Energi21

National Strategy for Research, Development, Demonstration and Commercialisation of New Energy Technology

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Contents

1 Preface

The Energi21 initiative was launched by the Ministry of Petroleum and Energy in 2008 with the aim of designing and implementing a national research and development strategy for the energy sector. The initial Energi21 strategy report was presented in February 2008, marking the first time that energy stakeholders in Norway were unified behind a collective research, development and demonstration (RD&D) strategy in the energy sphere. The vision for Energi21 was defined as follows: "Norway: Europe's energy and environment-conscious nation – from a national energy balance to green energy exports". The 2008 strategy laid the foundation for intensive RD&D activities to realise the substantial potential for value creation and generate awareness of the major challenges associated with ensuring security of supply under an energy regime with clearly-articulated climate targets, strong focus on environmental considerations and requirements for effective resource management.

Once Energi21 was established as a permanent body, the board was given the assignment of drawing up a more action-oriented strategy. The revised strategy presents energy stakeholders with concrete alternatives as well as decisions about what to give – and what not to give – priority. The utility of the strategy will be measured by the degree to which industry, the research community and the authorities find the analysis so persuasive that it actually influences the paths they choose to follow and the allocation of resources. The pace of innovation in the traditional energy sector in Norway has been too slow. The country will not be able to meet national and international climate targets without boosting investment in research and development from all sides, including energy companies. Norway has competitive advantages in a number of areas of great significance to realising Europe's energy system of tomorrow, and must make the most of the window of opportunity that is now open.

The desire to realise climate-friendly energy systems for the future has been an important driving force behind the effort to formulate the strategic recommendations presented in this strategy. Future climate-friendly energy systems will require effective, flexible integration of various types of energy carriers, well-functioning infrastructure and energy nodes where electricity is produced and consumed. Investment in and focus on research, development and demonstration of climate-friendly energy technologies are essential to achieving this. The Energi21 board has sought to draw up an integrated strategy that encompasses the entire value chain for energy systems as well as the entire innovation chain, from research to market.

Our mandate has been limited to stationary energy production and consumption and CO2 capture. In light of current – and not least future – use of electricity and biomass in transport systems, we have wondered at times whether the decision to separate stationary energy and transport energy is a fruitful one, but have chosen to remain within our given mandate. This division should be reconsidered when drawing up future strategies. The revision of this strategy has been an industry-driven process comprising interdisciplinary cooperation between trade and industry, research and educational institutions, and the authorities, and is the culmination of a comprehensive effort. Over 140 people from the energy sector have participated in Technology Target Areas (TTA) working groups and have drawn up strategies for their respective TTAs. In addition, a number of players have provided input when the draft report was circulated for review. The Energi21 board would like to thank everyone who has contributed their time and resources in the preparation of this second national RD&D strategy for climate-friendly energy technology.

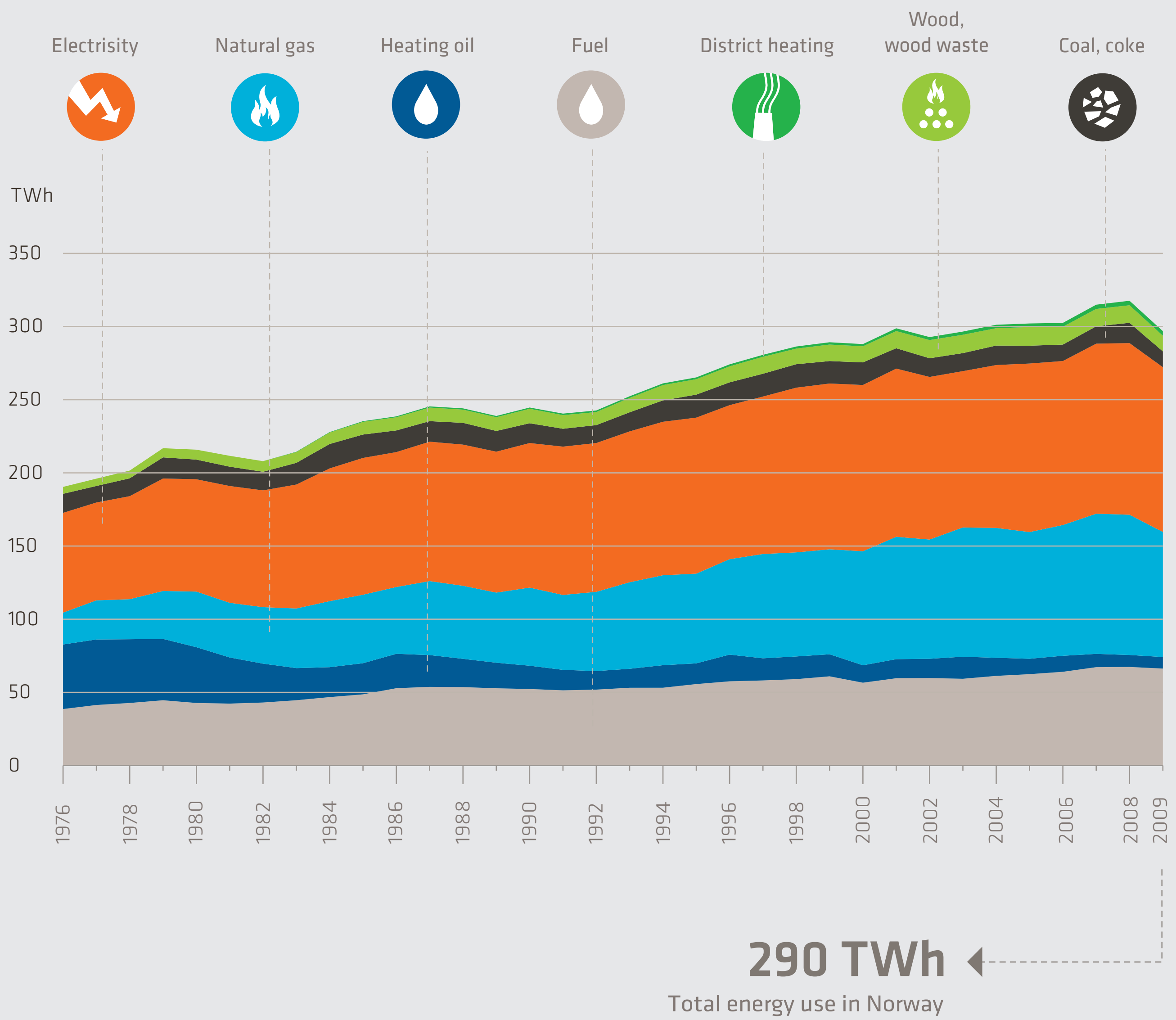
The board of Energi21 is appointed by the Ministry of Petroleum and Energy. Energi21 has a designated secretariat (administration) led by Lene Mostue. The board is comprised of members from a wide range of fields who have been appointed on the basis of their expertise and experience. They are not meant to be representatives of their particular area of activity or employer. The board consists of the following members: Sverre Gotaas (Statkraft, Kongsberg Gruppen), Petter Støa (SINTEF Energy Research), Anne Strømmen Lycke (Statoil), Kjell Olav Skjølsvik (Enova), Audhild Kvam (Powel, Enova), Monica Havskjold (Xrgia), Anna Maria Aursund (Troms Kraft), Morten Røsæg (Hydro), Gunn Oland (Norwegian Water Resources and Energy Directorate (NVE)), Mona Askmann (Energy Norway, Energiakademiet), Arne Sveen (ABB), Bjørg Andresen (Institute for Energy Technology (IFE)), Arne Bredesen (Norwegian University of Science and Technology (NTNU)), Fridtjof Unander (Research Council of Norway), Svein Eggen (Gassnova), Lars Kristian Vormedal (Statnett), and observers Ann-Ingeborg Hjetland and Tore Grunne (Ministry of Petroleum and Energy).

The Energi21 board is extremely pleased with the way in which the authorities and the public agencies within the research and innovation system have followed up the conclusions and recommendations of the previous strategy. This has already led to active research programmes, stronger research communities and greater value creation. There are great expectations that the revised strategy will promote continued growth in the energy sector and appurtenant industries.

Sverre Gotaas,
Board chair

Energy use in Norway

1976 - 2009, by energy carrier



Source: NVE Energistatus 2011

Summary and conclusions

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Photo: Shutterstock.

Ambitions for energy research must be high in the years to come if we are to succeed in finding solutions to current and emerging European and global energy and climate challenges. The development of such solutions will generate substantial growth in markets for new technology.

Meeting the needs of the national and international energy markets of the future will require international cooperation on access to resources, technological development and commercialisation. Multidisciplinary research cooperation across national borders will be crucial.

Norway has resources, expertise and fully-matured industrial activities in many of the areas in which activities must be intensified.

The mandate of the Energi21 board was to set priorities – on a scientific basis – among and within the Technology Target Areas, and to recommend instruments to be implemented. Priority focus areas have been defined based on the primary objectives of the Energi21 strategy: to increase value creation, facilitate energy restructuring with the development of new technology, and cultivate internationally competitive expertise. The board has also taken into account the ambitions and plans of business and research communities in the relevant focus areas as well as the degree to which Norway has competitive advantages in these. The board further analysed the focus areas in relation to the potential future scenarios described in the strategy.

The Energi21 board has decided to give priority to strengthening 6 of the 14 thematic and technology areas under the broader Technology Target Areas (TTA) analysed in connection with the revision of the strategy.

The new Energi21 strategy recommends increasing RD&D activities in the following thematic and technology areas:

Solar cells – enhanced industrial development
The solar energy industry has experienced tremendous growth in the past 15 years, and this growth is expected to continue. The Norwegian solar energy industry, including an emerging supplier industry, and Norwegian research groups are at the international forefront, and Norwegian players have great potential in the segments of the value chain in which they have competitive advantages.

Offshore wind power – industrial development and utilisation of resources
Norway has a number of competitive advantages with regard to the rapidly growing market for offshore wind power. The petroleum and maritime industries are in an excellent position to provide value-creating deliverables to this market.

Improved utilisation of resources using balance power
Norway has significant potential as a producer and supplier of balancing services, which will enhance utilisation of renewable power in an integrated European market. This will require RD&D activities across a wide spectrum, which will in turn facilitate growth in value creation and a rise in the share of renewable energy in Europe.

Generating and safeguarding value creation through CO_2 capture, transport and storage
Carbon capture and storage (CCS) is a pivotal technology for achieving climate targets. Norway has already invested considerable resources in development activities in this field, and has made great strides in the design of cost-effective solutions. Good solutions will also increase the value of Norwegian gas reserves in the future.

Flexible energy systems – smart grids
Achieving progress in all of the strategic priority areas described in the strategy will require flexible energy systems that integrate renewable energy and offer reliable operation within a far more complex totality.

Utilisation of energy – converting low-grade heat into electricity
Utilisation of waste heat and conversion of low-grade heat into electricity is a field characterised by many unsolved problems but with vast untapped potential in Norway and internationally. More efficient utilisation of energy will play a vital role in efforts to deal with climate challenges.

Scientific and international integration is vital

The Energi21 strategy emphasises that value creation in the energy sphere must be built on international task-sharing as well as on multidisciplinary processes and close cooperation between sectors. These components have been incorporated into the designation of priority focus areas, as well as in the determination of recommended instruments. The strategy calls for increased coordination between relevant sectoral authorities and close cooperation between industry and educational institutions.

Research institutions and the business sector must also cooperate to a greater degree on long-term research and development.

Better coordination between stakeholders

Experience in the wake of the broad-based political agreement on climate policy achieved in the Storting (Norwegian parliament) in 2008 shows that increased investments have boosted research activity and triggered innovation in organisation as well as funding instruments, such as the establishment of the scheme for Centres for Environment-friendly Energy Research (FME) under the Research Council of Norway. The Energi21 strategy highlights the need for a common strategic foundation underlying the coordination of various objectives and instruments. Among other measures, the strategy recommends the introduction of a top-level management forum for the public agencies within the research and innovation system. Along the same lines, setting up a meeting-place for stakeholders from this system and the research community is recommended.

Strengthened support for testing and demonstration facilities

Instruments must be differentiated in relation to the type of technology to be developed and the stage along the innovation chain. The Energi21 strategy recommends strengthening support for testing and demonstration facilities for offshore wind power, hydropower/pumped-storage hydroelectricity, and transmission/distribution grids.

Support for testing and demonstration facilities must encompass funding as well as adaptation to regulatory instruments.

New research centre for future flexible energy systems

The strategy describes the thematic priority areas and the instruments recommended under the auspices of Energi21. These include the establishment of a new FME centre focusing on flexible energy systems for the future. Analyses indicate that tomorrow's energy systems will consist of parallel infrastructure and will require a much higher degree of flexibility than today's energy systems. A key research question to be addressed by the new FME centre will be facilitation of balancing services based on hydropower.

Energy restructuring, increased value creation and improved security of supply

Many of the strategy's recommendations could be realised immediately through the introduction of market incentives, and effective support schemes already exist in certain areas. The strategy further identifies and prioritises a number of areas in which more public investment is still needed. This need is estimated to represent twice the current public investment in research, development and demonstration in the field of renewable energy.

Broad-based innovation and targeted activities in strategic priority areas

Growth in the budget for energy research resulting from the broad-based political agreement on climate policy has had a strong mobilising effect. It has led to a significant increase in the number of high-quality grant proposals submitted under the Research Council's funding announcements in programmes across all of the priority areas defined in the initial Energi21 strategy.

Support for innovation projects within the entire scope of energy research must be continued alongside the intensification of strategic activities in the six focus areas defined in this revised strategy. There is an estimated need for a doubling of public investment in research, development and demonstration in the fields of renewable energy, energy-efficient solutions and CCS.

Faster-paced innovation – a key success factor

It is also vital that the commercial players in the energy sector understand that creating future energy solutions will require investment in research and development on a much larger scale than has previously been common in segments of the Norwegian energy sector. Increasing the pace of innovation in the business sector will be a key factor for achieving success in future energy markets.

The expansion of focus sought in the wake of the broad-based political agreement on climate policy has been achieved. The energy industry has mobilised its forces and is well equipped to take on a leading role in important areas in the field, thereby ensuring the development of effective energy solutions and future value creation in a rapidly-growing international market.

Priority focus areas under the Energi21 strategy

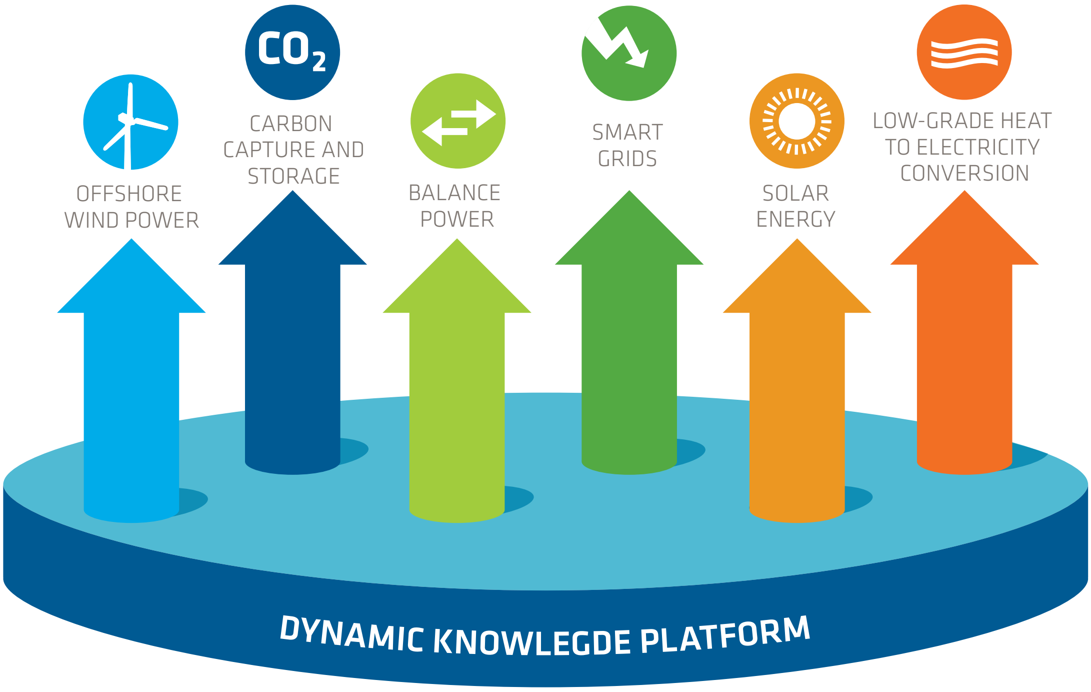

Figure 2.1. Priority focus areas under the Energi21 strategy.

Introduction

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Photo: Hurtigruten/Nina Bailey.

This report sets out an integrated national strategy for research, development and demonstration (RD&D) of climate-friendly energy technology. The strategic approach and delimitation of the strategy are based on the mandate issued to the Energi21 board by the Ministry of Petroleum and Energy in 2008.[1]

The purpose of the strategy is to describe what is required to achieve the following primary objectives:

- To increase value creation on the basis of national energy resources and utilisation of energy.
- To facilitate energy restructuring with the development of new technology and efficient production of environment-friendly energy.
- To cultivate internationally competitive expertise and industrial activities in the energy sector.

In keeping with the mandate, this strategy has been limited to stationary energy production and consumption. This means that an important area of research – transport energy – has not been addressed in the strategy's recommendations. Nevertheless, clear links between the two areas that have a direct impact on the energy system have been analysed and integrated into the strategy.

This strategy is the result of a broad-based process involving interdisciplinary cooperation between trade and industry, research and educational institutions, the authorities and other relevant stakeholders. The strategic recommendations attach great importance to openness and transparent processes.

The main focus when drawing up this strategy has been to revise and operationalise the Energi21 strategy from 2008, giving it a more direct focus. The revised strategy is based on reports submitted by working groups and sub-groups in the following Technology Target Areas (TTA):

- Renewable energy production
  - Hydropower
  - Wind power
  - Solar energy
- Future energy systems
  - Transmission grid
  - Distribution grid
  - Policy structures, framework conditions and power market
- Raising energy efficiency in industry
- Renewable thermal energy
  - Bioenergy
  - Geothermal energy
  - Distributed heating and cooling
- CO_2 capture, transport and storage
- Frameworks and social analysis

Consideration has been given to the fact that future energy systems will most likely be comprised of parallel infrastructure involving several energy carriers in addition to electricity.

Definition of a renewable energy resource:

Renewable energy resources are resources that are naturally and continually replenished. The natural cycle for these resources is very short compared to resources such as oil, coal and natural gas. Hydropower is the most important renewable energy resource in Norway.

Source: Enova.

The strategy has been adjusted to reflect developments in the energy sector, nationally and internationally. Identifying strategically important thematic areas within the larger TTAs has also been an important task. The strategy describes research areas and proposes measures for achieving industry objectives. The degree of maturity of the various technologies has been analysed, as has the extent to which they advance the vision and primary objectives of the Energi21 strategy as set out in the mandate from the Ministry of Petroleum and Energy.[2]

The strategy presents specific actions for realising these objectives.

The primary objectives may be achieved by implementing various types of instruments and through contributions from the various players. The measures are differentiated in relation to the degree of maturity of the technology and the market, respectively. The following terms are used to describe the required measures for realising industry ambitions and objectives:

1 The mandate issued by the Ministry of Petroleum and Energy may be found in Attachment A.

2 The primary objectives of Energi21 are set out in the mandate from the Ministry of Petroleum and Energy, June 2008.

Research (R)	The term "research" refers to activities in specific thematic and technology areas that aim to expand the knowledge base within thematic and technology areas with a low degree of maturity and a high level of research needed. Strategic basic research is research of an experimental or theoretical nature that is primarily conducted to generate new knowledge to enhance the knowledge base in selected areas or topics. *Applied research* is also research of an original nature which is conducted to generate new knowledge primarily targeting specific practical objectives or application areas.
Development (D)	The term "development" refers to activities in specific thematic and technology areas that aim to expand the knowledge base within thematic and technology areas where a relatively low level of research is needed. The term encompasses the use of prototypes, component testing and small-scale pilots.
Testing and demonstration (demo, D)	Testing and demonstration facilities are relevant for thematic and technology areas in which there is a need for verification and adjustment of technology products and solutions at a realistic scale. Testing and demonstration facilities may be standalone facilities or integrated into operational facilities.
Market instruments	Market instruments are employed when RD&D activities are not the drivers for commercialisation. They are relevant for thematic and technology areas which are technologically mature and ready for market introduction.

In the long term, the most important instrument for realising the objectives of this strategy is the education and training of skilled professionals who will use their knowledge in trade and industry and society at large to solve problems and develop new solutions.

Structure of the strategy report

The first half of the report is comprised of introductory chapters which provide general information about the role and function of Energi21 and further clarification of the objectives and purpose of the strategy (Chapters 1-4). Chapter 5 describes how the recommendations set out in the first Energi21 strategy report have been followed up. Chapter 6 provides an overview of the landscape of national and international strategies, with a focus on the drivers and cooperation arenas that have a bearing on the revised Energi21 strategy. This establishes the foundation and framework – together with the Energi21 vision and industry objectives – for the strategic analyses and recommendations in Chapter 7.

Chapter 7 also presents a review and comparison of the various technology and thematic areas in an integrated energy perspective and in relation to the primary objectives of the Energi21 strategy. Future energy markets are characterised by uncertainty yet also represent a wealth of opportunity. With this in mind, the board has created a set of scenarios for future energy markets (up to 2030) against which it has assessed its recommendations. Chapter 8 presents these scenarios and provides a backdrop for understanding future potential for value creation and what is necessary for achieving it. Chapter 9 describes the six priority focus areas of the Energi21 strategy identified on the basis of the strategic analysis. The final chapter of the report, Chapter 10, proposes measures for implementing the strategic recommendations.

Global population in 2020

(Percentage of global total)

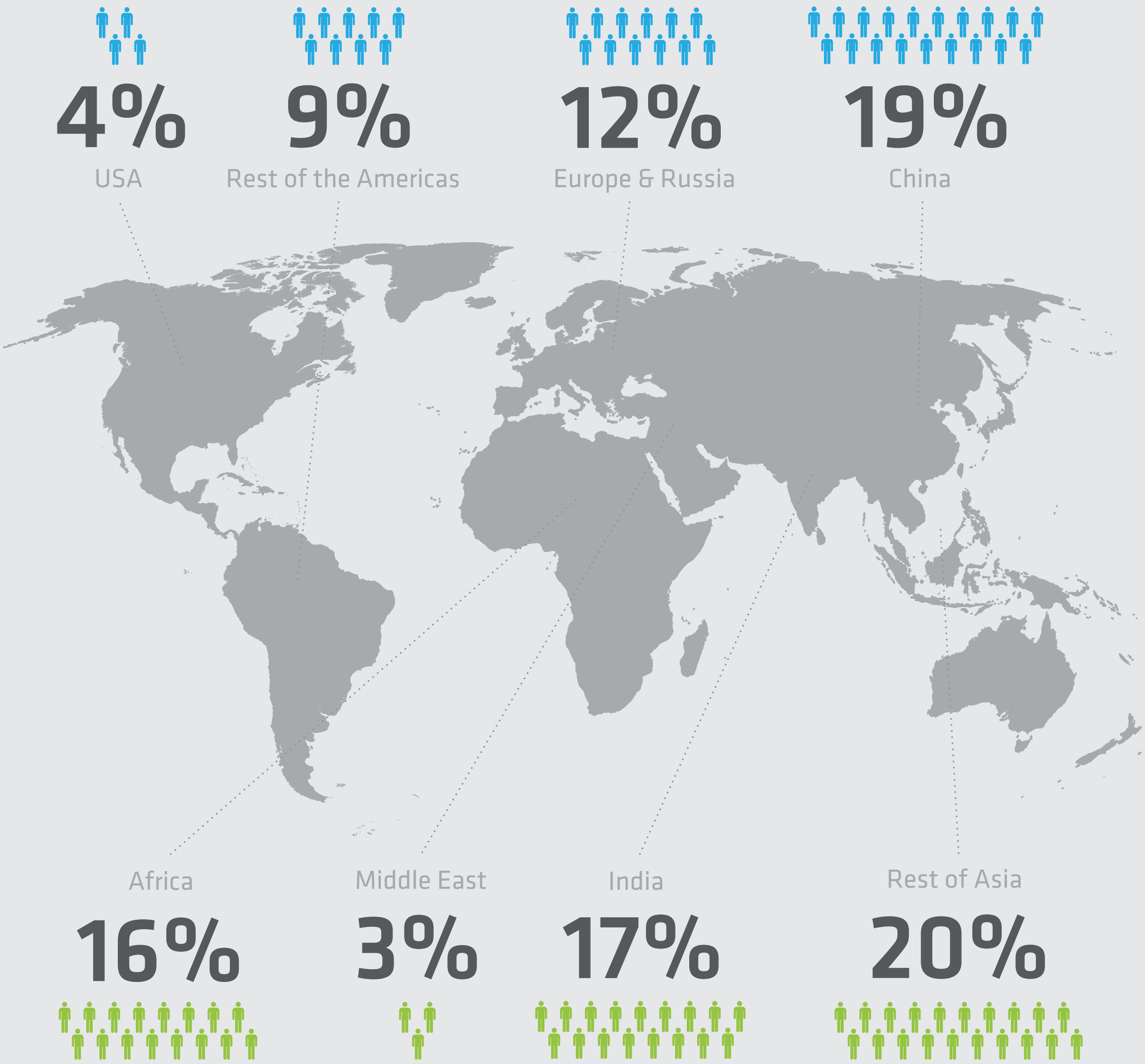

Illustration: altkanendres.no © 2011.
Source: CIA.

