Støa, SINTEF Energy Research
Birte Holst Jørgensen, Nordic Energy Research
Tore Kristian Grunne, Ministry of Petroleum and Energy (observer)

Programme board, 1 February 2008 – 30 November 2012
Elizabeth Baumann Ofstad, Statoil (Chair)
Bengt Gunnar Svensson, University of Oslo
Ingrid Bjotveit, Climate and Pollution Agency
Birte Holst Jørgensen, Technical University of Denmark
Per Lillebø, Cambi
Tove Pettersen, Hafslund
Kirsten Lindberg, Statsbygg
Lennart Hjalmarsson, University of Gothenberg
Bjørg Andresen, Institute for Energy Technology
Petter Støa, SINTEF Energy Research
Tore Kristian Grunne, Ministry of Petroleum and Energy (observer)
Astrid Stavseng, Ministry of Petroleum and Energy (observer)

Programme coordinator for the entire programme period
Hans Otto Haaland, Research Council of Norway

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