Energi21

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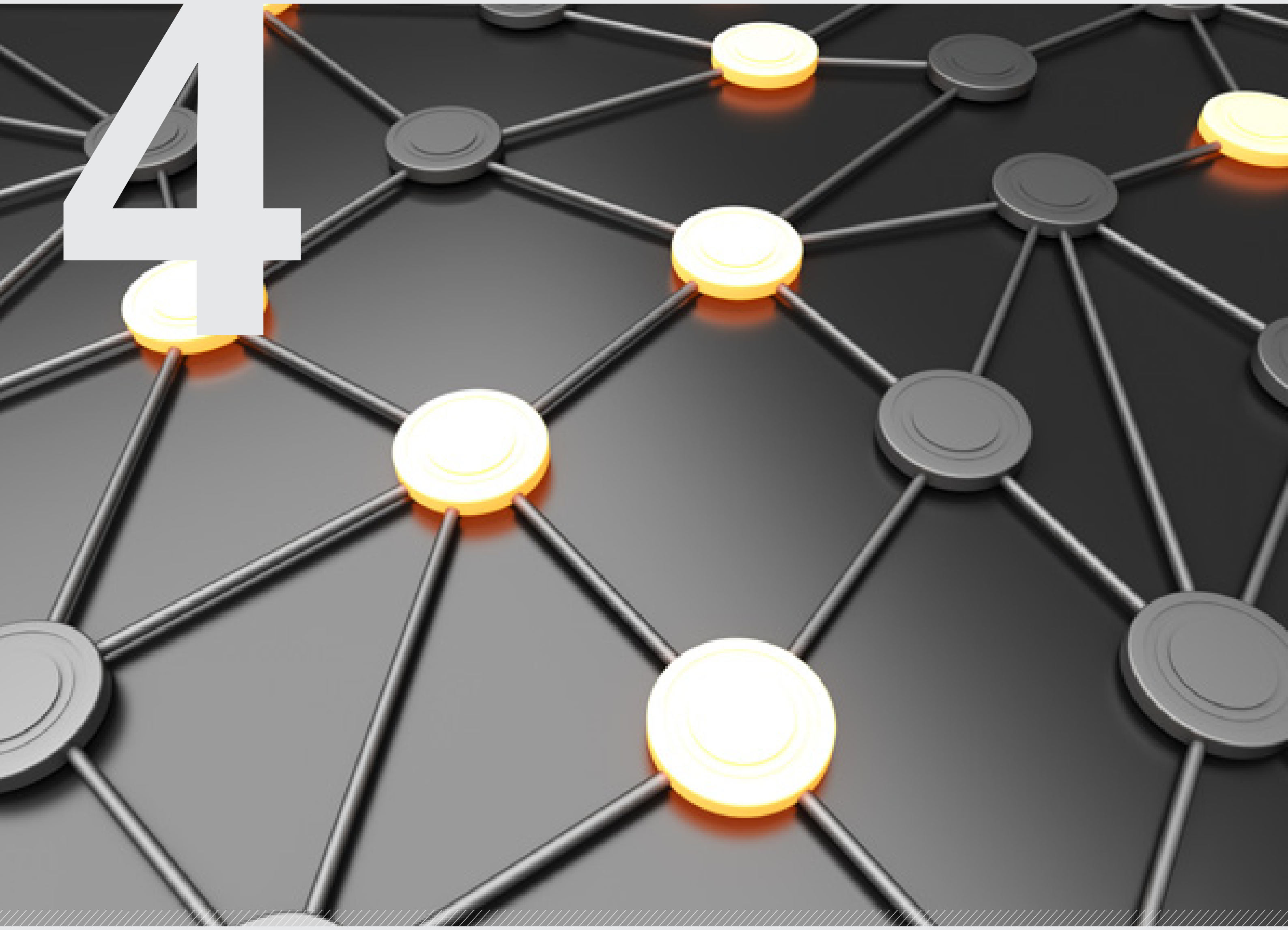

Photo: Shutterstock.

The Energi21 strategy emphasises the importance of integrated thinking in efforts to promote climate-friendly energy technology through strategic multidisciplinary cooperation between the authorities, trade and industry, and research and educational institution.

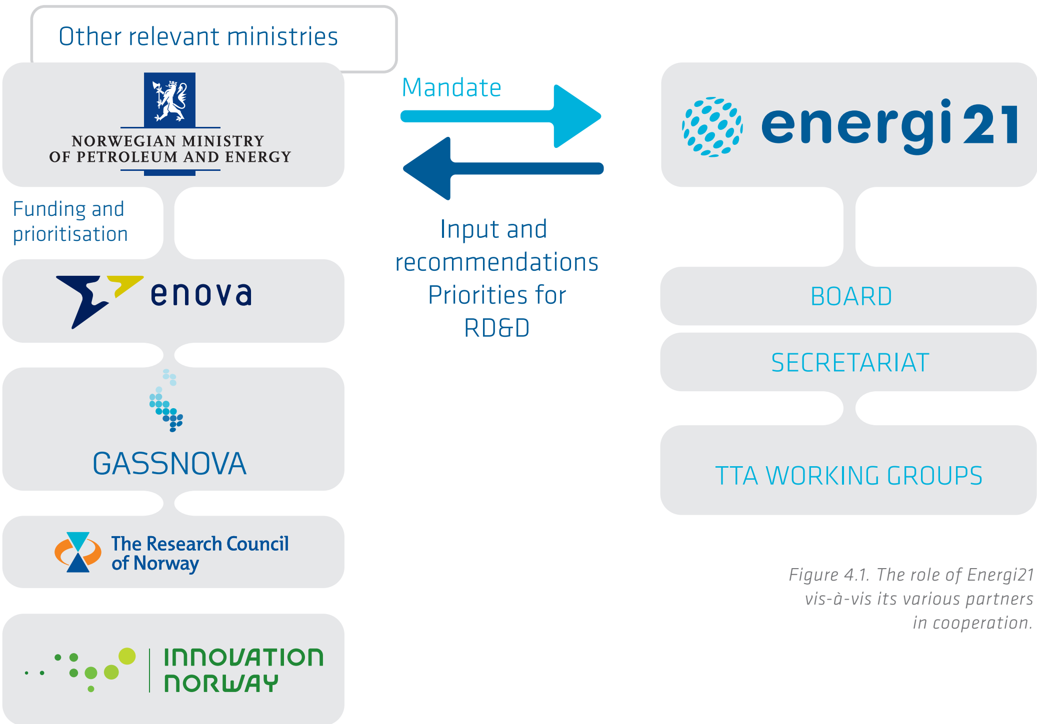

Figure 4.1. The role of Energi21 vis-à-vis its various partners in cooperation.

Energi21 is organised to promote sustainable value creation and security of supply through the intensified and coordinated involvement of the energy sector. Energi21 has a secretariat and its board is appointed by the Ministry of Petroleum and Energy.

The strategic analyses on which this report is based have been conducted by working groups in each of the Energi21 Technology Target Areas (TTA) and affiliated sub-groups:

- Renewable energy production
  - Hydropower, wind power and solar energy
- Energy systems
  - Transmission, distribution, policy structures, framework conditions and power market
- Raising energy efficiency in industry
  - Renewable thermal energy Bioenergy, geothermal energy, and distributed heating and cooling solutions
- CO_2 capture, transport and storage (CCS)
- Frameworks and social analysis

The TTA working groups are industry-led and have involved multidisciplinary collaboration between the industrial, research and educational sectors.

Attachment B lists the members of the working groups and affiliated sub-groups.

Figure 4.2 on the next page illustrates the structure of Energi21 and the organisation of the work process in drawing up the strategy document.

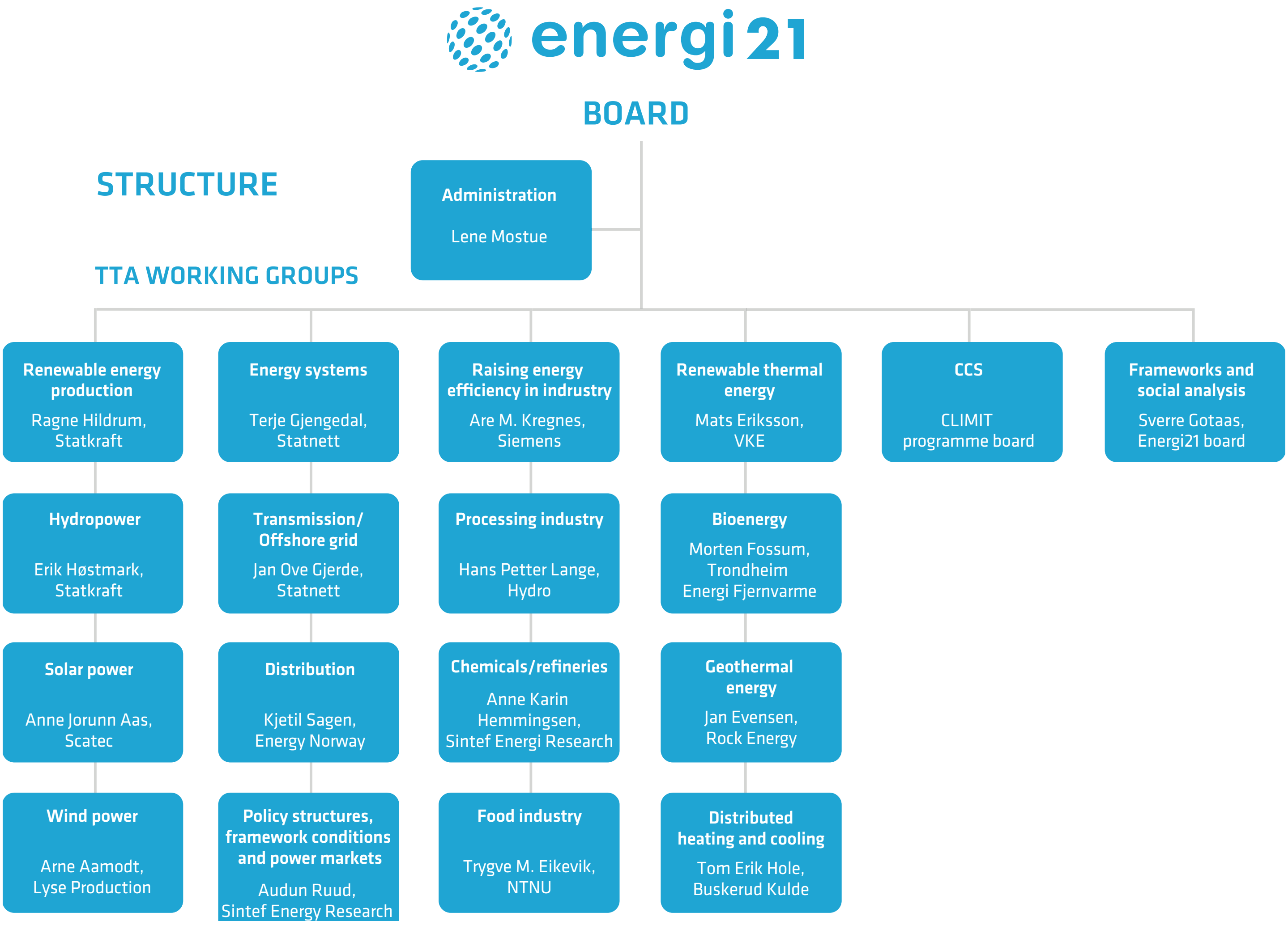

Figure 4.2. Organisation of the work process in drawing up the Energi21 strategy.

Percentage of the global population without access to electricity

Figures in millions

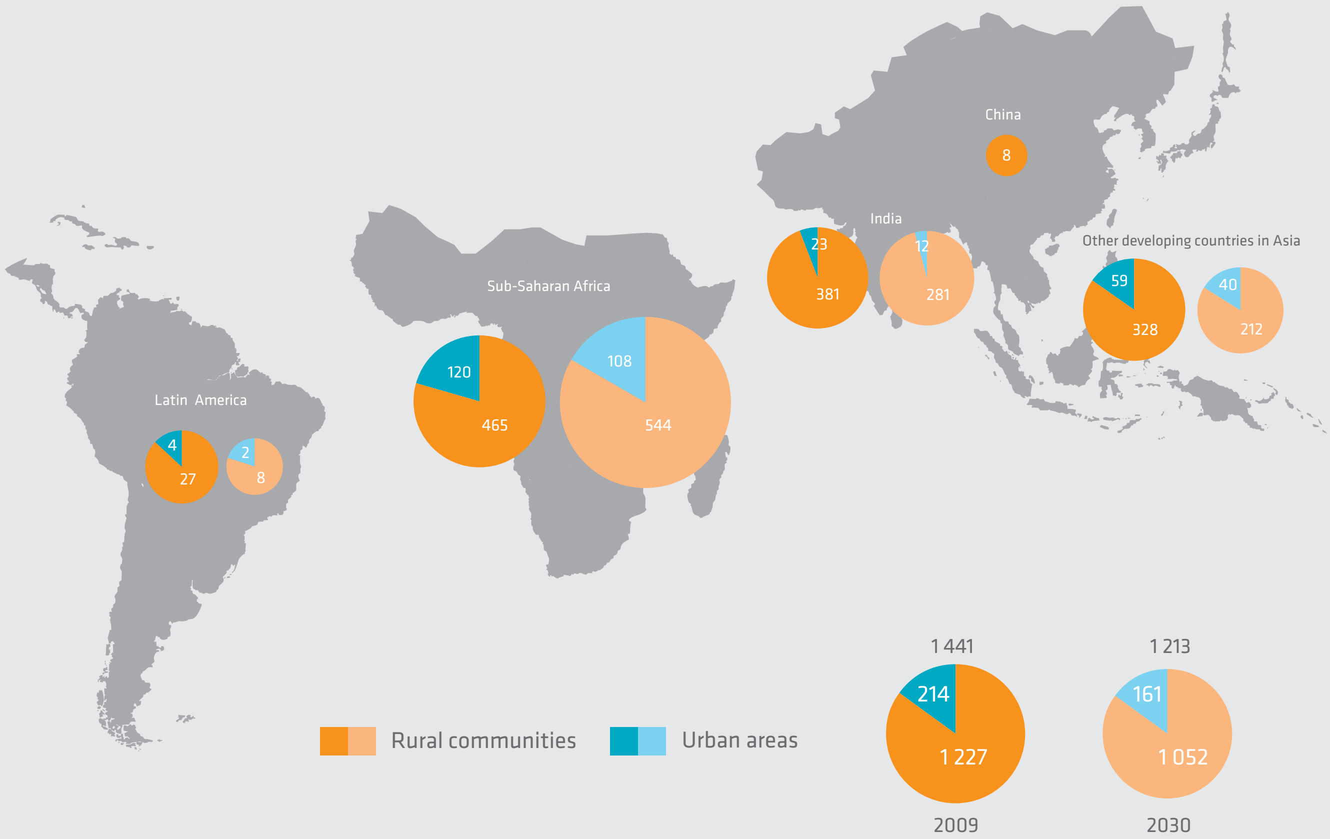

Illustration: www.altkanendres.no © 2011.
Source: IEA, World Energy Outlook 2010.

Impact of the Energi21 strategy

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Photo> Shutterstock.

The Energi21 board is extremely pleased with the way in which the authorities, trade and industry and the public agencies within the research and innovation system have followed up the recommendations of the previous Energi21 strategy from 2008. Recommendations related to the funding and organisation of research activities have been put into action, providing an excellent basis for further initiatives within the energy sector.

The 2008 Energi21 strategy was drawn up during a period characterised by a strong focus on climate and major modifications taking place in the energy sector. In the interim since the first strategy report was published, energy-related issues have become a more integral component of climate policy, and the framework conditions have changed.

Energi21 – setting the strategic agenda for the political agreement on climate policy

The Energi21 strategy report, with its well-grounded recommendations based on thorough analyses and the participation of all energy stakeholders in Norway, helped to set the stage for the negotiations leading up to the broad-based political agreement on climate policy achieved in the Storting in 2008.[1] The strategy report, with its clear recommendations, provided the Storting with a scientifically-considered foundation and a well-thought-out plan for strengthening the climate policy. This in turn provided an excellent basis for drawing up an ambitious, comprehensive political agreement on climate policy.

Recommendations from 2008 – What has happened?

The main recommendations of the Energi21 strategy from 2008 were:

- To achieve a major increase in public research funding.
- To establish centres for climate-friendly energy technology and social science-related energy research. These were to be international, industry-oriented and leaders in their field.

1 Negotiations in the Storting in the wake of Report No. 34 (2006-2007) to the Storting on Norway's climate policy resulted in a broad-based political agreement in 2008.

The authorities' follow-up of the strategy provides a sound basis for further initiatives in the energy sphere. Photo: Stortinget©

- To establish Energi21 as a permanent body with a board and a secretariat.

The broad-based political agreement on climate policy achieved in the Storting acted as a catalyst for the implementation of the strategic recommendations of the 2008 report. Significantly more resources were allocated to research and development.

Analyses of the Research Council portfolio show that allocations from the authorities to energy related research more than doubled during the period 2007-2010.

A large portion of the increased allocations has been channelled via the programme Clean Energy for the Future (RENERGI) and the Norwegian RD&D CCS programme (CLIMIT).

A number of other research programmes have also seen growth to their budgets. These programmes supplement the energy research conducted under the RENERGI programme, focusing on, for example, energy-related materials research. The distribution of funding among programmes is illustrated in Figure 5.2 on page 23 .

In addition to boosting resources for programme initiatives, the recommendation to establish centres for climate-friendly energy technology and social science-related energy research was implemented. Eight Centres for Environment-friendly Energy Research (FME) were launched on 9 February 2009, and three Centres for Social Science-related Energy Research (FME Samfunn) were added to the portfolio of the FME centre scheme on 15 February 2011.

The scheme is designed to foster intensive and systematic competence-building, integrated energy research and enhanced long-term cooperation between research communities, educational institutions and trade and industry.

The FME centres are guaranteed funding from the authorities and partner companies/institutions for up to eight years, providing them with a stable budget framework conducive to producing results.

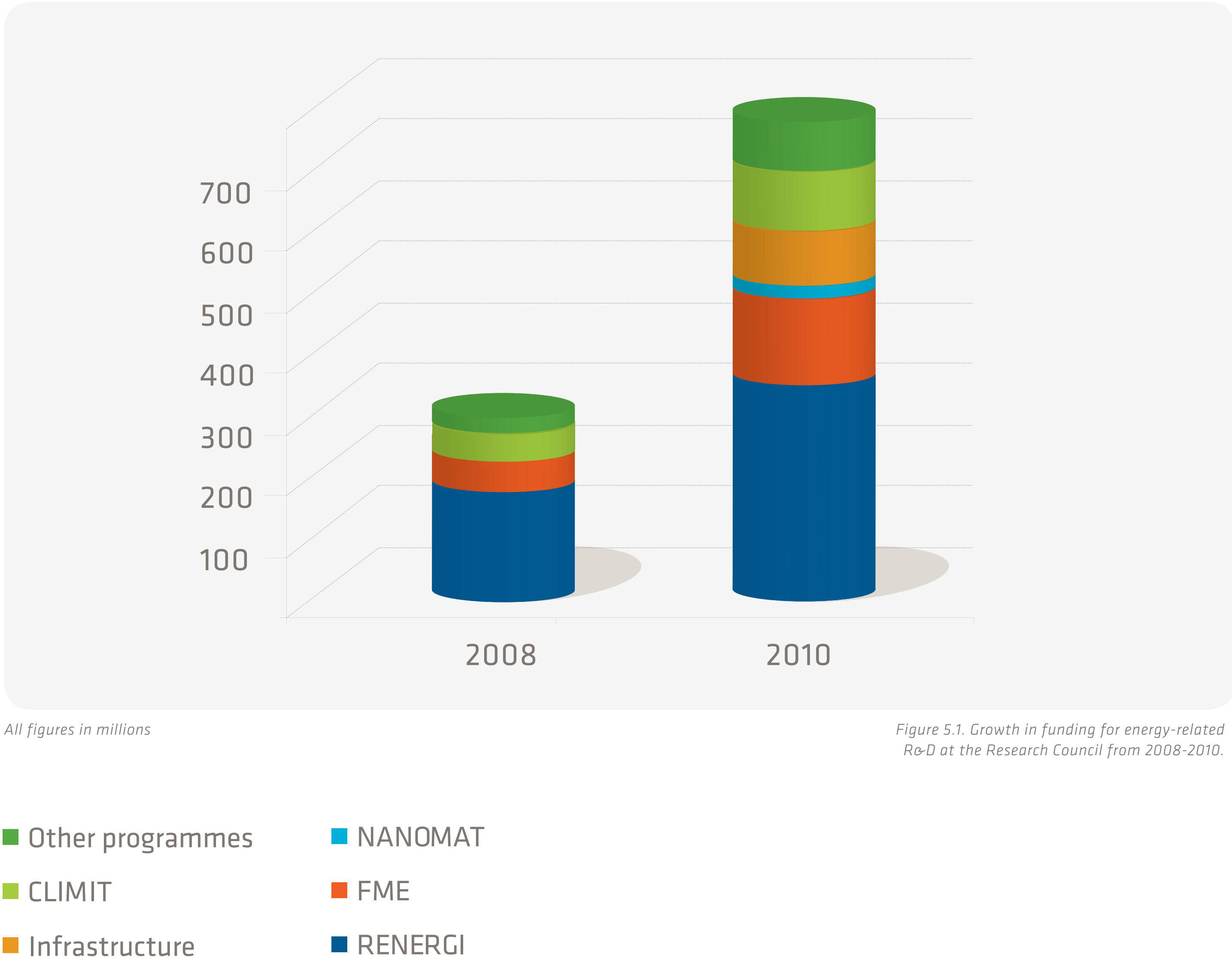
In spring 2011 the first step was taken to develop a national-level, interdisciplinary educational programme in renewable energy research. This will involve making use of the researcher training already underway for the fellowship-holders at the 11 FME centres to create a national graduate-level researcher school in the field of renewable energy.

The parlamentary agreement resulted in an increase of NOK 600 million in allocations to energy research in the period 2008-2010. The distribution of these allocations among relevant programmes at the Research Council is shown in Figure 5.1.

The significant increase in activities relating to research and development in the energy sector – in terms of both their funding and their organisation – has already spawned good results. These provide an excellent foundation for future efforts and served as the basis for the actions and priority focus areas proposed in this strategy report.

In addition to enhancing the funding and organisation of R&D activities, Energi21 was established as a permanent body with a board (2008) and a secretariat (2009), as recommended.[1]

1 The structure of Energi21 is illustrated in Chapter 4.



All figures in millions

Figure 5.1. Growth in funding for energy-related R&D at the Research Council from 2008-2010.

Distribution of allocations resulting from the broad-based political agreement on climate policy

– in total NOK 600 million in 2009 and 2010

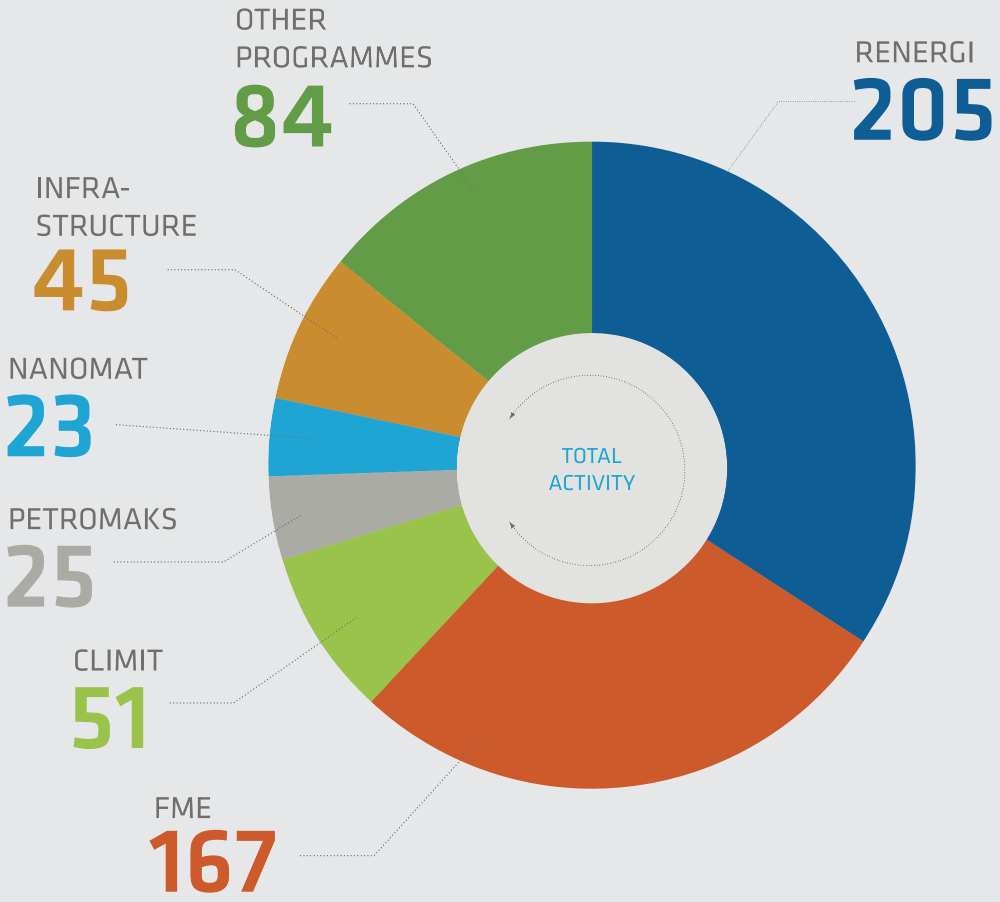


Figure 5.2. Distribution of funding resulting from the agreement, in total NOK 600 million in 2009 and 2010.

All figures in millions.

Norway as an energy nation in the 21st century

6

Photo: NorWind.

Ambitions for energy research must be high in the years to come if we are to succeed in finding solutions to current and emerging European and global energy and climate challenges. The development of such solutions will generate substantial growth in markets for new technology. Faster-paced innovation will therefore be a key success factor. There will be a need for international cooperation on access to resources, technological development and commercialisation. Multidisciplinary research cooperation across national borders will be crucial. Norway has resources, expertise and fully-matured industrial activities in many of the areas in which activities must be intensified.

6.1 Global climate challenges

Climate challenges represent some of the most pressing challenges facing the world community. Targeted, long-term national and global investment in climate-friendly energy technologies is essential to meeting the goal of the Intergovernmental Panel on Climate Change (IPCC) to limit the global temperature rise to two degrees C, which will require slashing the world's greenhouse gas emissions by 85% by 2050. Substantial international emission reduction targets have been set, and there are ambitions to achieve a zero-emissions society. Innovative solutions that are the fruit of international and multidisciplinary cooperation will be vital to achieving a zero-emissions society.

Climate-friendly energy and technology – a prerequisite for future welfare development

We are completely dependent on energy in order to fulfill our fundamental human need for food, clothing, shelter, transport, health care, recreation etc. – in short to provide us with what we need to live a healthy, satisfying life. The energy sector thus plays a major role in welfare development, and energy is one of the main pillars of social infrastructure. For many developing countries, secure, stable access to electricity is the key to overcoming poverty as well as the basis for industrial development and value creation.

According to the International Energy Agency (IEA), 68% of the world's total CO_2 emissions stem from industrial activities and stationary energy production and consumption. Production of electricity and heating alone account for 41% of this.[1] Fossil energy sources are the locomotive of today's welfare society and will continue to play an important role in the energy chain for many years to come. A vital challenge is therefore to make the shift to an efficient global energy system based on climate-friendly resources and technologies that help to reduce emissions from fossil energy sources.

Technology mix – pivotal to future energy systems

Analyses conducted by the IEA show that a wide array of energy technologies must be put into use if we are to meet our climate goals and targets, including raising energy efficiency.[2] No stone must be left unturned, and technology development activities must be intensified across the board. Achieving a zero-emissions society will require substantial investment in an effective combination of new and existing technology. Increased investment costs to meet the two-degree target are estimated at USD 1 100 billion on average per year up to 2050. On a positive note, this represents major market opportunities for technology suppliers. According to the IEA, technology transfer to developing countries and wide-reaching energy policy instruments will be crucial to carrying out the "energy revolution" we need.

6.2 International markets

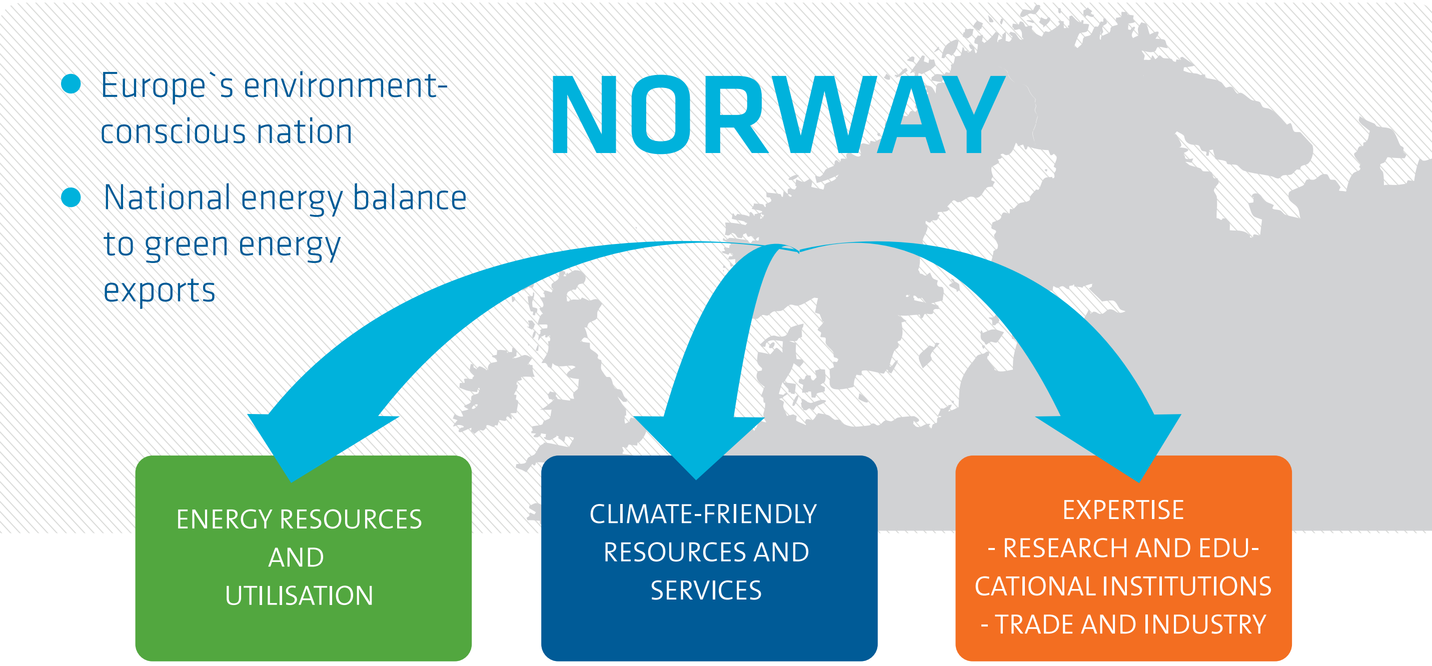
Climate-friendly technology is now one of the world's fastest-growing technology markets even though that segments of today's market primarily comprise new and immature technologies. High-paced growth in the global market is expected in the years to come. Estimates vary from technology to technology, with solar energy and wind power technology showing the greatest growth in recent years. Estimates regarding future growth in the climate-friendly energy technology market also vary from player to player. Nevertheless, all of the estimates indicate extensive growth potential.
Many players are identifying business opportunities in this new industry, and more and more countries are positioning themselves in this market. Many countries select some number of limited areas of environmental technology in which to concentrate their investments and design funding instruments to promote growth along the entire innovation chain in these particular areas. For example, Germany is immersing itself heavily in the wind power area.

Many countries are now formulating very ambitious goals for constructing renewable energy production facilities, and for enhancing the efficiency and implementation of various types of climate-friendly technology. It is vital to carve out a position as a player in these rapidly-developing markets.

Norwegian companies may have competitive advantages in these growth markets as a result of their access to resources, technological expertise and experience. Expertise from the petroleum, maritime, process and materials technology industries as well as the power market is important in this context, and provides a solid foundation for developing profitable Norwegian industrial activities in the fast-growing climate-friendly energy technology market. A large proportion of Norwegian technology products and services are targeted towards the European export market. Norway has already made a name for itself as a supplier of technology and services to the solar, hydropower and offshore wind power industries. Comparatively speaking, Norway has excellent competitive advantages within several technology areas. These must be effectively and fruitfully utilised to ensure future value creation and make optimal use of resources.

1 The IEA, "CO2 Emissions from Fuel Combustion" 2010.

2 The IEA, "Energy Technology Perspectives" 2010.



Vision: Europe's energy and environment-conscious nation – from a national energy balance to green energy exports.

6.3 Energy and research policy drivers

International energy and research policy is being targeted towards future energy and climate challenges to an increasingly greater extent, seeking goals that will enable us to become less dependent on fossil energy sources and replace them with effective, climate-friendly alternatives.

Energy policy plays a critical role in setting the framework for energy research. Security of supply, job creation and climate-friendly energy technology currently serve as prominent motivating factors on the international energy policy agenda, and are helping to shape the direction and type of future research efforts.

The EU climate and energy package – 20-20-20 targets

The European Commission adopted the Renewables Directive (2009/28/EC) in December 2008 as one of several measures to reduce greenhouse gas emissions. The directive defines clear targets for emissions reduction, use of renewable energy sources, and raising energy efficiency. By 2020 the EU will reduce its CO_2 emissions by 20%, cut energy consumption by 20% and increase the renewable energy share from 8.5% to 20% of final consumption.

The Renewables Directive applies within the EEA, and therefore lays the foundation for Norway's energy policy. In connection with the implementation of the directive Norway will have to increase its renewable energy share, primarily in the transport and heating sectors as electricity production in Norway is already nearly 100% renewable.

The energy restructuring required to achieve a sustainable system is proceeding too slowly in relation to meeting the 20-20-20 targets and the long-term objective of an 85-90% reduction in emissions by 2050. In response to this, the European Commission has drawn up a new European energy strategy towards 2020[1] and a roadmap for implementation of proposed measures.[2]

The main focus of the Energy 2020 strategy is on the sustainable development of a common European internal and external energy policy.

The strategy sets out five priorities:

- Achieving an energy-efficient Europe.
- Building a pan-European integrated energy market.
- Empowering consumers and achieving the highest level of safety and security.
- Extending Europe's leadership in energy technology and innovation.
- Strengthening the external dimension of the EU energy market.

The third EU Internal Energy Market Package

Adopted by the European Commission in 2009, the third Internal Energy Market Package involves structural changes in the EU energy market. The main aim is to ensure a well-functioning market through stricter organisational divisions between the various energy actors (in production, consumer sales and the various infrastructures). A key measure is to develop a common European grid development plan to ensure more efficient use of resources, a smoothly-operating market, adequate market access and improved access to new, climate-friendly energy production.

1 Energy 2020 – A strategy for competitive, sustainable and secure energy (10 November 2010).

2 EU Roadmap 2050 (March 2011).

Norway is involved in the efforts associated with the Internal Energy Market Package.

NER300

The European Commission has awarded approximately EUR 1 billion to six demonstration projects as part of the crisis package in the wake of the economic crisis in 2008. The EU will also use income generated by selling allowances on the carbon market to fund demonstration facilities. In accordance with the NER300 Decision, 300 million carbon allowances may be sold and the proceeds used to provide co-funding for CCS demonstration projects and demonstration projects for innovative renewable energy technologies. Facilities must be operational by 31 December 2015 to be eligible for NER300 grants.

Creating a new energy industry and new jobs

The EU is implementing its climate targets as a tool to promote industrial development and job creation within the energy sector. Energy policy is deliberately being linked to industrial policy to encourage the establishment of a European energy industry that will serve its home market as well as compete on the international market. The use of strong incentives and instruments to stimulate investment in new renewable energy production and new energy technology to meet the 20-20-20 targets will also generate favourable framework conditions for establishing and regulating the new European energy industry.

The EU Seventh Framework Programme (2007-2013)

The EU Seventh Framework Programme for Research and Technological Development (2007-2013) is crucial for energy research, providing funding for RD&D projects targeted towards climate-friendly energy sources, raising energy efficiency, power grids and CCS in particular. The EU framework programme is an important supplement to our national research programmes. Funding announcements under the framework programme are often very detailed, as European industry and research groups tend to be closely involved in determining the content of the calls, which thus become very specific and adapted to the research questions with which these groups are working. Efforts are now underway to determine the direction of the EU Eighth Framework Programme.

Strategic Energy Technology Plan

The Strategic Energy Technology Plan (SET Plan) is designed to accelerate the development and implementation of climate-friendly energy technologies in Europe, and is the main technology pillar of EU energy and climate policy.[1] The plan provides a framework for stepping up RD&D activities for technologies that can contribute to achieving the 20-20-20 targets. In a long-term perspective, the plan is designed to help to further cut costs for technologies aimed at realising the EU vision of an 85-90% reduction in emissions by 2050. The plan is designed to cultivate a European energy industry, and its implementation will greatly intensify international cooperation and boost joint funding of projects.

Norwegian-Swedish electricity certificate market

On 15 April 2011, the Norwegian Government proposed a bill to establish a common Norwegian-Swedish market for green electricity certificates in 2012. This market-based instrument is designed to encourage investment in renewable energy production, and is expected to result in the production of 26 TWh of new, climate-friendly energy in Norway and Sweden.

6.4 National policy framework

Political agreement on climate policy

The broad-based political agreement on climate policy achieved in the Storting in 2008 led to:

- recognition of the challenges relating to climate change;
- agreement on a national initiative to reduce greenhouse gas emissions;
- channelling of resources towards achieving emissions reduction targets, including funding for RD&D activities;
- fixed target figures.

The agreement on climate policy also provided the political basis for the establishment of the common green electricity certificate market with Sweden.[2] It is a key component of the foundation underlying the Energy21 recommendations.

Climate Cure 2020

The analysis in the Climate Cure 2020 report is based on the target for national emissions cuts stipulated in the broad-based political agreement on climate policy. The aim is to reduce emissions in Norway by 15-17 million tonnes of CO_2 equivalents by 2020 in relation to the reference path presented in the national fiscal budget for 2007, the effect of forests included. Forestry measures are estimated to yield a net uptake of 3 million tonnes of CO_2. Domestic emissions must therefore be reduced by 12-14 million tonnes of CO_2 equivalents, so that they do not exceed 45-47 million tonnes of CO_2 equivalents by 2020. Norway aims to be carbon neutral by 2050. Calculations show that there is significant potential for emissions reductions in connection with energy use in buildings, and the report lists regulations, financial instruments and competence-building as possible tools in this context. The report also states that CCS measures will be valuable in reducing emissions, primarily via capture of CO_2 from major industrial point sources.

The Government is now working on designing future climate policy instruments in connection with the new white paper on

1 European Strategic Energy Technology Plan (SET Plan). A collective plan for development of energy technology in the EU.

2 A common Norwegian-Swedish market for green electricity certificates will result in the production of 26.4 TWh in renewable energy in the period 2012-2020. Each country will be responsible for producing 13.2 TWh. Start-up is scheduled for 1 January 2012.

climate policy to be presented in 2012. It is expected that the white paper will address the proposals in the Climate Cure 2020 report.

White paper on energy in 2012

The Government is scheduled to present a white paper on energy in 2012. The white paper will address the energy and power balance in Norway in a long-term perspective up to 2030 and up to 2050, in addition to key impact factors. The white paper on energy will establish a clearly-defined framework for national energy and energy research policy.

White paper Climate for Research

In Report No. 30 (2008-2009) to the Storting: *Climate for Research*, the Government sets the course for Norwegian research policy in the years ahead.

The white paper points out that climate change is one of the most pressing challenges facing society and is therefore a priority area for research.

The Government has set specific goals for its research policy. These involve the role that research is to play in meeting global challenges relating to access to energy, climate change, and the environment and development, among others; in further developing the Norwegian welfare state, for example through research on welfare state-related professions; and in laying the foundation for future value creation. Energy is listed as a key strategic area for industry-oriented research.

The white paper also defines five strategic goals that address how Norway can generate high-quality research, gain international renown, use research results and funding more efficiently, and ensure the implementation of a well-functioning research system.

OG21 and Maritim21

A national strategy corresponding to Energi21 has been drawn up for the Norwegian oil and gas industry and maritime sector, respectively – OG21 and Maritim21.[1] These strategic platforms identify valuable arenas for cooperation in various research areas covered by the Energi21 strategy. There are significant synergies that can be exploited between these areas, both in terms of processes and in terms of joint development of strategic activities in areas with a shared interface. Each strategic platform involves different industries and industry stakeholders.

Cooperation will benefit all parties and result in more effective strategic recommendations and action-oriented solutions.

Klima21

The Klima21 strategic forum for climate research was established as part of the follow-up of the broad-based political agreement on climate policy achieved in the Storting in 2008.[2] The task of the Klima21 forum is to ensure that climate policy and climate-related management and actions are rooted in research-based knowledge. The forum focuses on the research areas of climate development, climate change and its impacts, adaptive responses to climate change, climate policy, and measures to reduce greenhouse gas emissions.

In accordance with its mandate, the Klima21 strategic committee has drawn up a strategy report which identifies areas that are of relevance for Energi21 as well. In addition to those mentioned above, strategic bodies are being established for the aquaculture industry and construction industry, respectively – Hav21 and Bygg21. It is expected that these strategies will also address areas that share an interface with Energi21.

6.5 Energy systems for the future – international knowledge and competitive arenas

Tomorrow's climate-friendly energy systems will require innovative solutions developed through multidisciplinary national and international cooperation. Targeted research and innovation activity, both on the part of the authorities and trade and industry, is a key factor for success.

Participation in international research cooperation is essential to the establishment of necessary knowledge platforms and the development of innovative energy solutions.

National research groups of high international calibre are crucial for establishing and gaining access to international knowledge production. International cooperation will also promote and further develop a competitive, knowledge-based industrial sector in Norway. Cooperation within the European framework is a priority and comprises the main arena for international cooperation for Norwegian researchers. Norway has participated in, and benefited greatly from, the EU Framework Programmes since 1994. Norway is an active participant in several initiatives under the SET Plan as well as in projects funded under the EU Seventh Framework Programme.

In addition, Norway participates on a broad scale in the IEA's Technology Collaboration Programme, particularly in Multilateral Technology Initiatives (also known as Implementing Agreements) on renewable energy, end-use/electricity, and fossil fuels.

Norway's presence in these arenas is crucial if the country is to gain a position at the international research front. It is important that Norway maintains its role in international cooperation efforts and enhances this role in areas in which it will have the greatest effect.

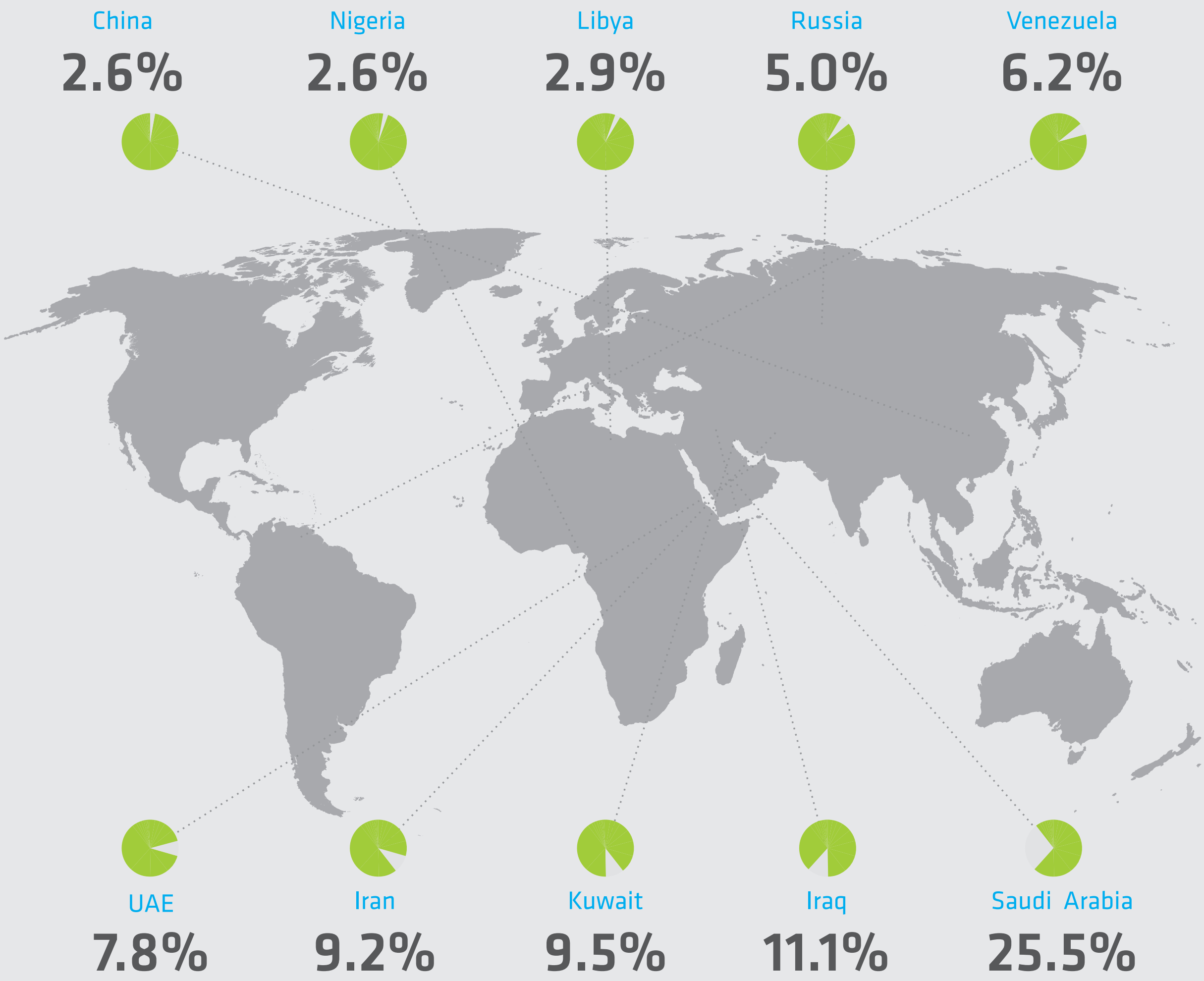
Priority should also be given to bilateral cooperation with rapidly-growing research nations outside Europe in areas in which it will boost research quality, expand the knowledge base and provide a basis for cultivating opportunities for Norwegian trade and industry in international markets. North America and the Asian countries with fast-growing economies are particularly relevant partners for cooperation.

1 The OG21 strategic body has the same structure as Energi21, and the board has also been appointed by the Ministry of Petroleum and Energy. Maritim21 is a cohesive research and innovation strategy for the maritime industry in Norway drawn up on assignment from the Ministry of Trade and Industry. See the following websites for further information: www.og21.no, www.maritim21.no.

2 The Klima21 strategic committee received its mandate from the Ministry of Education and Research and submitted its initial strategy report to the ministry in February 2010.

Global oil reserves

In percentage



Other:

USA	*2.2%*
Mexico:	*1.5%*
Qatar:	*1.4%*
Algeria:	*1.3%*
Norway:	*1.0%*
Brazil:	*0.8%*
EU:	*0.7%*
Indonesia:	*0.7%*

Source: Global Oil Reserves.

Energi21 – a strategic analysis

Photo: Shutterstock.

7.1. Introduction

This chapter presents an overall analysis of relevant thematic and technology areas. Most of the basis for analyses have been conducted by working groups and sub-groups under the Technology Target Areas (TTA). The analyses identify the factors to which the Energi21 board has attached the greatest weight and which form the basis for the priority focus areas presented in Chapter 9. The analyses also present more targeted courses of action in vital areas.

The review of each thematic and technology area is concluded with a brief summary of the following key elements:

- industrial ambitions;
- strategic research areas and objectives;
- measures for implementation.

In their reports, the TTA working groups and sub-groups present a detailed account of specific industry ambitions and objectives, as well as research activities and recommended measures for achieving these ambitions and objectives. Supplementary information for each of the thematic and technology areas given priority in the Energi21 strategy may be found in these reports.

The board of Energi21 would like to point out, however, that the reports contain the views and input from the individual groups, representing their own assessment of their specific area of concern. The Energi21 board has carried out an overall assessment of all the TTAs, considering each thematic and technology area in relation to the others.

A simplified diagram has been prepared for each thematic and technology area, illustrating which of the Energi21 strategy's primary objectives the technology supports; please see the example in Figure 7.1 below.

The colours of the technology arrows indicate the degree of a technology's maturity (Figure 7.2), i.e. whether a given technology can be implemented by 2020 (green arrow) or whether current research challenges will delay implementation of the technology until after 2020 (orange arrow).

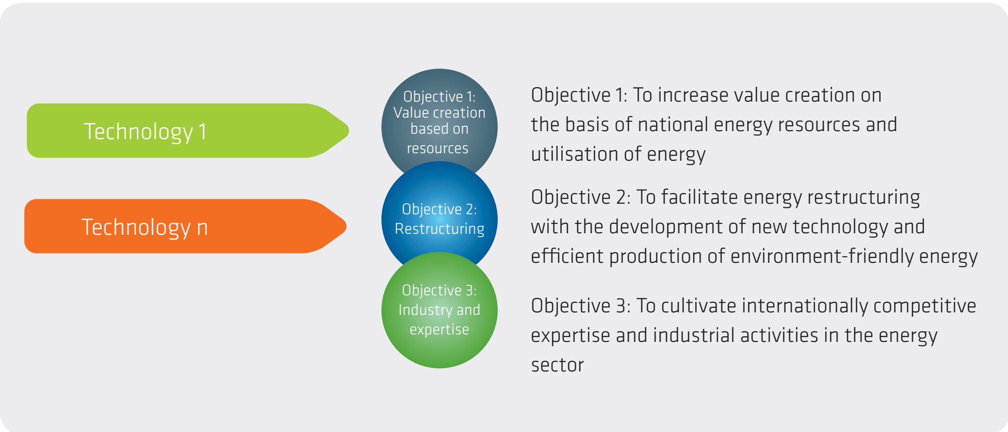


Figure 7.1. Relative contribution to realising the primary objectives. The green arrow represents technological maturity, while the orange arrow indicates a continued need for technological advances.

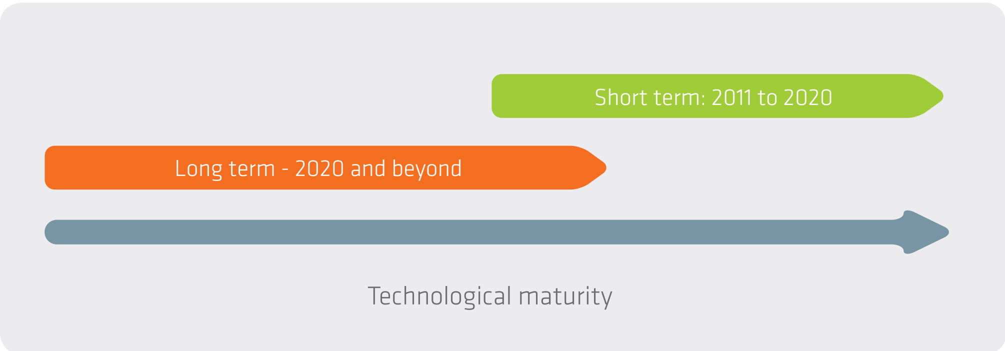
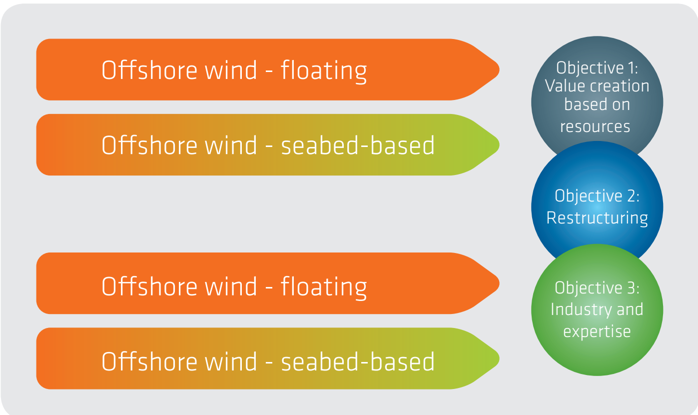


Figure 7.2. Technological maturity and time perspective are illustrated by the colour and placement of the technology arrows.

The first pilot wind turbine of the Hywind concept was deployed southwest of Karmøy, Norway, in autumn 2009. Photo: Statoil.

7.2 Review of technology areas



7.2.1 Offshore wind power – seabed-based and floating

Norway's supplier industry is currently involved in both offshore and onshore wind farms. Norwegian companies are hoping to achieve substantial exports of technology and services to the growing market for offshore wind power. Some Norwegian suppliers and energy companies have already found success in this market, particularly in Denmark, Germany and the UK.

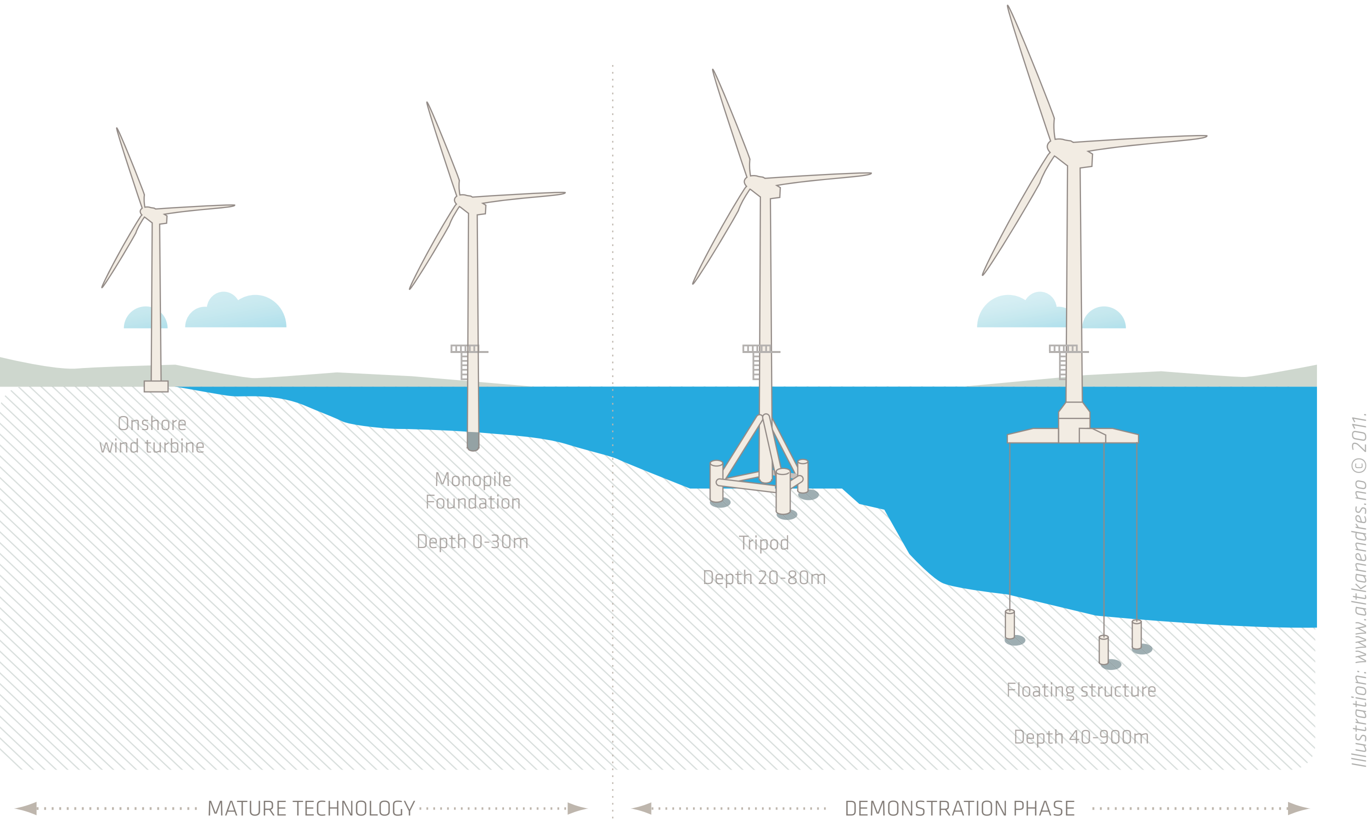
International market

Offshore wind power is a new area of activity in which the market and technology are still immature. Norwegian players have acquired a considerable competence base from offshore oil and gas activities dating back to the 1970s. This expertise is widely perceived to have commercial potential in the offshore wind power segment.

As of 2010, just over 3 000 MW of offshore wind power capacity had been installed, nearly all of it (2 946 MW) in Europe.[1] Outside of Europe, only China (103.5 MW) and Japan (28.5 MW) had installed offshore wind power capacity as of 2010. The market for offshore wind power is expected to grow rapidly in the future. Worldwide, offshore wind power accounts for just 1% of all installed wind power capacity (197 000 MW in 2010), and few Northern European countries have established activities in this area. Strong policy drivers, subsidy schemes and high willingness to invest portend rapid future growth in the international market for offshore wind power. The European Wind Energy Association (EWEA) defines its targets as 40 000 MW of offshore wind power capacity by 2020 and 150 000 MW by 2030. In 2011 the EWEA expects to see 1 000 to 1 500 MW of new installed capacity, with an overall turnover of more than EUR 3 billion for the industry.

It is vital to keep in mind that the market for offshore wind power is an international one, and that this will also encompass the prospective – and promising – Norwegian market. Although geographic proximity to the domestic market will clearly entail certain advantages for the wind power industry in Norway, it is unrealistic to build an industry exclusively targeting a Norwegian market that will not emerge until well into the future.

1 Norwegian Wind Energy Association (NORWEA).



It appears likely that the initial developments in offshore floating wind power will take place on continental shelves other than Norway's, and the players seeking a position within offshore wind power will have to target their efforts at these international markets.

Norway's competitive advantages

New , improved methods and technology for installation and anchoring foundations at sea – for both seabed-based and floating turbines – together with efficient operational and maintenance systems may help to reduce the costs of offshore wind power substantially. This opens up opportunities for Norwegian companies to develop new technology and services for a growing international market. National competitive advantages in the form of experience and expertise obtained from the oil and gas and maritime industries place Norwegian industry in an excellent position to succeed in this market.

The Maritim21 strategy fills the same role for Norway's maritime sector as Energi21 does for the energy sector. Maritim21 points to ships and ship's gear for maritime operations as an important research area in which Norwegian players have great potential.

AMBITIONS

- Developing a Norwegian supplier industry for offshore wind power – seabed-based first, then floating.
- Increasing cost-effectiveness in all phases, from design to installation to operation and maintenance, without compromising health, safety and the working environment (HSE).

STRATEGIC RESEARCH AREAS AND OBJECTIVES

- Designing optimal foundations for different seabed conditions.
- Improving the installation of and anchoring foundations for offshore turbines.
- Designing cost-effective systems for operation and maintenance.
- Developing methods and systems for condition-based maintenance.

MEASURES FOR IMPLEMENTATION

- Launching KPN projects[1] and Researcher Projects[2] within the strategic research areas described above.
- Providing funding for industry initiatives with value-creating potential in this area.
- Providing funding for testing and demonstration facilities.

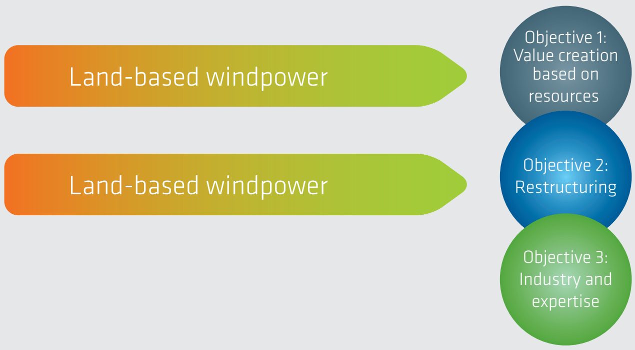
1 KPN projects are Knowledge-building Projects for Industry, a project type at the Research Council of Norway in which research institutions and universities develop the expertise that industry says it needs, and where companies take part and provide co-funding.

2 Researcher Projects are strategic basic research projects carried out at universities, university colleges and independent research institutes.

Smøla Wind Farm. Photo: Statkraft.

Hundhammerfjellet Wind Farm. Photo: Nord-Trøndelag Elektrisitetsverk (NTE)/Steinar Johansen.

7.2.2 Land-based wind power



AMBITIONS

- Increasing the cost-effectiveness of utilising available resources.

STRATEGIC RESEARCH AREAS AND OBJECTIVES

- Designing cost-effective systems for operation and maintenance.
- Developing methods and systems for condition-based maintenance.

MEASURES FOR IMPLEMENTATION

- Will be realised through the already planned green certificate scheme.
- Providing funding for industry initiatives within the strategic research areas above.
- Providing funding for industry initiatives with value-creating potential in this area.

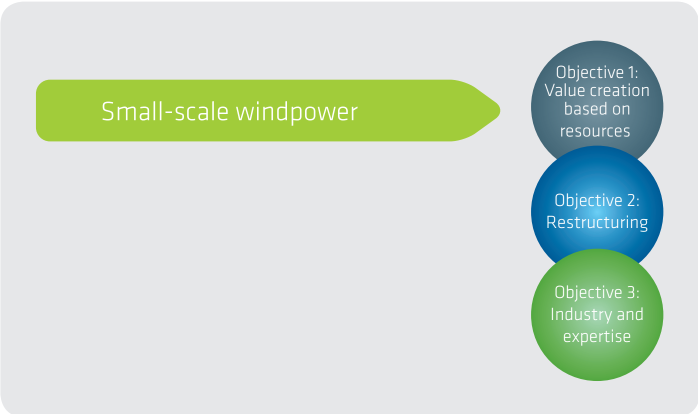
There is great potential for utilising land-based wind power in Norway, and this can be realised without carrying out major technological research. The soon-to-be established common Norwegian-Swedish market for green electricity certificates may facilitate the development of land-based wind power.

The value of Norwegian wind power is enhanced by the potential for coordination with the nation's hydropower system. Hydropower plants with pumped-storage capacity could enhance this even more. The value-creating potential of wind power may be realised through ordinary existing and future incentives.

A small-scale hydropower plant at Hyen in Sogn & Fjordane county, Norway. Photo: Endre Barstad.

A salmon trap. Photo: Seagull Production.

7.2.3 Small-scale hydropower plants



Over the past five years, interest in developing small scale hydro-power has risen significantly. These small scale plants are basically scaled-down versions of large hydropower facilities. Developing and constructing small-scale hydropower plants represent marginal investments and require cost-effective solutions.

To pave the way for expanded use of small-scale hydropower plants, it is vital to ensure that projects are financially sound both during the development phase and in terms of long-term revenues over the plants' lifespan.

It is essential to have effective cost controls and technical solutions to ensure lower development costs. Equally important is the projected revenue base to remain steady over time. Watershed runoff is one of several critical factors for revenues. Often there is not a clear enough picture of future runoff, which poses a substantial financial risk. Historical hydrological time series are normally used to forecast future production, but where there is little historical record available, the financial uncertainty and risk can be high.

AMBISJONER

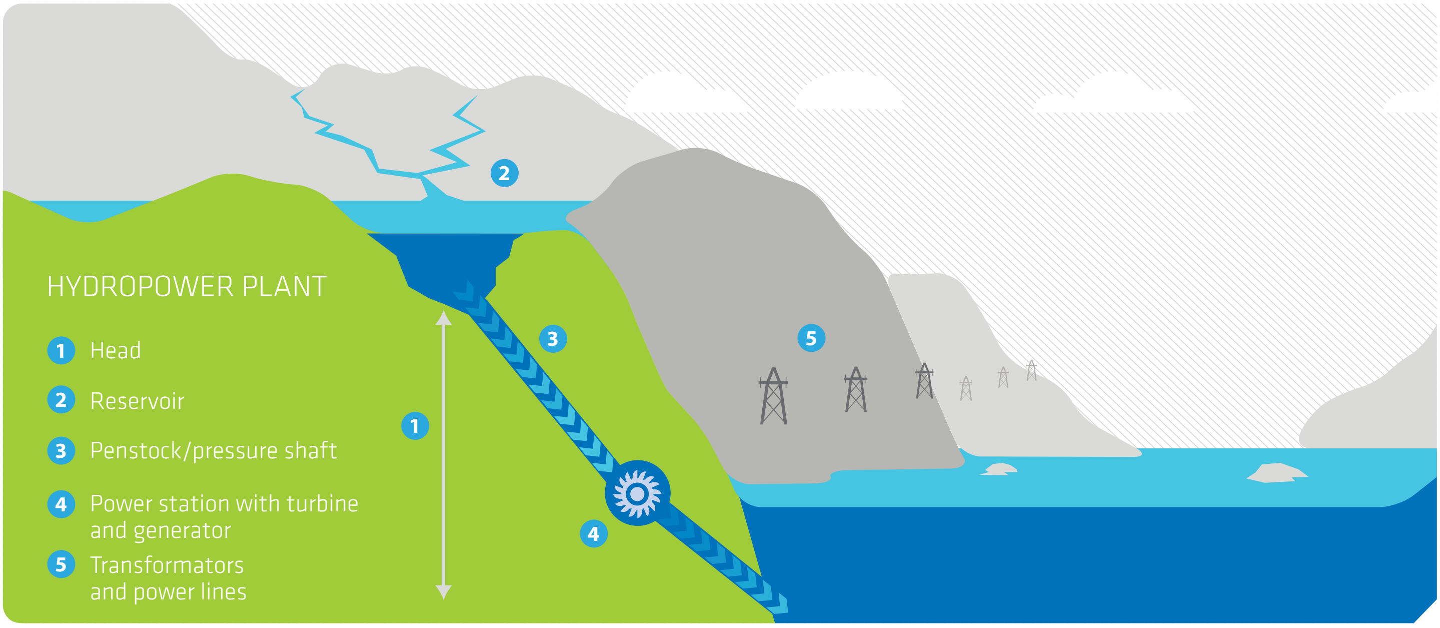
- Utilisation of available resources.

STRATEGIC RESEARCH AREAS AND OBJECTIVES

- Hydrology and watershed runoff – improving systematisation of experiential runoff data for small drainage basins and development of good hydrological calculation methods for unmeasured areas.
- Further developing drilling technology for environment-friendly waterways without visible impact.

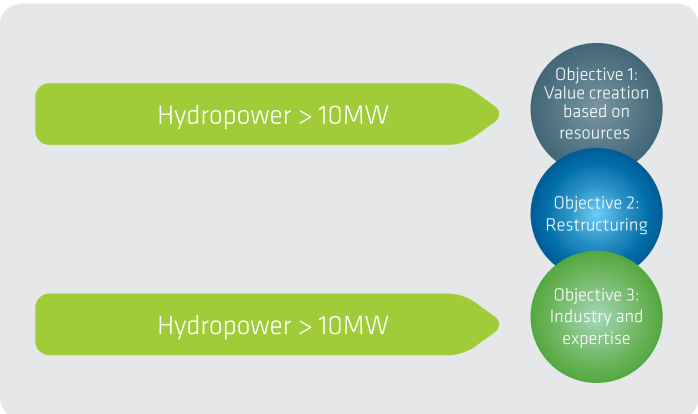
MEASURES FOR IMPLEMENTATION

- Will be realised through the already planned green certificate scheme.
- Launching KPN projects and Researcher Projects within the strategic research areas described above.



The principle elements of a larger-scale hydropower plant. Illustration: © www.altkanendres.no 2011.

7.2.4 Hydropower technology, facilities >10 MW



There are opportunities for Norway's industrial and energy sector to play a part in the expansion of international large scale hydropower development that is installations with more than 10 MW installed capacity. Major hydropower projects are relevant in Asia, Latin America, the Balkan states and in time in Africa as well. With over a century of experience in the construction and operation of hydropower facilities, Norway possesses a solid knowledge and experience base.

It is important for Norway to nurture and strengthen its position in the field of hydropower in order to maintain and continue developing Norwegian expertise in environment-friendly hydropower technology. Moreover, this expertise is fundamental to ensuring efficient operation and maintenance of existing hydropower facilities in Norway. Future value creation and industrial development in the hydropower segment will require extensive experience and expertise in hydropower technology.

AMBTIONS

- Promoting the environment-friendly, cost-effective construction of new hydropower capacity internationally.
- Refining and enhancing Norwegian hydropower expertise in order to:
  - ensure sound operation and further development of Norwegian facilities;
  - become an attractive partner for constructing, owning and operating international projects.

STRATEGIC RESEARCH AREAS AND OBJECTIVES

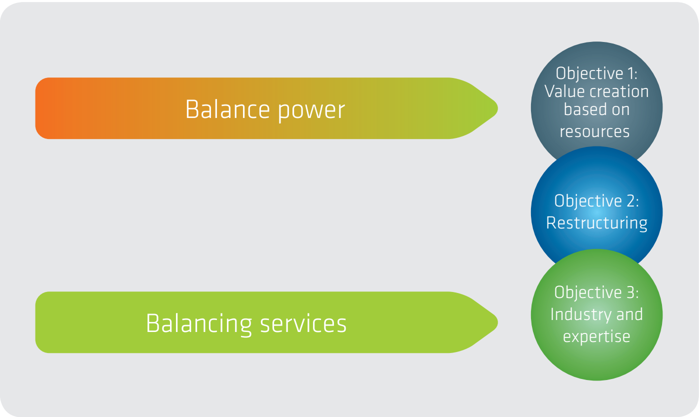
- Ensuring the efficient and proper operation and maintenance of existing hydropower facilities.
- Addressing international issues related to large-scale hydropower, including:
  - erosion and sediment transport;
  - greenhouse gas emissions from reservoirs;
  - methods for integrating environmental and social impacts of hydropower plants;
  - impact of climate change on potential.
- Further developing Norwegian specialist expertise in tunnelling and underground facilities.
- Assessing the consequences of directives concerning water and flooding for new and existing hydropower plants.

MEASURES FOR IMPLEMENTATION

- Launching KPN projects and Researcher Projects within the strategic research areas described above.
- Establishing measures specifically targeted towards master's and doctoral-level education and ensuring researcher recruitment.
- Providing funding for industry initiatives with value-creating potential in this area.

Blåsjø reservoir. Photo: Statkraft.

7.2.5 Balance power[1] – storing energy in hydropower reservoirs



Nearly 50% of Western Europe's total storage capacity in hydropower reservoirs is in Norway. However, Norwegian hydropower has primarily been developed for covering Norwegian energy demands rather than for supplying flexibility. Thus the average uptime of Norwegian hydropower exceeds 4 100 hours, in contrast to the roughly 1 750 hours of the Union for the Co-ordination of Transmission of Electricity (UCTE) system.

European challenge

Driven by the climate crisis and the need for security of supply, the North Sea countries have specific plans for accelerating the development of offshore wind power. The UK alone is planning to add 15-30 GW of capasity by 2020. A great deal of wind power is expected to be produced in or along the coast of the North Sea, initially on the continental shelves of countries other than Norway. Intermittent power production based on solar cells is also being installed throughout Europe, particularly in countries such as Germany, Italy and Spain, which already have large installed capacity and plans for installing even more capacity on a widespread scale.

At times, production from wind and solar power will exceed the consumption and transmission capacity of neighbouring countries, resulting in zero or negative power prices if this power is not scaled back. In periods of little wind or sunshine, on the other hand, wind and solar power production will drop, resulting in a power deficit that drives prices up. So there will be a substantial need for sources of balance power.

Norway's competitive advantages

Europe must be prepared to find its own solutions on the challenge of intermittency. Norwegian hydropower reservoirs is one possibility, but will face competition from other forms of energy production and other solutions for energy storage. Flexibility in the demand will also be a part of the solution. From technological and cost perspectives, using Norwegian hydropower is attractive but will require the development of new European solutions for power regulation and a market design that will also ensure adequate security of supply at all times. Regardless, Norway will clearly be able to play a role in this market by exploiting the opportunities afforded by its existing hydropower reservoirs to supply a significant amount of the flexibility needed by Europe's energy system.

1 Production of balance power or short-term balance power is sometimes referred to in the literature as swing production.

There is a need for balancing the intermittency of solar and wind power. Photo: Shutterstock.

Svartevatn lake, the reservoir for the Vemundsbotn hydropower plant. Photo: BKK.

Potential solution for implementation

Capitalising on these opportunities means that waterways, turbines and installed generator power capacity must be expanded and increased. It would be advantageous to boost the turbine capacity of Norway's hydropower plants, install reversible pumps where suitable, and connect the Norwegian energy system more closely to the rest of Europe's by installing more DC cable capacity. This represents both a major business opportunity for Norwegian companies and a way to reduce CO_2 emissions substantially by replacing a portion of fossil fuel-based power generation.

This would increase the economical output from the Norwegian hydropower, while also addressing regulatory challenges posed to the European energy system by the rapid rise in the share of renewable energy sources such as wind and solar power.

The potential role of hydropower as a balancing resource in Europe will create a need for investment in existing facilities and plants. The supplier industry and consultancy companies will increase their activity, while the hydropower industry will grow stronger by applying hydropower expertise in new ways.

Increased utilisation of Norwegian hydropower to supply balance power can be realised at three different levels:
Level 1: Optimal utilisation of Norwegian hydropower facilities in their current state, using existing transmission lines, to produce electricity when wind and solar power is in short supply on the Continent.
Level 2: Increased utilisation by installing more turbine capacity at existing facilities to boost potential for supplying higher output.
Level 3: Optimal utilisation of reservoir capacity by installing more turbine and pumping capacity at existing reservoirs in order to pump water during periods of surplus and quickly discharge it during periods of shortage.

Level 1 can be achieved under the current regimes for system development. The other two levels require structural measures at the national and European levels.

Regardless of level, one requirement for realising balance power is a well-functioning energy system, including a highly developed transmission system with the necessary capacity as well as a European market for balancing power. This is discussed in Chapter 7.2.6 Energy systems – transmission and flexible energy systems – smart grids.

AMBITIONS

- Developing economical values by utilizing hydropower for flexible balancing services.

STRATEGIC RESEARCH AREAS AND OBJECTIVES

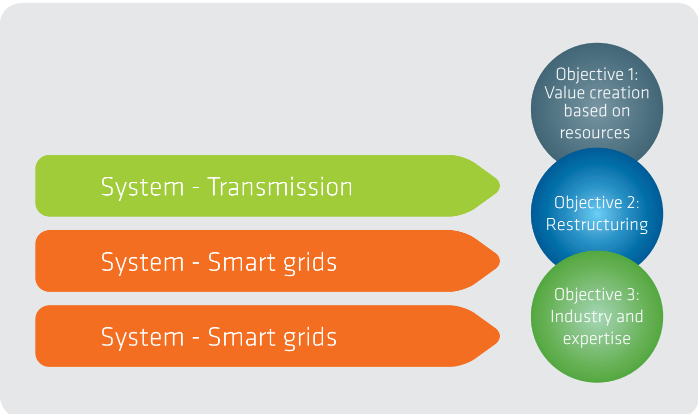
- Developing frameworks for a power market and insight into the size of the European market for balancing power:
  - devising a model for how to establish and operate a market for power
  - identifying the scope of Europe's demand and willingness to pay for power.
- Devising models for determining the environmental impacts of short and long-term balance power.
- Developing technological solutions and systems for pumped-storage capacity.
- Identifying the environmental impacts of rapid discharges and major changes in reservoirs.
- Enhancing understanding of turbine and electromechanical stresses from increased power output and dynamic operation.

MEASURES FOR IMPLEMENTATION

- Establishing a new FME centre focusing on flexible energy systems and balance power and addresses the strategic research areas above (refer also to the recommendations in Chapter 7.2.6).
- Providing funding for industry initiatives with value-creating potential in this area.
- Providing funding for testing and demonstration facilities as well as a large-scale laboratory at an operational facility for testing and verification of new technical solutions. Such a facility would also function as a training centre for hydropower experts with a focus on short and long-term balancing power.

Flexible energy systems. Photos: Statkaft, Nexans, Siemens, Shutterstock. Collage: Trond Moengen.

7.2.6 Energy systems – transmission and flexible energy systems – smart grids



Transmission

Strengthening the capacity for transmission to Europe will be determined in part by the Continent's need for balancing services. Norway has a unique position as a potential large-scale supplier of balancing and system services based on Norwegian hydropower and reservoir capacity, as described in the previous section. Cable connections and international market solutions for balance power are essential elements that must be in place if Norway's role as a supplier of balancing services is to be realised. In addition, the possible future integration of large-scale offshore wind power and electrification of North Sea petroleum activities would create the need for a complex North Sea grid. Optimally coordinating such a grid will require research and development for electrotechnical components and system solutions.

Norway, with its industrial clusters and abundant natural resources, can gain an international foothold in a number of transmission-related niches, including offshore technology developed for power exchange and for subsea oil and gas applications. There are challenges as well as opportunities for value creation in connection with the supply of system services, output, energy and technology.

System challenges – facilitating increased renewable energy production and balance power for Europe

Developing and expanding renewable energy will yield more energy production, which may in turn increase exports. Periodically this will entail more strain on energy system operations. The various production technologies differ in degree of intermittency and ability to regulate and also production profile over the course of a year, creating a need for balancing reserves. Experience has shown that during certain periods of the year, hydropower cannot generate these reserves due to large variations in runoff and grid limitations. The challenge ahead will therefore be that large amounts of balancing reserves will have to be used to balance the variability from the growing share of intermttent production of renewable energy.

Boosting transmission capacity between Norway and Europe via high voltage direct current (HVDC) systems will also pose major challenges, primarily related to momentary balancing, that is, the discrepancy between changes in production and in consumption, including the energy system's import and export. Already, substantial problems with systems operations are occurring due to large, rapid fluctuations in volumes of power transmission (several thousand MW) to the Continent. The most pressing challenge of exchanging system and balancing services via international connections will be to handle more and larger fluctuations in planned power flow in the period immediately prior to and during operations, i.e. major fluctuations over a short period of time.

Norway can become an even larger supplier of balance power for export when consumption in Europe is high during periods of low production of solar and wind power, as well as an importer of balance power when Europe's renewable production exceeds demand. If, however, realising the vision of "green energy exports" entails large-scale production and delivery of renewable, unbalanced electricity, this production will take up a share of the Norwegian energy system's regulating and balancing reserves.The role as a major exporter of green energy may therefore conflict with the role of exporter of balancing power to Europe.

These challenges must be solved if the vision of Norwegian hydropower as a green battery for Europe is to be realised. Flexibility and export of climate-friendly energy as well as products that require large amounts of energy to manufacture, such as metallurgical products, could be an important contribution in this context.

Flexible energy systems – a smart grid for Norway's needs

Energy restructuring will place new demands on the energy system, related both to feed in new renewable power and reducing energy consumption, requiring the active involvement of end-users. Important to note here is that Norway has a substantial amount of energy-intensive industry – which represents considerable challenges as well as opportunities in connection with flexible, smart energy systems.

Efficient energy systems also includes the adequate of thermal energy. This will require the development of flexible smart grids that can accept not only electricity but also heat.

To tackle these types of challenges, an energy system must be dynamic and have the capacity for dealing with:

- substantial amounts of feed-ins from intermittent renewable energy sources and output, mainly from small-scale hydropower plants and wind power;
- active end-users who become more energy-efficient and more closely connected to the market thanks to advanced measurement and control systems and new rate and market structures;
- new types of consumption (e.g. electric vehicles) with less predictable output and energy consumption;
- prosumers[1], such as energy-plus homes, that at one moment may consume output from the grid, then in the next moment feed electricity back into it.

It must be expected that the grid in general, and the distribution grid in particular, will be accessed and utilised by external players, primarily producers and end-users. This is not possible on today's grid without compromising personal safety , security of supply and quality of supply.

It is necessary to develop the distribution grid to meet these challenges. It is also reasonable to expect that end-user and societal demands for supply quality and security of supply will increase. An energy grid that can handle all these challenges will be an interactive grid, known increasingly as a smart grid.

There may be differing definitions of a smart grid, but one commonly agreed feature is that its various components work together far more dynamically than in current structures in order to ensure security of supply. For example: the load on energy consumers is utilized actively more or less continuously; individual components such as electric vehicles are charged and used to store energy according to demand; decentralised production solutions are integrated and utilised to reduce the flow of electricity and to deal with bottlenecks in the grid. Smart grids are to a large extent automated, making extensive use of modern information and communications technology. A great deal of research is targeted towards this concept.

AMBITIONS

- Developing tomorrow's energy systems, with associated primary and secondary technologies (smart grid solutions, monitoring, control and protection) as well as the necessary tools for planning and operations that increase flexibility and maintain Norway's security of supply.
- Facilitating the sale of system services (balance power) to Europe by integrating tomorrow's energy systems with the Continent, first via expanded HVDC connections and, later, by developing a single integrated offshore power system in the North Sea.

STRATEGIC RESEARCH AREAS AND OBJECTIVES

- Developing primary and secondary technologies (electrotechnical components and systems solutions).
- Developing smart grid technologies and transition strategies from current architecture and technology utilisation.
- Generating new knowledge to enhance profitability and value creation related to Norwegian deliveries of primary components and infrastructure solutions.

MEASURES FOR IMPLEMENTATION

- Establishing a new FME centre that focuses on flexible energy systems and balance power and addresses the strategic research areas above (refer also to recommendations under Chapter 7.2.5).
- Launching KPN projects and Researcher Projects within the strategic research areas described above.
- Providing funding for industry initiatives with value-creating potential in this area.
- Providing funding for testing and demonstration activities to test out and verify system-technical solutions and systems for future transmission and distribution grids.

1 The term prosumer refers to nodes in the energy system that can both consume and supply electricity to the grid, such as households with microgenerating capability.

Smart Grid

The smart solution for efficient utilisation of energy

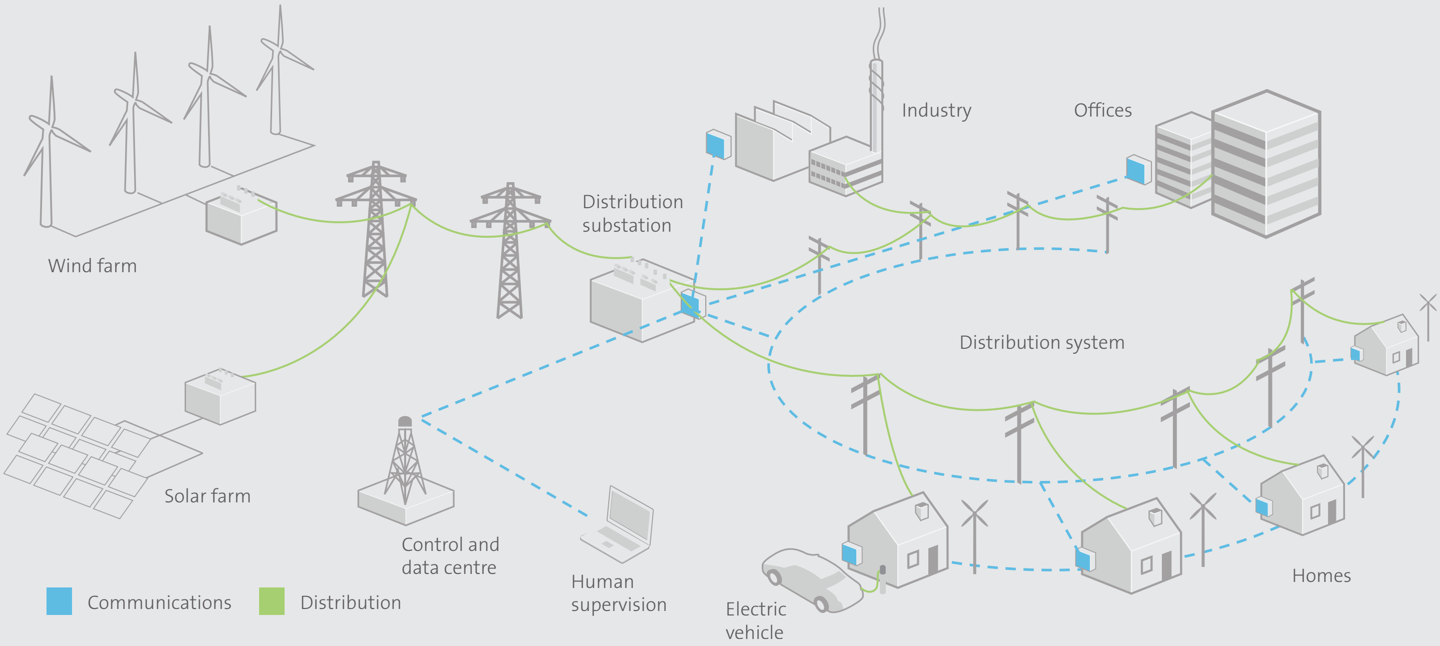
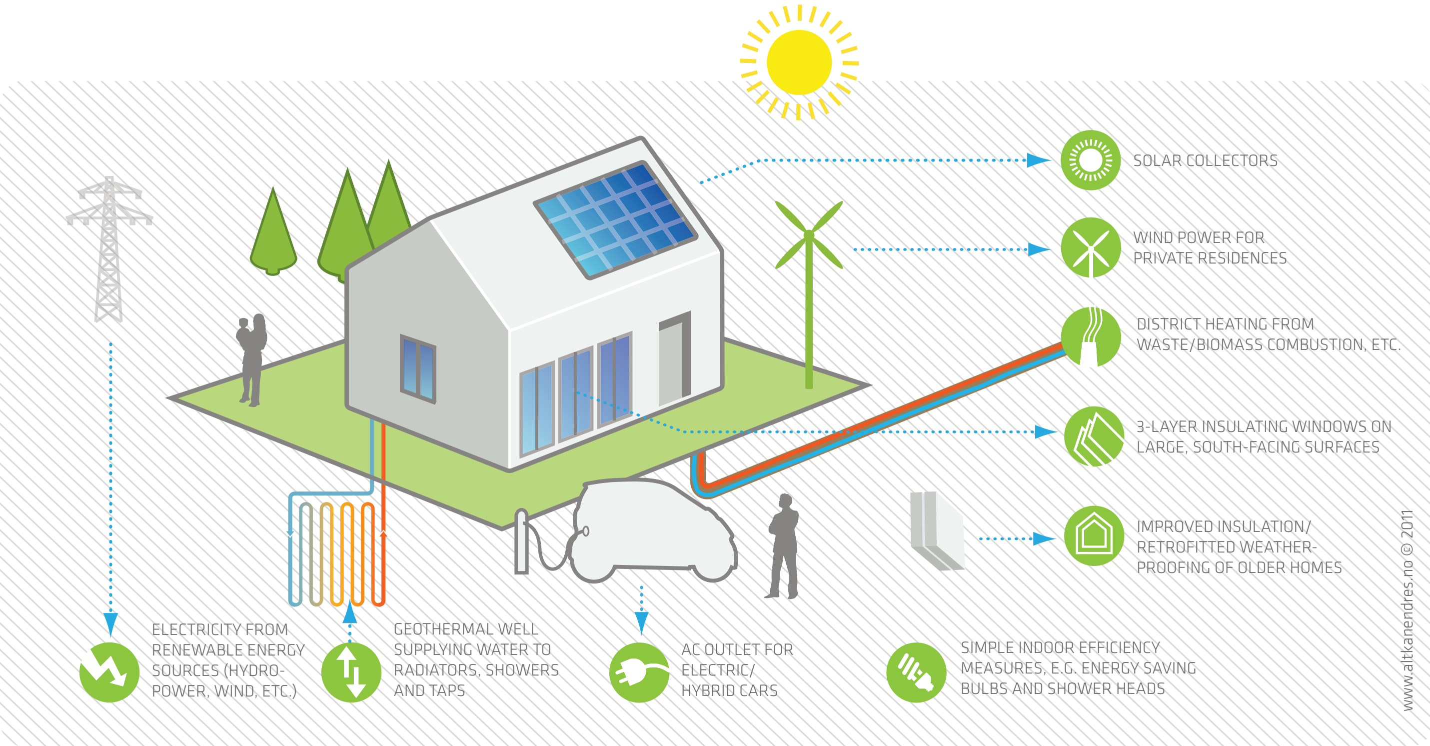
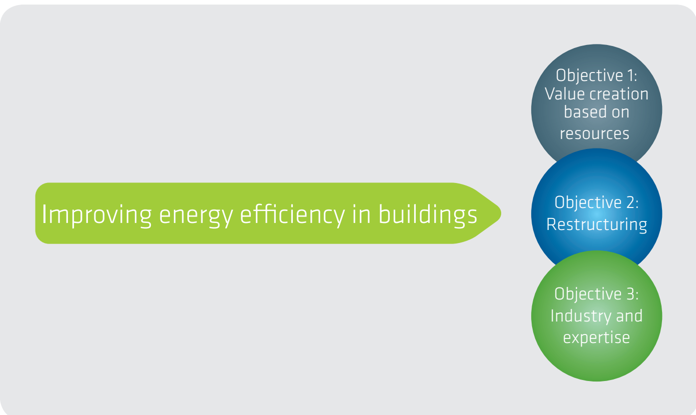


Diagram of an interactive grid, also known as a smart grid.
Illustration: Endre Barstad © 2011. www.altkanendres.no.



7.2.7 Improving energy efficiency in buildings



The board of Energi21 has not established a sub-group tasked with identifying research challenges in the area of energy use in buildings. A wide assortment of technologies and solutions is ready for implementation in this area – for both new and existing building structures. For existing buildings, there is a significant obstacle related to knowledge and behaviour.

Instruments to promote the implementation of measures to reduce energy use are therefore important. In the short run, the most essential research is of a non-technological nature, and is discussed in more detail in Chapter 7.2.14 Developing incentives and frameworks. Technical research should be targeted towards innovative solutions with major potential.

New buildings must comply with the requirements and energy-use guidelines set out in the Planning and Building Act. Furthermore, the use of the passive house standard is rapidly gaining momentum, which will significantly reduce specific energy consumption in new building structures.[1] In a more long-term perspective, buildings of the future will be zero-energy buildings and eventually become energy suppliers. Norwegian players will be able to play a role in certain niches to pave the way for such buildings.

Annual energy use for the operation of buildings in Norway totals 80 TWh. The potential for reducing energy use is estimated to be 10 TWh by 2020 and 40 TWh by 2040.[2] There are many mature technologies and solutions ready for use in this field; the challenges are related to implementation. However, there is still a need for new solutions, on which several Norwegian research groups are working.

AMBITIONS

- Reducing energy consumption in Norwegian building structures.

STRATEGIC RESEARCH AREAS AND OBJECTIVES

- Developing effective incentives for promoting new energy solutions and changing behaviour.
- Developing technology related to future "plus-energy houses".
- Addressing topics related to utilising surplus energy and demand side management .

MEASURES FOR IMPLEMENTATION

- Launching KPN projects and Researcher Projects within the strategic research areas described above.
- Providing funding for industry initiatives with value-creating potential in this area.

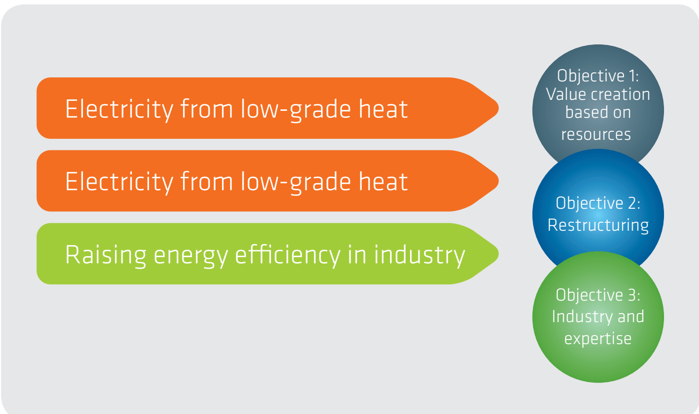
1 Passive house: a building with very little need for supplied energy for heating.

2 Ministry of Local Government and Regional Development working group on improving energy efficiency in buildings.

A processing plant. Photo: Shutterstock.

Excess heat from a processing plant. Photo: Siemens.

7.2.8 Raising energy efficiency in industry – utilising low-temperature heat



There is significant potential to improve energy efficiency in industry. Much of this potential can be realised using currently available technological solutions, but this is heavily dependent on factors such as industry's need for economic returns, energy prices, and other framework conditions for the companies involved. This underscores the importance of developing technology to lower the cost of energy-saving measures and developing the knowledge needed to create favourable framework conditions that facilitate the realisation of this reduction potential.

Some of this potential will require industry-specific as well as pan-industrial technology development.

Industry-specific technology development is often considered a competition-sensitive advantage, making it difficult to share with other companies. The Energi21 strategy therefore emphasises pan-industrial technology development.

The conversion of low-temperature heat into electricity holds great potential across branches of industry. The challenge Norway faces is its relatively large industrial point emissions of low-value heat in locations where there is no corresponding need for low-value heat. Recovered energy must therefore be converted into electricity in order to be utilised. Norway is at the forefront of high-grade heat conversion, so this expertise should be applied to develop competitive solutions for conversion at lower temperatures as well.

AMBITIONS

- Reducing specific energy consumption and increasing utilisation of excess heat in all land-based industry.
- Utilising low-temperature heat for heating and electricity production.

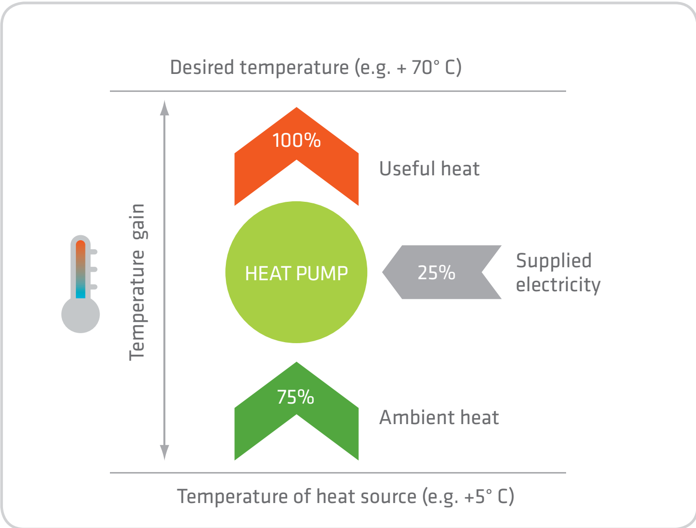
STRATEGIC RESEARCH AREAS AND OBJECTIVES

- Developing new technological solutions and methods for conversion of low-grade heat.

MEASURES FOR IMPLEMENTATION

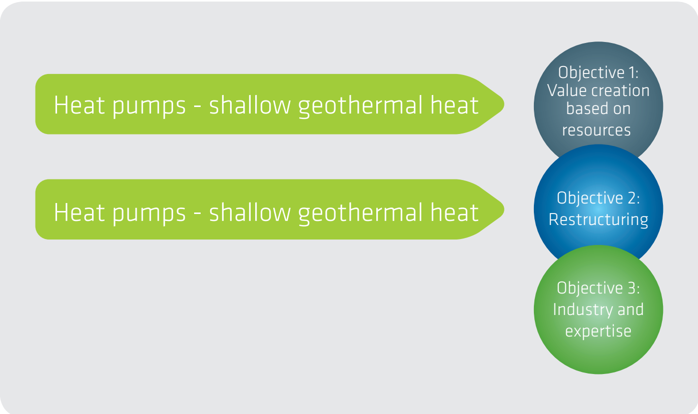
- Launching KPN projects and Researcher Projects targeting solutions for converting low-temperature heat into electricity.
- Providing funding for industry initiatives with value-creating potential in the area of low-temperature heat and other areas that may benefit industry in the form of higher energy efficiency.

Photo: Shutterstock.



The heat pump principle. Illustration: www.altkanendres.no © 2011.

7.2.9 Heat pumps



The heat supplied by heat pumps in Norway is calculated at 8-9 TWh per year (with 5-6 TWh in energy savings). It is estimated that this amount can be increased by another 10-14 TWh annually by 2020 in a commercially feasible manner.[1] This will release roughly 8-9 TWh of electricity This gain will require relatively little in the way of new, wide-ranging research activities. The use of other instruments aimed at end-users and the construction industry will be of greater importance to achieve this.

Norwegian players possess valuable expertise in this field. The International Energy Agency (IEA) estimates in its ETP 2010 report that 38% of the gap between its Baseline and BLUE Map scenarios (57 and 14 GT of CO2 in 2050, respectively) should be covered by improved energy efficiency.[2]

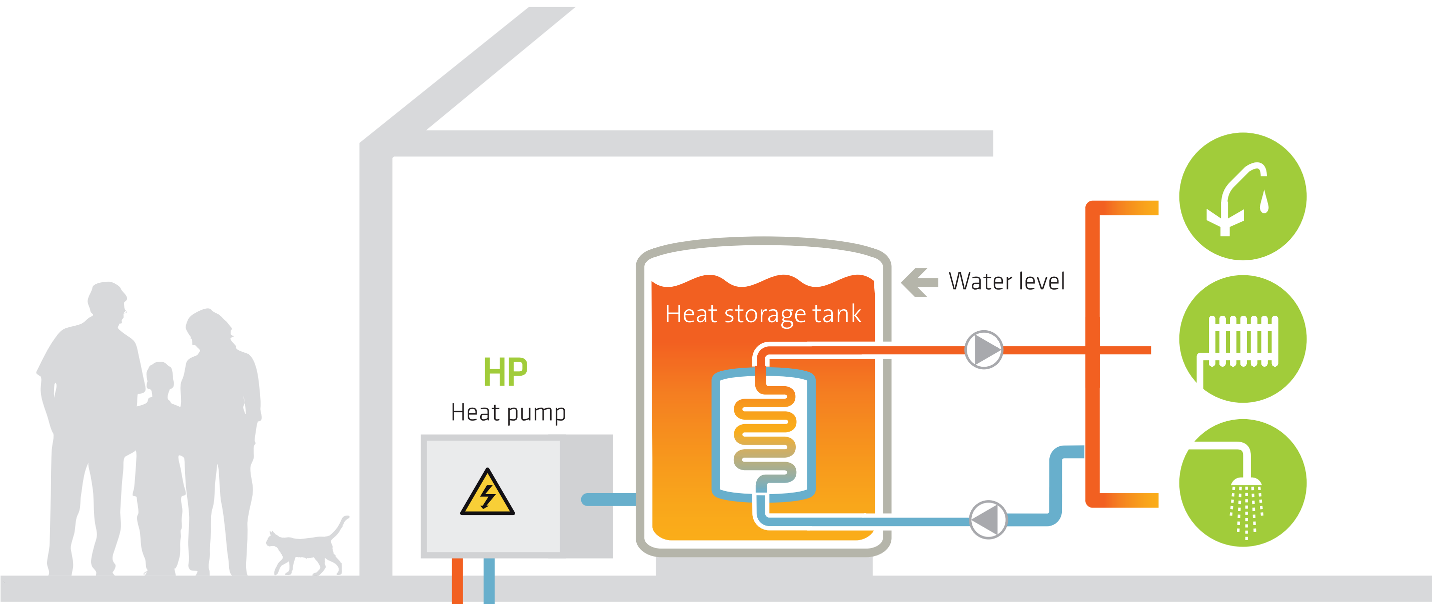
Optimal use of heat pumps and cooling units in the Norwegian energy system along with other renewable energy production comprises a vital component of energy restructuring. Current energy production is changing from a situation primarily characterised by electricity and fossil fuels into a more complex situation. Heat pumps and cooling units occupy an important place in this new picture, but the technology is dependent on proper temperature levels.

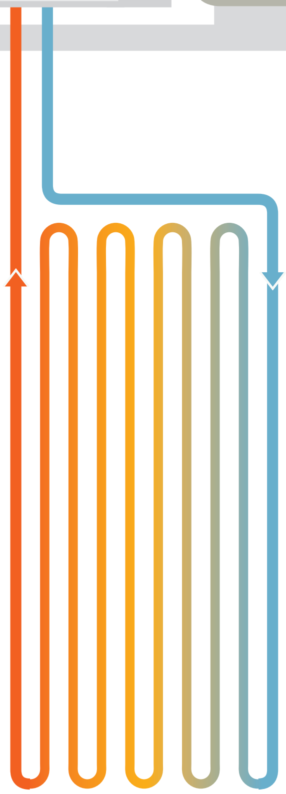
Implementing heat pump technology in the energy system primarily requires moderate temperature levels at district heating facilities and infrastructure that is adapted for heat pumps and cooling units.

Since the mid-1980s Norway has played a key role in international research on the use of CO_2 as an environment-friendly working medium in heat pumps. The Norwegian University of Science and Technology (NTNU), SINTEF Energy Research and industry have collaborated on strategic research projects and have built up international expertise in applying CO_2 as a working medium. The technology that has been developed is ready for industrial application and has been commercialised in Japan, among other countries. In Norway, however, there is limited industrial activity in this area.

1 Grorud, Rasmussen & Strøm, 2007.

2 The IEA report Energy Technology Perspectives (ETP), 2010. Its Baseline scenario represents "business as usual" while its BLUE Map scenario depicts a future in which the potential technological solutions are implemented.





The heat pump principle for use in a residential building.

Ill: Endre Barstad/www.altkanendres.no © 2011

Norwegian expertise in this field should nevertheless be maintained and made available for training specialists in Norwegian industry for developing and supplying tap-water heat pumps for larger buildings. This technology will have an even greater relative effect as low-energy buildings become more common, since the energy spent on heating tap water will comprise an increasing relative share.

In the area of heat pumps and shallow geothermal heat, the necessary technical solutions are largely available. The obstacles to more extensive use lie elsewhere and are related to the need for more information and knowledge among users and for economic incentives.

AMBITIONS

- Increasing awareness and knowledge about using heat pumps for higher energy efficiency and using renewable heating and cooling in buildings and industry.
- Boosting implementation of heat pumps and cooling units in Norway's energy system.
- Enhancing user competence – in trade and industry and among consumers.

STRATEGIC RESEARCH AREAS AND OBJECTIVES

- Developing new technologies that can lower costs and raise efficiency.
- Developing freely available computer models for calculating the profitability of using heat pump technology.
- Developing local and district heating facilities that use low-grade energy.

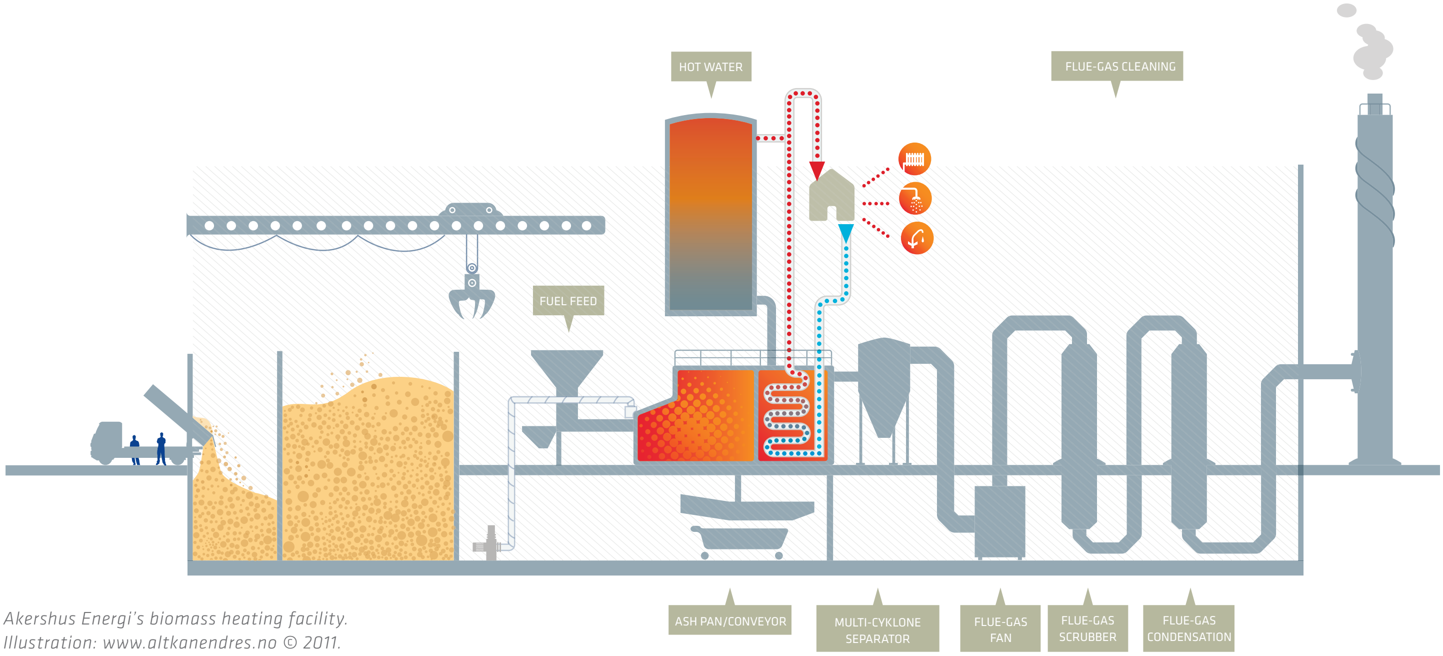
MEASURES FOR IMPLEMTENTATION

- Providing funding for industry initiatives with value-creating potential in this area.
- Developing user knowledge:
  - carrying out field measurements for identifying the best solutions, and disseminating knowledge about these;
  - identifying and communicating best practice for cooling and heat pump installations.
- Strengthening market-oriented instruments.

Lowering the temperature just 1°C

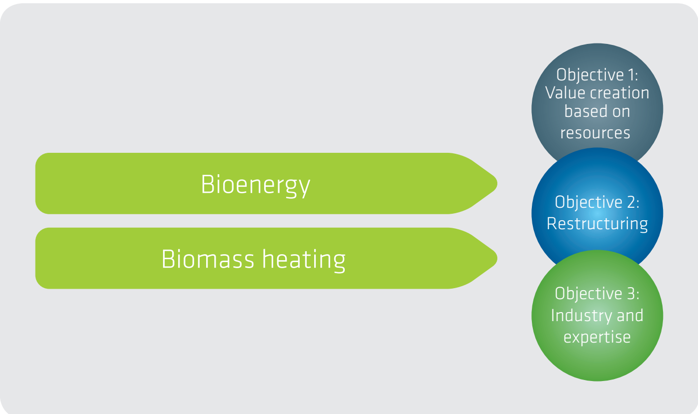
Setting the indoor temperature down just 1°C saves 5-10% on the electricity bill while sparing the environment up to 300 kg of CO2.

Source: the EU



Akershus Energi's biomass heating facility.
Illustration: www.altkanendres.no © 2011.

7.2.10 Bioenergy



There is potential to better utilise bioenergy in the Norwegian energy system. Several mature technologies and solutions exist that could be implemented now, but a more systematic review of how to make optimal use of the available biomass for energy purposes is needed, given that this is a limited resource. This review should also encompass the use of biomass for fuel in the transport sector. In addition to assessing the cost-effectiveness of using biomass resources, the lack of alternatives should also factor into deciding how to allocate biomass resources.

An effort should be made to achieve a more consistent distinction between the various bioenergy resources. An important factor to consider is carbon binding in standing biomass. From a climate perspective it may be incorrect to equate the use of boreal forest-based biomass with, for instance, sewage sludge , landfill gas or other biological waste, including forest residues , where there is potential for increased utilisation.

A fundamental challenge of utilising biomass nationwide is therefore to enhance fact-based knowledge about how to make optimal use of the country's standing forest-based biomass and for which purposes, and the impact this will have on greenhouse gas emissions.

In the future a growing number of integrated facilities will produce a combination of second-generation biofuels and other products, including heat for space heating or refined biomass products for stationary purposes.

Close cooperation between Norwegian industry and research communities and leading international research groups in the Nordic countries and other parts of the world will be critical for developing such solutions.

AMBITIONS

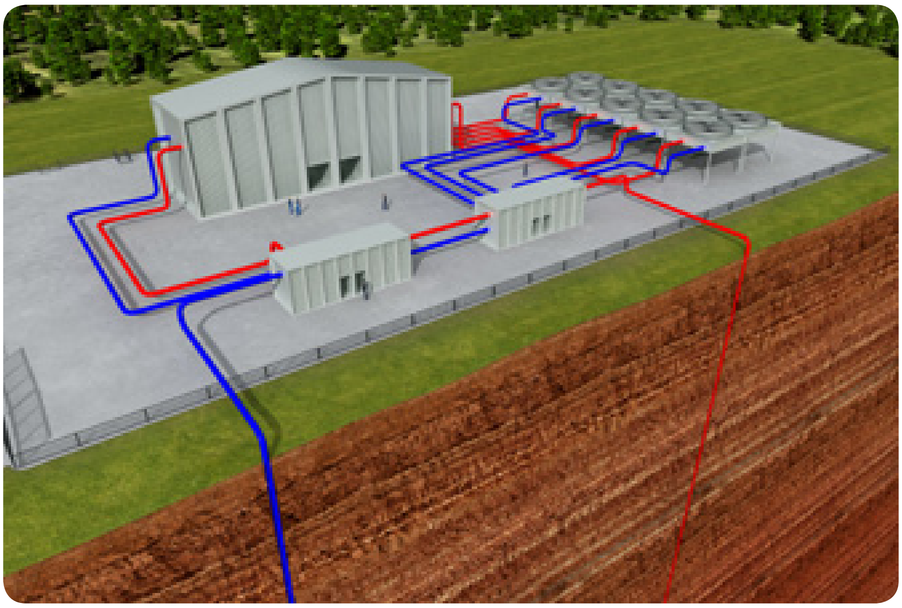
- Increasing value creation through the use of bioenergy from sustainable biomass.
- Achieving a broad-based understanding of sound, climate-friendly management of Norway's biological biomass.

STRATEGIC RESEARCH AREAS AND OBJECTIVES

- Addressing obstacles to increasing the use of bioenergy in the Norwegian system.
- Generating fact-based knowledge about carbon cycles and ecosystem impacts involving standing forest-based biomass.

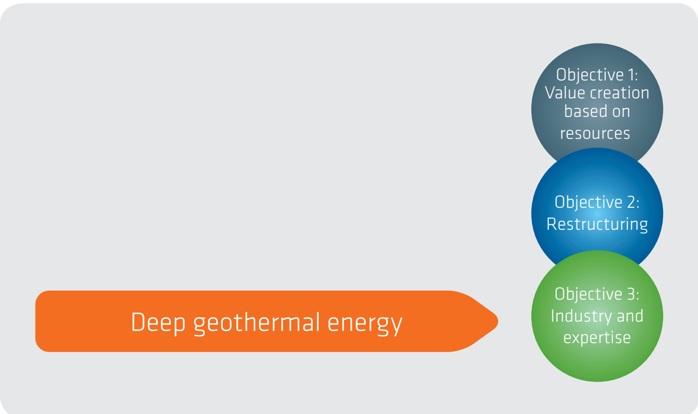
MEASURES FOR IMPLEMENTATIONS

- Launching KPN projects and Researcher Projects within the strategic research areas described above.
- Providing funding for industry initiatives with value-creating potential in this area.



A plant for utilising deep geothermal energy. Photo: Shutterstock.

7.2.11 Deep geothermal energy



Current activities targeted towards utilising deep geothermal energy are relatively modest in scope. There are, however, certain minor players looking at opportunities for exploiting this energy resource.

There are a few areas of synergy between petroleum activities and geothermal energy production, such as drilling, wells and reservoirs. Drilling costs are considered the greatest obstacle to developing deep geothermal energy; currently, some 50-70% of the cost of establishing such plants is associated with drilling deep geothermal wells and well systems.

The companies now looking to seize opportunities in geothermal energy generally have roots in the oil and gas industry. Norwegian players have the potential to supply a deep geothermal energy market, but this market is not yet well developed.

There are still major unutilised resources for shallow geothermal energy and it may be assumed that it will be more cost-effective to draw upon these first. In certain international markets, such energy plants are profitable without subsidies.

It is therefore unlikely that a large Norwegian market for deep geothermal heating will emerge in the short or medium term.

AMBITIONS

- Developing a new Norwegian industry.

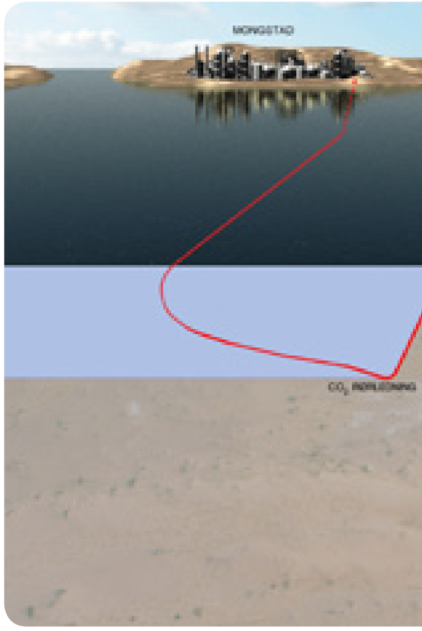
STRATEGIC RESEARCH AREAS AND OBJECTIVES

- Developing hard-rock drilling technology.

MEASURES FOR IMPLEMENTATION

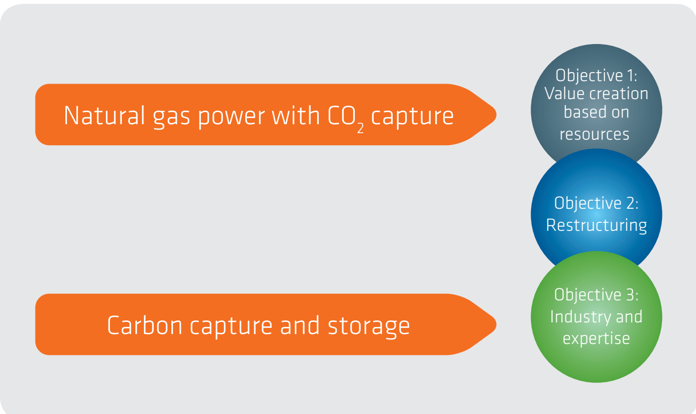
- Providing funding for industry initiatives with value-creating potential in this area.

At the Sleipner gas field, over 10 million tonnes of CO_2 has been injected and sequestered in the Utsira reservoir so far, an amount that exceeds two years' worth of Norway's total vehicle emissions. Photo: Statoil.



CO2 is transported from an onshore capture facility to an offshore injection site on the continental shelf. Illustration: Gassnova.

7.2.12 Carbon capture and storage (CCS)



Two main elements of a carbon capture and storage (CCS) strategy are: 1) maintaining or enhancing the competitiveness of existing Norwegian industry in this field, and 2) establishing a new, competitive Norwegian supplier industry.

Safeguarding the value of Norwegian resources

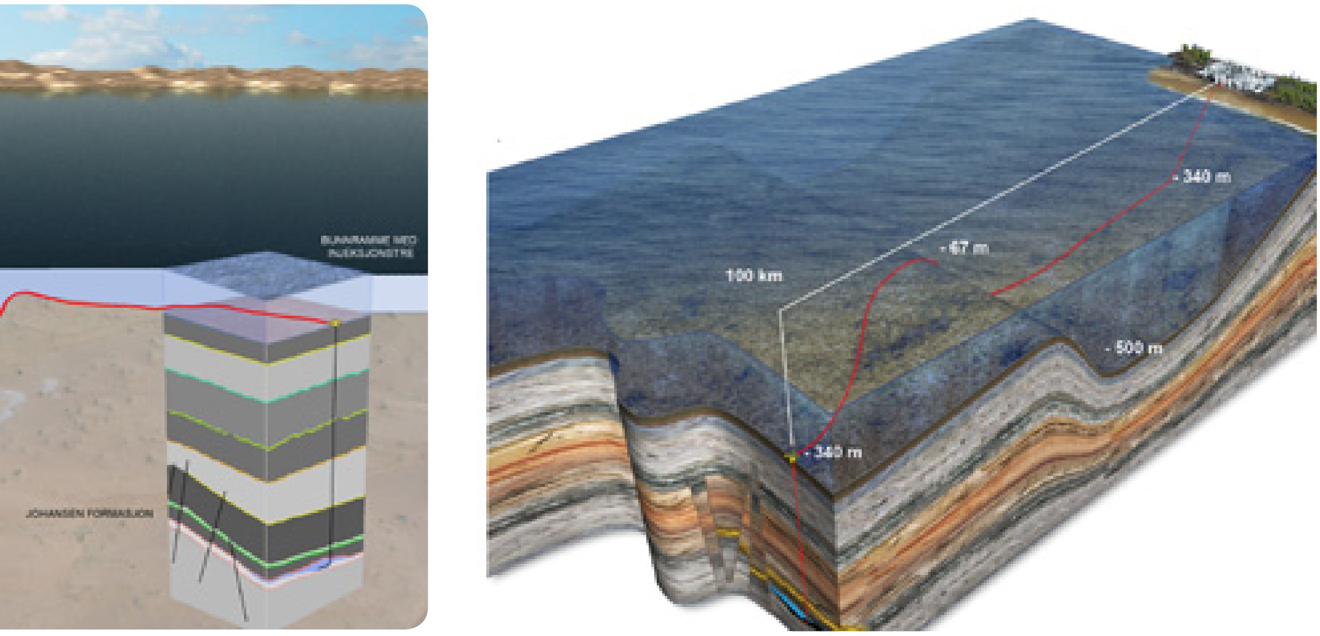
As a global petroleum producer, Norway has taken the initiative to promote CCS as a means of mitigating climate change. Potentially more restrictive climate change regimes in the future could pose a risk that Norwegian natural gas reserves drop in value.

Research to develop solutions for natural gas power generation with CCS may help to ensure the competetiveness of the remaining gas reserves, which would safeguard their value and thus be of great significance in a socio-economic context. Gas power with CCS has the potential to challenge the dominance of coal power, and can be used to balance a large share of intermittent renewable energy in Europe.

A future international regime based on more stringent climate measures could change framework conditions for the petroleum and processing industries. Compulsory measures and regulations affect cost levels as well as the demand for products. It is conceivable that the oil and gas industry will have to assume either direct or indirect responsibility for CO_2 emissions from petroleum products sold. In the long run this could mean that the availability of cost-effective CCS solutions will be of increasing significance for the production value of Norwegian natural gas.

CCS – potential advantages for other industrial activities

CCS could also be a substantial cost factor in other types of industries, giving a competitive edge to companies with CCS knowledge. There may also be changes in the regional competitive landscape arising from changes in framework conditions and possibilities for CO_2 storage.



A concept for storing CO_2 from a capture facility at Mongstad, Norway, which plans to inject CO_2 into the Johansen formation – a regional saline aquifer off the coast of Mongstad. Illustration: Gassnova.

Norway's competitive advantages

Future development will be based on competitive advantages acquired from the efforts of the past decade within this field and from experience and technology within the Norwegian petroleum and processing industries. The expansion of knowledge, technology and services for this field will primarily be targeted towards the national and international market for CCS. Norway has built up expertise along the entire chain of capture, transport and storage. The country's most prominent competitive advantage is likely in the area of storage, thanks to many years of experience from petroleum activities and CO_2 injection at the Sleipner and Snøhvit fields. Access to reservoirs for storing CO_2 on the Norwegian continental shelf is another potential advantage in terms of value creation.

AMBITIONS

- Developing cost-effective capture and storage as well as monitoring of CO_2.
- Developing natural gas power generation with CCS.

STRATEGIC RESEARCH AREAS AND OBJECTIVES

- Developing knowledge and verifying technology for secure, cost-effective storage and monitoring of CO2.
- Developing entirely new technologies with potential to reduce costs of CO_2 storage from power production and the processing industry.
- Developing, verifying and commercialising methods and services for assessing and qualifying storage sites for CO_2 with regard to storage capacity and storage security.

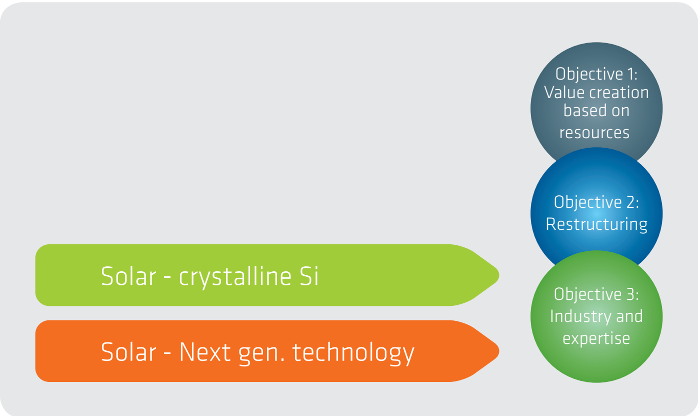
MEASURES FOR IMPLEMENTATION

- Launching KPN projects and Researcher Projects within the strategic research areas described above.
- Providing funding for industry initiatives with value-creating potential in this area.

Photo: Elkem Solar/Nicolas Tourrenc.

Photo: Scatec.

7.2.13 Solar electricity – industrial development



International development

The solar energy industry is undergoing rapid growth and development. Although subsidies are still widely applied, the cost of solar electricity has declined substantially, turning this form of electricity into a competitive alternative in areas with abundant sun and high daytime demand, including major energy markets such as California, Germany, Italy and Japan.

A further reduction in costs is nevertheless essential if this trend is to continue.

In 2008 and 2009 roughly 7 and 13 GW of solar panels, respectively, were produced. In 2010 this figure leapt to an estimated 27 GW.[1]

This rapid growth is continuing and the market is approaching high volume. Such growth creates opportunities in the market for those already positioned and for new players seeking to enter this market.

New branch of industry for Norway

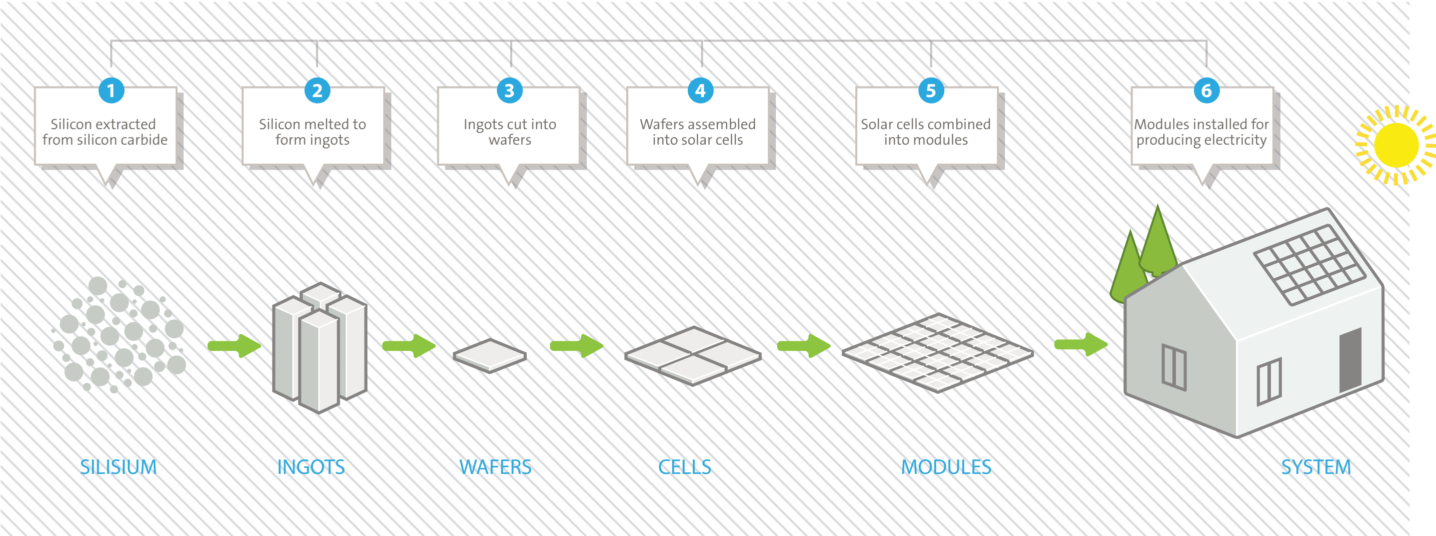
Since the mid-1990s the Norwegian solar cell industry has grown from one company established in 1995 to a substantial industry and a solar energy cluster. In the period 2003-2009, turnover increased by over 2 000%.

The Norwegian solar cell industry now comprises dozens of companies, employing roughly 2 500 persons in Norway in 2010 with a turnover of approximately NOK 10 billion. Once an industry rooted in silicon production, it now encompasses a diversity of companies along the entire value chain. In addition, a supplier industry has emerged to provide technology and services for segments of the value chain. These promising new companies have the potential to gain a foothold in the international market, and many have already done so.

Norway is home to a large solar energy research community, with sizeable research groups affiliated with companies, independent research institutes and universities. These have accumulated wide-ranging expertise in a number of areas along the entire value chain for producing silicon-based solar cell panels – from the production of silicon to the development of modelling and characterisation techniques to the manufacture of components.

1 PHOTON International, 2011.

SOLAR CELL VALUE CHAIN



Solar cell value chain. Illustration: Endre Barstad©2011 www.altkanendres.no.

Norway's competitive advantages

The industry has expressed a clear intent to maintain its position as a leading global supplier of solar-grade silicon and wafers by applying its extensive silicon expertise to optimise silicon materials aiming at lowering production costs and improving material quality.

More work is needed to cut the cost of solar electricity by reducing costs per watt for solar cell panels. This will be achieved by raising operational efficiency and lowering production and installation-related costs. Another objective is to facilitate long-term development of new materials and technologies for the solar cell panels of the future.

Norwegian players have a strong position in the production and processing of silicon. Industrial maturity, an increasing degree of specialisation, and sharper international competition all point to the importance of concentrating efforts in segments of the value chain in which Norway has the greatest competitive advantages. Ensuring adequate knowledge development in this area is essential to developing next-generation solar cells based on silicon.

AMBITIONS

- Maintaining Norway's position as a leading global supplier of solar-grade silicon and crystalline silicon wafers.
- Generating a knowledge base for further development of Norway's solar cell cluster and new industry based on next-generation solutions.

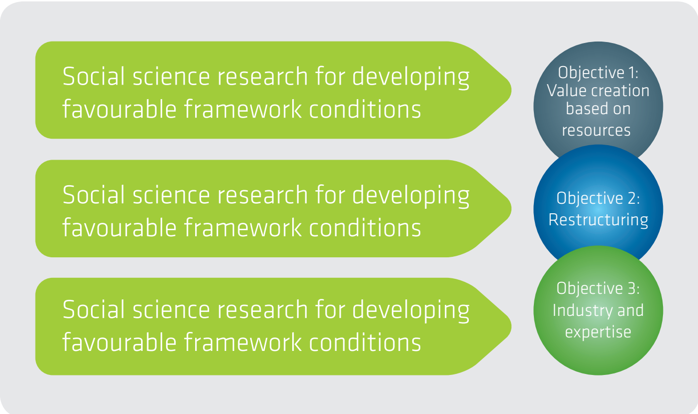
STRATEGIC RESEARCH AREAS AND OBJECTIVE

- Enhancing understanding of silicon as a solar cell material.
- Strengthening materials research with a focus on applications for next-generation solar cells based on silicon and other materials.

MEASURES FOR IMPLEMENTATION

- Launching KPN projects and Researcher Projects within the strategic research areas described above.
- Providing funding for initiatives from solar cell manufacturers and the supplier industry which show value-creating potential in this area.

7.2.14 Developing incentives and frameworks – market development



To round off the analysis, the Energi21 board wishes to address the significance of new knowledge about framework conditions, incentives, instruments and market mechanisms for realising industry and energy-related ambitions.

Energy restructuring will require a market characterised by effective incentives and regulations that encourage increased production of environment-friendly energy as well as reduced energy consumption. This will involve promoting central and distributed environment-friendly energy production and increased utilisation of heat.

At the same time, development needs to continue on incentives and regulations that limit the consumption of energy and raise energy efficiency. Much remains to be learned about the impacts of various framework conditions and incentives, so this is an important area for continued research and developing new knowledge.

Balance power based on Norwegian resources will require development of a market for power and balancing services . There is a need for balancing and there are opportunities for Norway to contribute to achieving it, but a market for this does not currently exist.

Realising the potential for reducing energy consumption in buildings requires insight into the decision-making mechanisms of residents, building owners and building contractors.

Technical solutions that allow desired functionality are a prerequisite for a smoothly functioning energy system. However, such a system is unattainable without the development of effective market mechanisms and regulations. There must be instruments and market mechanisms in place to promote the phasing-in of more renewable energy in Norway and Europe. The introduction of a green electricity certificate scheme for renewable energy production is one such instrument.

Generating insight as a basis for policy development, market design and decision-making will be fundamental in implementing effective solutions that are or will be possible. The TTA working group frameworks and social analysis addresses a wide range of these issues in its report.

AMBITIONS
- Creating social framework conditions that promote energy restructuring.
- Acquiring a basis for developing necessary energy infrastructure.

STRATEGIC RESEARCH AREAS AND OBJECTIVES:
- Which incentive structures and other mechanisms will facilitate optimal consumer response to price signals?
- How can we learn more about the effects of promoting new power production in a market with conventional production?
- How can equal market access be combined with the supplying country's desire to have national consumers pay for the most cost-effective projects? How can immature technologies be brought to fruition in such a market?
- What is the potential for consumption of renewables, and what are the social impacts of restructuring within, for example, the transport sector (electric vehicles), petroleum sector (electrification), and the heating segment?

MEASURES FOR IMPLEMENTATION
- Launching KPN projects and Researcher Projects within the strategic research areas described above.
- Providing funding for initiatives from industry and other users in this area.

Megacities

Megacities

As of 2009, the world has roughly 20 megacities, defined as a metropolitan area of at least 10 million people. Despite their high visibility and dynamics, megacities account for just 9.4% of the global population, but this is expected to rise to 10.3% by 2025.

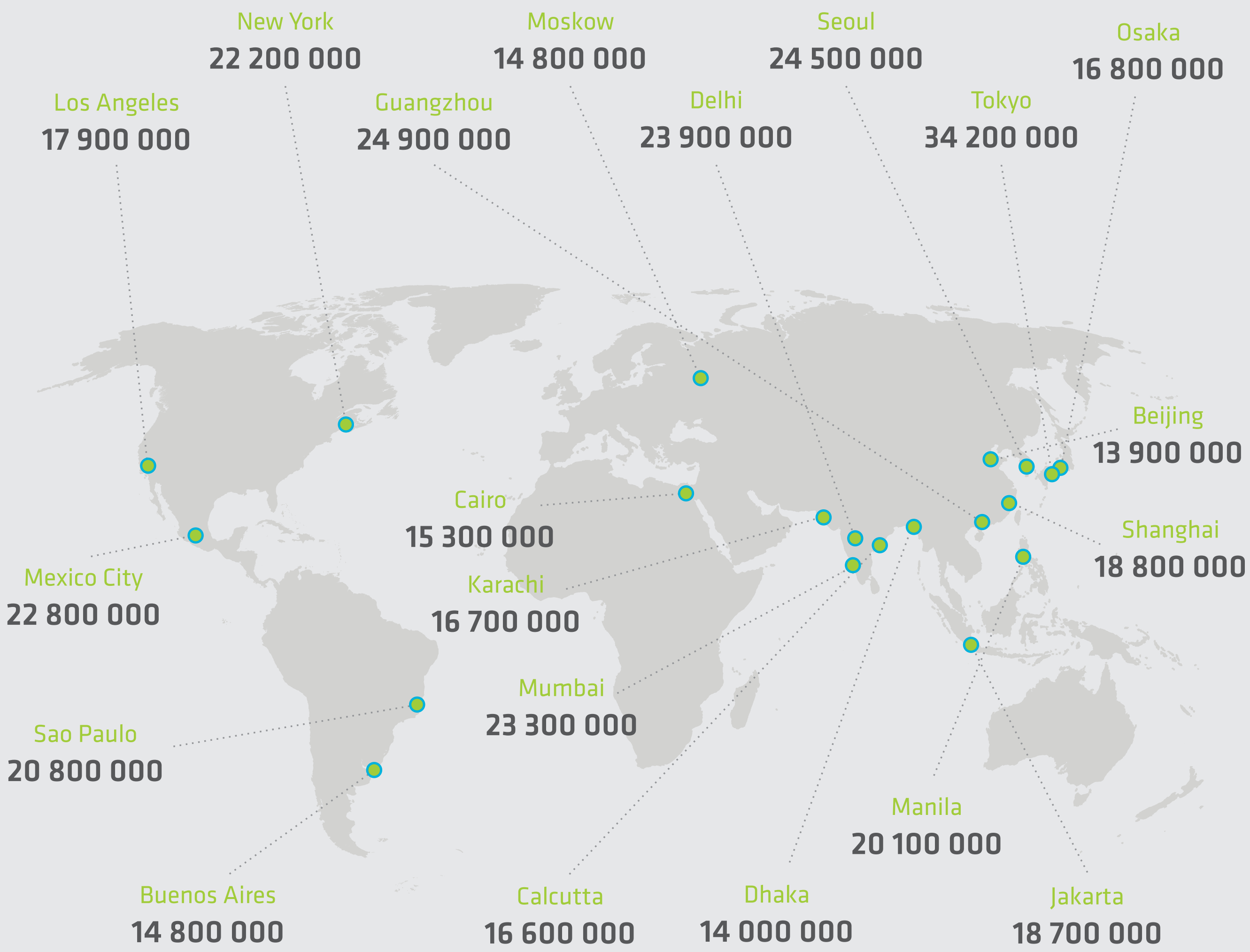


Illustration: www.altkanendres.no © 2011.
Source: National Geographic.

7.3 Cohesive strategic comparison of thematic and technology areas

The Energi21 strategy is based on recommendations from the TTA working groups, input to the circulated draft report, and the board's overall assessment in the context of the Energi21 vision and primary objectives. The strategic processes underlying the Energi21 strategy have led to the identification of technologies and activities that will help to achieve the following primary objectives:

1. Increased value creation on the basis of national energy resources and utilisation of energy.

2. Energy restructuring with the development of new technology for limiting energy consumption and efficiently producing more environment-friendly energy.

3. Development of internationally competitive expertise and industrial activities in the energy sector.

Strategic assessments of the various thematic and technology areas reflect industry ambitions, an integrated energy perspective, and the extent to which each area facilitates the achievement of the primary objectives. The assessments stress competitive advantages in terms of natural resources and the strength of industrial activities and expertise.

Technological maturity and the need for instruments

A multi-faceted system of technologies and solutions is needed to achieve strategic ambitions and objectives. The technologies and solutions vary in their potential and level of technological and commercial maturity. The need for instruments will differ depending on the individual technology's position in the innovation chain. Immature technologies require long-term R&D activities, in contrast to mature technologies, for which activities other than R&D are needed to realise their full potential.

Each phase of the innovation chain is vital for achieving successful commercialisation of results. This has been emphasised in all of the strategic analyses. Technology areas that are relatively mature, for instance, may provide a quick route that goes far in realising certain ambitions in the energy sector.

Intensive technology-oriented R&D activities are not considered a catalysing factor in areas such as these; what is needed here are market-oriented instruments. This means that these thematic and technology areas may not be given highest priority for research activities.

Cohesive strategic comparison

Based on the technology review in Chapter 7.1, the following section presents an overview of technologies and disciplines assessed on the basis of their maturity, potential and significance for realising the primary objectives of the strategy.

Technological maturity illustrates potential for advances in technology, which in practice often means potential for cost reduction.

The diagrams below have been created for each of the primary objectives to illustrate the following:

- **Potential**
  This indicates a technology area's potential (high, medium or low) relative to the relevant objective.

- **Technological maturity/technology area's position in the innovation chain**
  This indicates a technology area's current phase of development/position in the innovation chain.

- **Time perspective**
  This indicates the estimated time period needed for the technology area to develop into a competitive industry (green arrow = short term, orange arrow = long term).

It is important to note that technologies that have already been established in the market (indicated by a green arrow and placed far to the right of the diagram) may still be in need of research and improvements to strengthen their competitiveness by cutting costs and optimising performance. This applies to e.g. Norway's solar cell industry and the international automotive industry. Remaining competitive in the market and contributing to value creation will require continual advances, which must be driven by new knowledge, insight, innovation and enhanced industrial maturity.

Objective 1: Increased value creation on the basis of national energy resources and utilisation of energy

The utilisation of national energy resources has been a mainstay of Norwegian value creation for over a century. Access to energy resources comprising water, oil and natural gas has made Norway one of the world's wealthiest nations. Norway's natural resources will continue to play a dominant part in long-term value creation.

Hydropower plays a significant role in this context. There is room to expand hydropower production, and more resources for wind power and marine energy are also available. Hydropower represents substantial value-creating potential as energy, and its value is further enhanced by the ability to exploit reservoir capacity to provide balancing power. Furthermore, Norway has potential for efficiently utilising renewable thermal energy such as bioenergy or waste heat, which could add to the electricity supply.

Figure 7.3 below illustrates the Energi21 strategy's assessment of the significance and potential for value creation of the various energy resources in Norway, as well as the degree of technological maturity and the importance of R&D for realising this potential.

Utilising Norwegian energy resources to export power to Europe and offer system services such as balance power is a core aspect of the Energi21 vision. These are promising areas of revenue potential for Norway and Norwegian players. However, a range of complex energy-related research questions will have to be addressed, such as the mutual dependence of production and transmission capacity, and energy system considerations and requirements for regulatability will remain important parameters.

International energy restructuring prioritises the reduction of greenhouse gas emissions and increased cooperation between countries on resources, systems and markets. To this end Norway can contribute by:

1. Producing environment-friendly power based on water and wind;
2. Developing and efficiently utilising renewable thermal energy sources;
3. Developing and promoting the use of Norwegian energy resources for balancing power (system services).

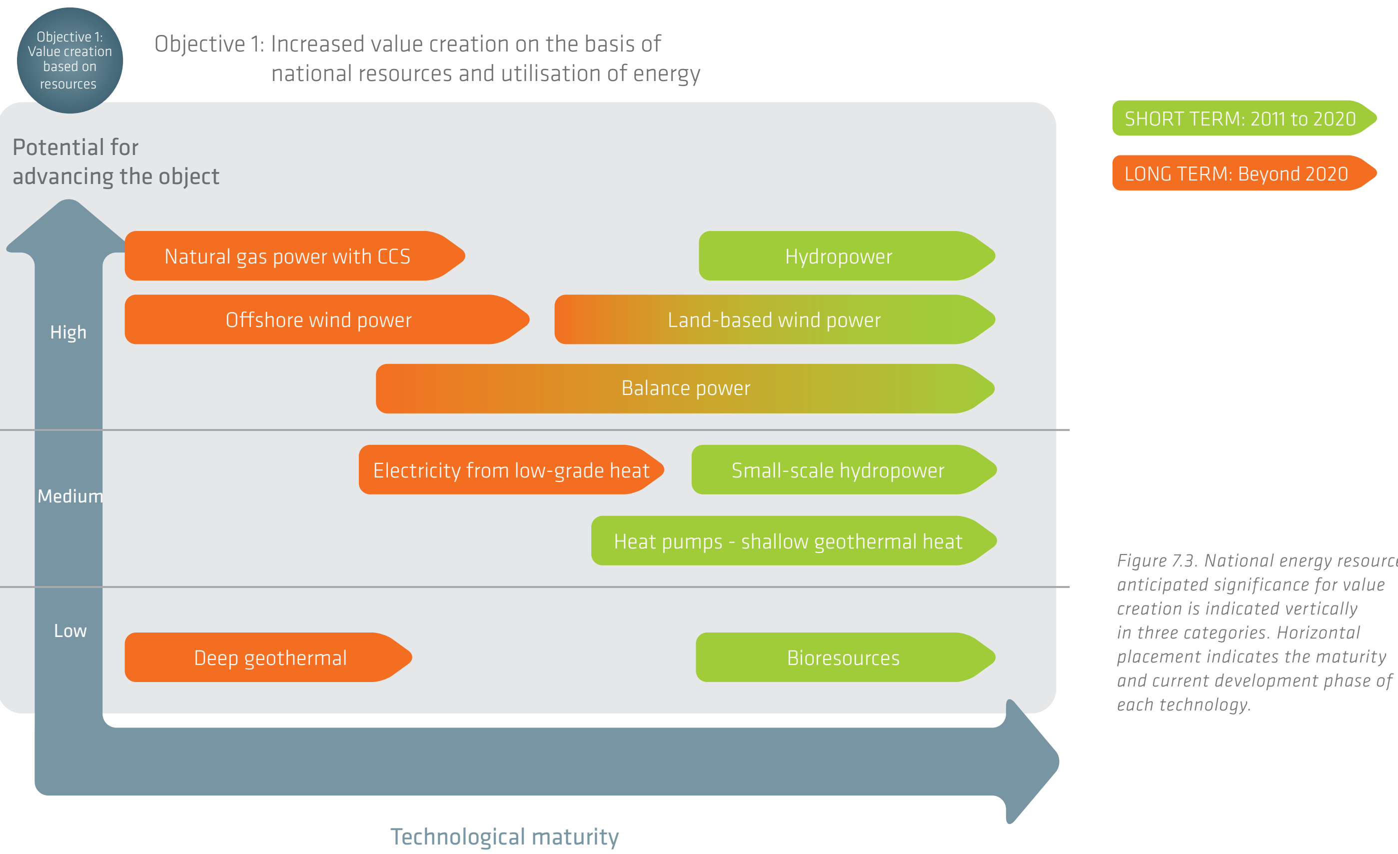


Figure 7.3. National energy resources: anticipated significance for value creation is indicated vertically in three categories. Horizontal placement indicates the maturity and current development phase of each technology.

Objective 2: Energy restructuring with the development of new technology to limit energy consumption and increase the efficient production of environment-friendly energy

Restructuring has been a key component of Norwegian energy policy in recent years. It is the object of international focus as well, and is given high priority as one of the solutions to meet climate challenges. The establishment of Enova and its mandate is an example of measures taken to promote energy restructuring in Norway. An increased share of distributed renewable energy, reduced energy consumption, higher energy efficiency, and flexible heating and cooling solutions are central elements in such a restructuring.

Implementing necessary changes will require new technologies and solutions, combined with various financial or regulatory incentives. Energy restructuring will also require knowledge transfer to consumers regarding new systems and the value of new solutions.

In nearly every case, the most environment-friendly, sustainable solution will be to cut energy needs. Changes to infrastructure and buildings have a long lifespan, so generating awareness and knowledge about measures being carried out will be important.

Since raising energy efficiency in buildings will yield major benefits, technology and solutions for realising energy efficiency measures are essential and must be given high priority.

A flexible energy system is critical for successful energy restructuring and optimising the utilisation of energy resources.

Figure 7.4 illustrates the thematic and technology areas assessed in the Energi21 strategy and their potential in terms of furthering the objective of energy restructuring.

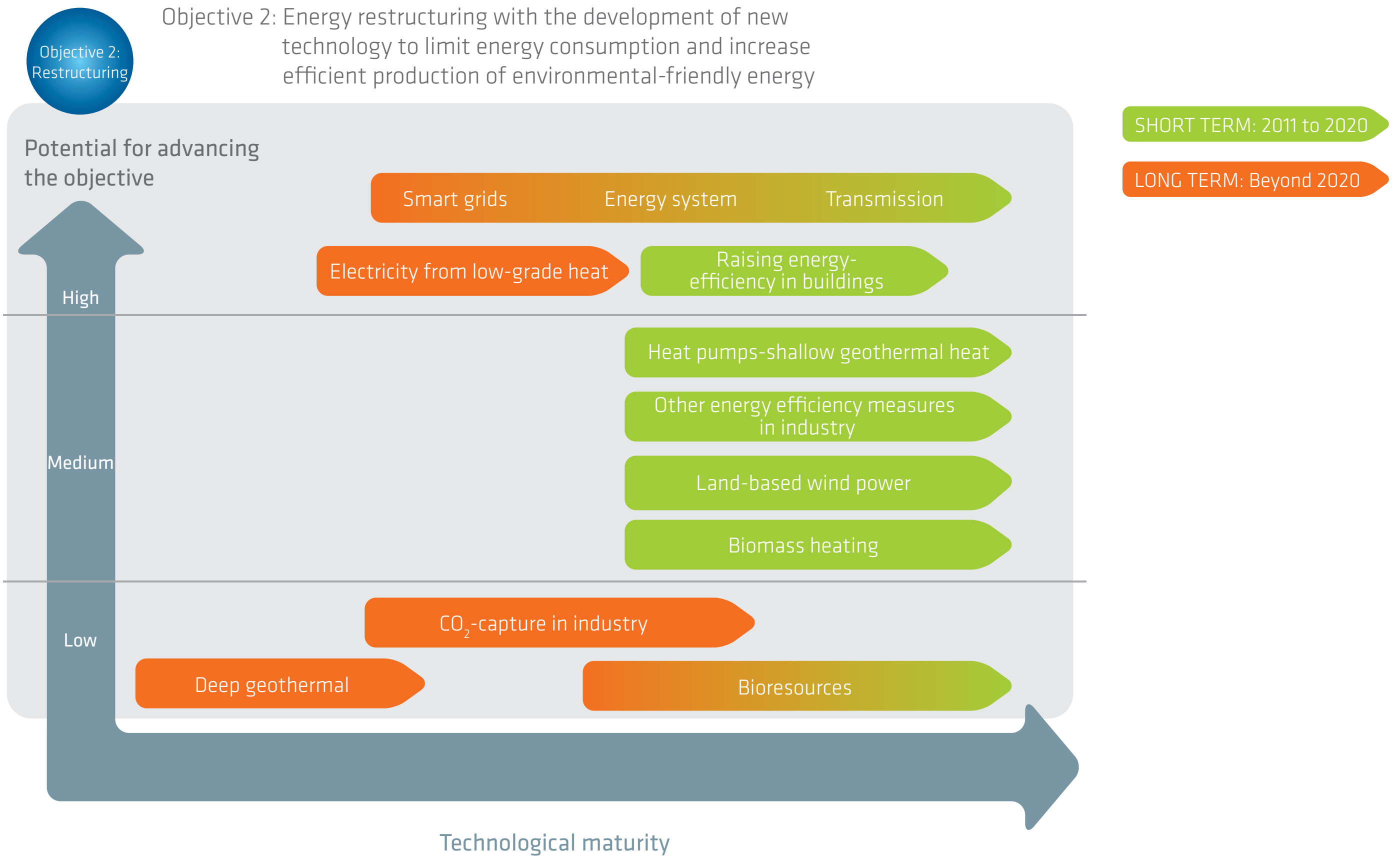


Figure 7.4. National energy restructuring: anticipated significance for energy restructuring is indicated vertically in three categories. Horizontal placement indicates the maturity and current development phase of each technology.

Objective 3: Development of internationally competitive industry and expertise in the energy sector

Around the world, strong political forces and energy policy objectives are helping to stimulate growth in the market for climate-friendly energy technologies.

Building international-level expertise will be vital to strengthening Norway's role as an energy nation.

Prospects for establishing a national industry with knowledge and technology-intensive players are already promising. Value creation will require gaining a foothold and recognition in a growing and steadily more competitive climate-friendly technology market. Success will depend on making the most of Norway's competitive advantages – namely expertise, experience and natural resources – and concentrating efforts in the areas of greatest potential.

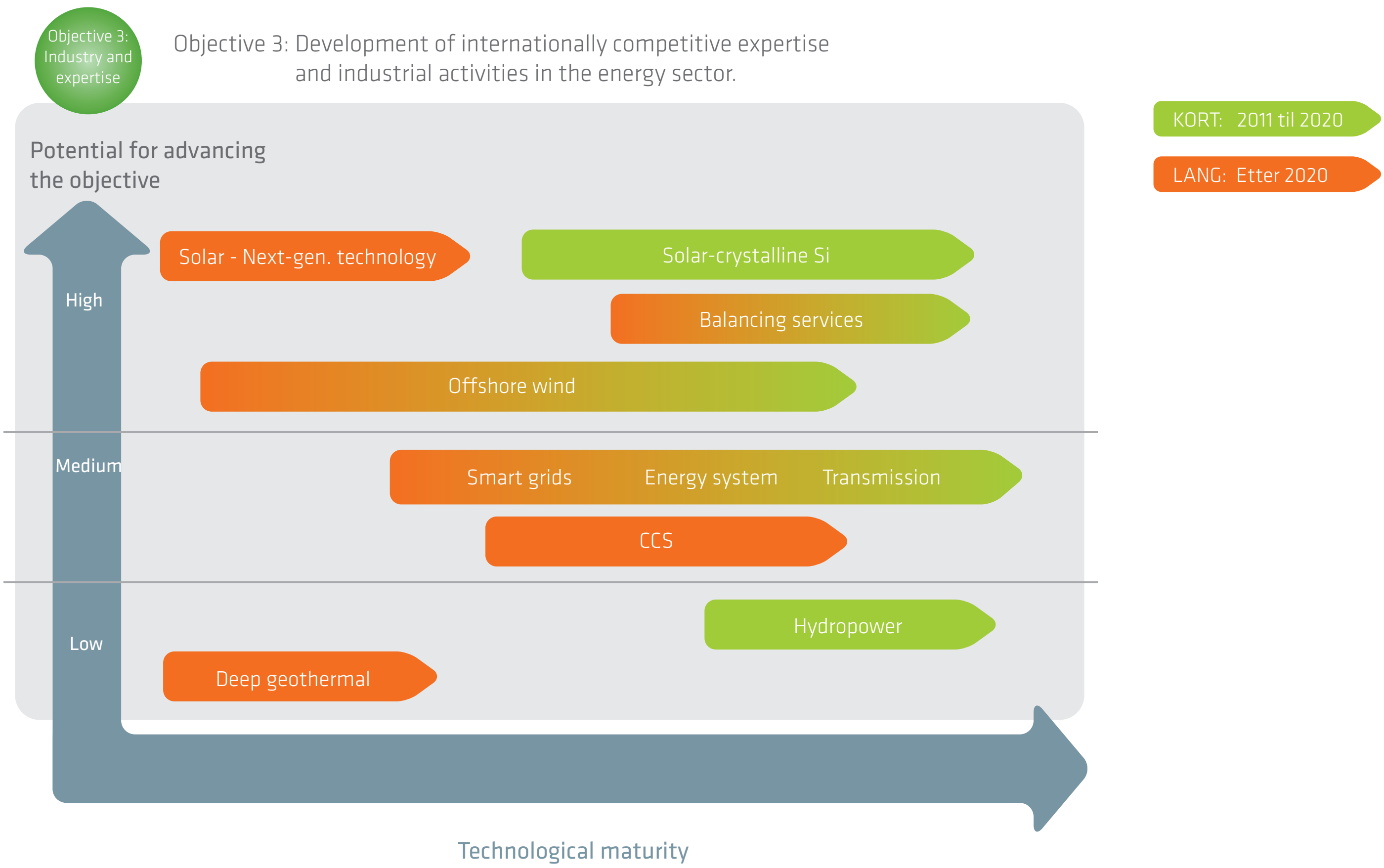


Figure 7.5. Development of competitive ***industry and expertise****: anticipated potential for developing competitive expertise or industrial activities is indicated vertically in three categories. Horizontal placement indicates the maturity and current development phase of each technology.*

Energi21 – scenarios – energy markets up to 2030

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Photo: Shutterstock.

Trying to foresee future framework conditions represents a major challenge to efforts developing energy technology and establishing industrial activities in this area. The uncertainties associated with this, combined with technological risk, pose the greatest obstacle for the players involved.

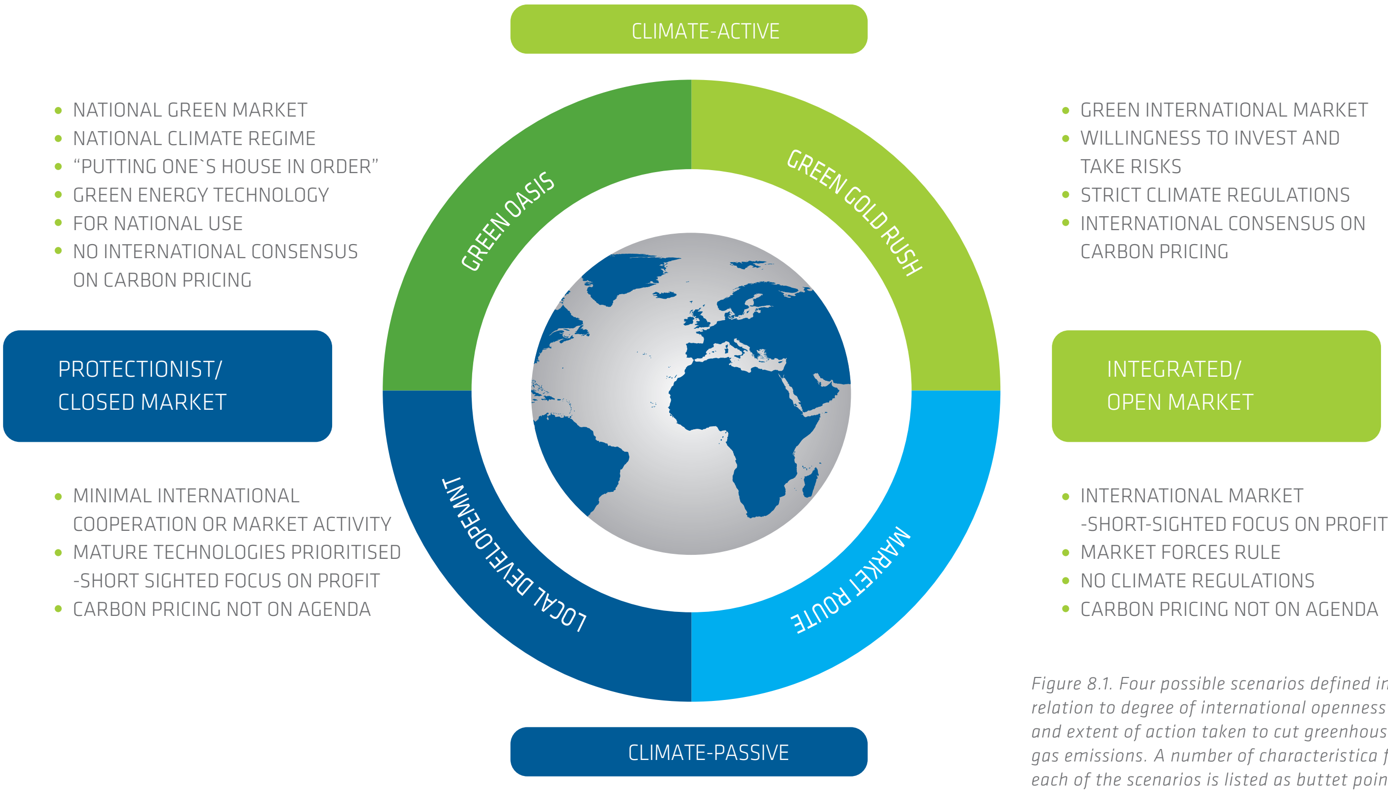


Figure 8.1. Four possible scenarios defined in relation to degree of international openness and extent of action taken to cut greenhouse gas emissions. A number of characteristica for each of the scenarios is listed as buttet points.

Future uncertainty regarding the development of the international energy market is closely tied to political regimes, regulations, incentives and market stimulants. In addition, isolated events or breakthroughs in other areas may influence market development, and thus policy design as well. A recent example is the developments around shale gas, which could lead to major modifications in the competitive situation among energy carriers. Shale gas may provide better security of supply, thereby diminishing the political will to invest in the market for climate-friendly energy.

This would have an effect on market opportunities for new energy technology. Similar "game changers" could emerge in other areas as well. The nuclear incident in Japan in spring 2011 is an example of a single, unforeseeable event that could affect this market and tilt the competitive balance between various alternative energy solutions.

To give this uncertainty more structure, the board of Energi21 has devised a set of potential scenarios to address the robustness of the various technology areas assessed in the strategy.

The scenarios are based on two fundamental questions in particular:

- How will the energy markets develop as we approach 2030?
- Which RD&D priorities will facilitate the highest possible value creation for Norway within Energi21's priority focus areas?

The attitude of the authorities and the general public towards climate challenges, as well as the willingness and ability to exchange electric power, expertise and climate-friendly solutions at the international level, will have a critical impact on the development of future energy markets. The vision of the Energi21 strategy is couched in an international perspective in which Norway is to make the most of its competitive advantages within climate-friendly energy resources, technology and expertise through energy exchange, the development of green products and services, and the establishment of an international research and education community. With this as the background, the following diametric opposites were chosen as a framework for developing the scenarios:

- Climate-active versus climate-passive
- Integrated/open energy market versus protectionist/closed energy market

Green oasis

In this scenario, Norway is a green-market oasis for climate-friendly solutions, systems and technology. The authorities actively strive to achieve their climate targets and to honour climate obligations. A strict regulatory regime is in place to promote and implement climate measures. International climate agreements have not been established, and various countries are "focusing on putting their own house in order". National RD&D activities in climate-friendly energy are given high priority. International researcher collaboration is problematical, as countries are protective of their knowledge platforms. Industry invests in Norway, and exports to international markets when profitable. Technology and knowledge are developed for a home market and the authorities focus on frameworks for the establishment of national climate-related industry and a national climate-friendly energy system. No international consensus on carbon pricing has been achieved, which poses challenges related to market opportunities for CCS and other cost-intensive energy technology.

Green gold rush

This scenario features an energy market that is international, with expertise, technology and energy in free flow across national borders. There is strong recognition of global climate challenges and motivation to take rapid action by introducing climate measures. Resilient systems have been set up to document the effectiveness of climate measures, with the possibility of initiating sanctions. Framework conditions and instruments that favour technology development and value creation involving climate-friendly technologies are in place. Commercial barriers have been reduced through the infusion of public funding. The authorities employ an international energy policy that emphasises international cooperation and utilisation of resources. Industry is characterised by a willingness to invest and take risks. There is an integrated European energy system with energy exchange and coordination of resources. There is a great deal of activity in research, development and demonstration of new technology. The authorities and industry have a long-term, climate-friendly focus, resulting in substantial public investment and good funding opportunities for industry players. International consensus on carbon pricing promotes the development of CCS and other cost-intensive, climate-friendly energy technologies.

The market route

In this scenario, the authorities employ a neutral energy policy with little follow-up of results in relation to climate targets or obligations. The market drives the development of energy technologies, and no regulation or instruments have been introduced to promote green value creation. Climate is simply considered one of a number of framework conditions. National resources are maximally exploited for commercialisation in a free international market. Mature technologies and solutions are given priority, and industry is risk-averse and reluctant to invest in climate-friendly energy projects. Transmission capacity to other countries is constructed only when it is profitable for evening out price disparities and ensuring the power balance.

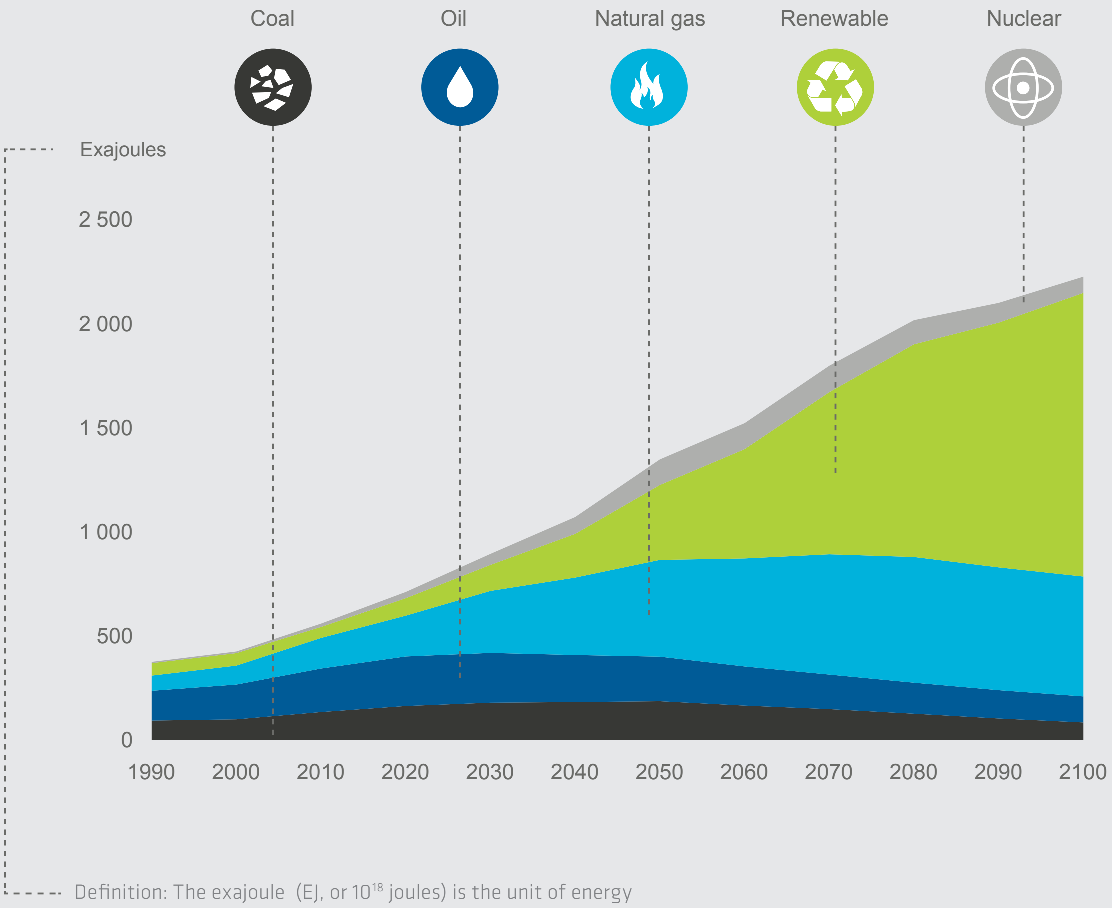
Local development

In this scenario, climate challenges are not a significant driver of energy and research policy development. Industrial policy takes precedence over climate policy, and there is no widespread use of instruments to promote green value creation. Industry focuses on short-term measures and profitability, and is reluctant to absorb costs in order to achieve long-term, effective climate targets. The energy market is market-driven and investment decisions are taken when the market is lucrative. Companies move to countries with better growth conditions for green technologies and services. A lack of international standardisation may prove to be an obstacle to the import and export of services.

Supply lines to other European countries are only constructed when there are problems with national security of supply. There is little international cooperation on trade or knowledge development. Research, development and demonstration of new climate-friendly technology is not given priority and the authorities and industry are not forthcoming with funding. The lack of international consensus on carbon prices dampens development of CCS and other cost-intensive energy technologies.

The world need more energy

Estimated future utilisation of various energy sources.



Definition: The exajoule (EJ, or 10^{18} joules) is the unit of energy most often used to measure annual global energy demand.

Illustration: www.altkanendres.no © 2011.
Source: The Intergovernmental Panel on Climate Change (IPCC), Special Report on Emission Scenarios (SRES) Alt. 1.

Energi21 – priority focus areas

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Photo: Shutterstock

The Energi21 board has decided to give priority to strengthening 6 of the 14 thematic and technology areas under the broader Technology Target Areas (TTA) analysed in connection with the revision of the strategy.

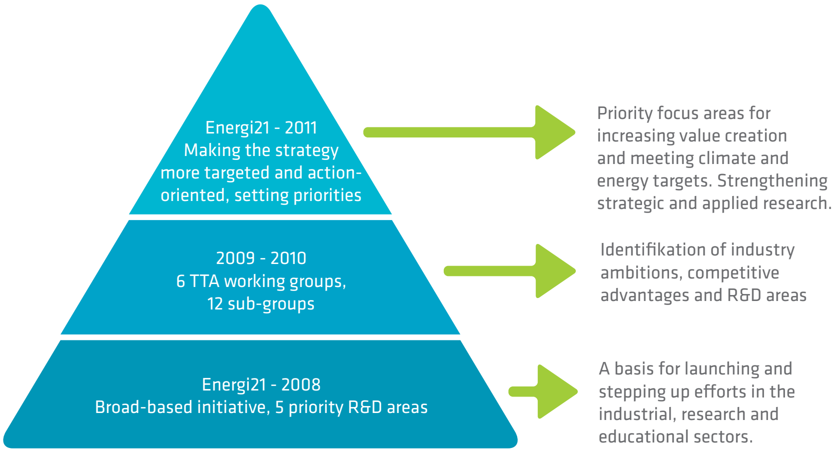

Figure 9.1. The strategising process carried out by Energi21 to provide a basis for identifying ambitions and competitive advantages and intensifying activities in priority focus areas.

Two important processes have been carried out since 2008 to strengthen Norway's position in the energy sphere. The first comprises the authorities' escalation of funding as recommended in the broad-based political agreement on climate policy achieved in the Storting and the initial Energi21 strategy report.

The second comprises Energi21's in-depth review and analysis to make the revised strategy more action-oriented and identify thematic and technology areas for increased activity. The Energi21 strategising process is illustrated in Figure 9.1 to the left.

Chapter 7 presents a strategic analysis of all 14 thematic and technology areas based on reports submitted by the TTA working groups and sub-groups and the assessments of the Energi21 board. The following factors have been given special weight in the board's analysis and when setting priorities:

- The expected significance of the individual area for achieving the three primary objectives described in the mandate of the Energi21 board.
- The ambitions and potential of Norwegian industry and research groups in the area.
- The existence of at least one competitive advantage for Norway in the relevant area in the form of:
  - specialist expertise in the industry;
  - strong competence base in the research community;
  - abundant natural resources.
- Robustness in relation to the scenarios presented in Chapter 8 and any changes in key aspects of these.

Chapter 7 describes the background on which the priority focus areas were selected, and also presents strategic research areas and appurtenant measures that should be implemented. Additional details about key R&D objectives and specific research challenges facing industry and the research community may be found in the reports of the individual working groups and sub-groups. Chapter 10 presents proposals for implementing the strategic recommendations as well as for refining and strengthening relevant instruments in order to achieve established objectives.

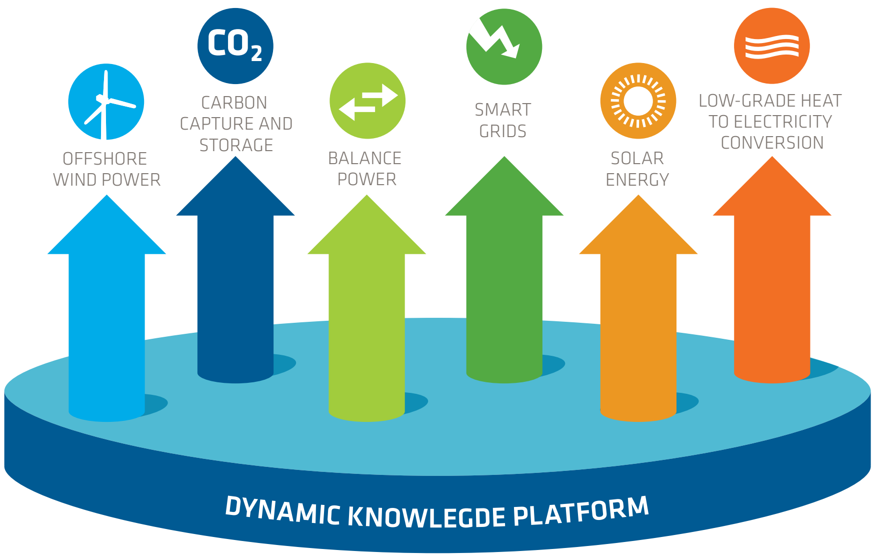

Figure 9.2. Priority focus areas under the Energi21 strategy.

The Energi21 board recommends increasing RD&D activities in the following thematic and technology areas:

Solar cells – enhanced industrial development

This area has experienced tremendous international growth in the past 15 years, and this growth is expected to continue. During this period, Norway has developed a solar energy industry and extensive research expertise in the area. This is primarily rooted in knowledge of materials in general and silicon in particular. Building on this expertise, a number of Norwegian suppliers of solar-grade silicon have emerged, with a varying degree of integration downstream in the value chain. A supplier industry is rapidly emerging to serve this business. International competition is tough, and a number of players from low-cost countries are establishing themselves. It is vital that Norwegian players concentrate their efforts and strengthen their position in the segments of the value chain in which they have competitive advantages. These are primarily segments at the beginning of the value chain involving materials expertise, and in which Norway has an early stage advantage. Cooperation between the players in Norway's solar energy cluster will also enhance the potential for success.

Intensifying activities in the solar cell industry is defined as robust in relation to all four scenarios developed by Energi21. The greatest elements of uncertainty are linked to possible radical changes in international incentive schemes for solar energy or a reversal of the globalisation of world trade.

Offshore wind power – industrial development and utilisation of resources

The international wind power market has experienced exponential growth in the past five years, and a corresponding level of growth is expected in the years to come. With a documented potential of 18-44 TWh in new offshore wind power capacity on the Norwegian continental shelf, major plans for international development and world-class offshore and maritime industries, Norway and Norwegian players have the motivation and the means to play a significant role in utilising this renewable energy resource and building an offshore wind power industry.

Norway has a number of competitive advantages in the rapidly growing market for offshore wind power. With a wide range of expertise obtained from and technologies developed for the petroleum and maritime industries, Norway is in an excellent position to provide value-creating deliverables to this market. A window of opportunity is now open, and Norwegian players must enter the field early if they are to gain a strategic position. They should not wait for projects to be launched on the Norwegian continental shelf as that is not a commercially sustainable strategy.

Any exploitation of national resources will occur well into the future. In the short and the medium term, the market for offshore wind power technology will be an international one, encompassing continental shelves other than Norway's. This applies to both seabed-based and floating installations.

Intensifying activities in offshore wind power is defined as robust in relation to the two scenarios with an open and integrated market, but less so if the market becomes less open and integrated. A diminishing of focus on climate challenges will also reduce incentives to promote offshore wind power and thereby weaken the offshore wind power market. There is some degree of uncertainty linked to the level of technical and regulatory system integration of the power markets. This applies to all electricity-related activities.

Improved utilisation of resources using balance power

Norway has significant potential as a producer and supplier of balancing services to improve the utilisation of intermittent renewable energy both in Norway and, not least, in Europe. It is possible to set our sights at different levels here, based on variables such as the upscaling of existing facilities, accompanied by increased turbine capacity and use of pumped-storage hydroelectricity. There is tremendous potential for enhancing value creation, while at the same time making an important contribution to increasing the share of renewable energy in Europe. Existing challenges have many facets and are related to the transmission capacity and dynamic characteristics of the power system, the development of a market that places a premium on balancing services, and the environmental and system effects of a more dynamic operation of Norwegian hydropower plants. Norwegian energy companies and research groups are already in an excellent position to develop the expertise and solutions to realise this potential. The utilisation of resources using balance power will require research activities across a wide range of disciplines, as well as international cooperation. Developing the market and associated infrastructure will also open up opportunities for energy-intensive industry in Norway with flexibility in consumption.

Intensifying activities in balance power is defined as most robust in relation to the two scenarios with an open market, and is dependent on closely integrated European cooperation on transmission capacity, willingness to develop a market for balancing services and integration of such services. There is political uncertainty in terms of the degree of protectionism in European and Norwegian policy and the willingness to carry out system integration.

Generating and safeguarding value creation through CO_2 capture, transport and storage

Carbon capture and storage (CCS) is a pivotal technology for meeting climate targets. According to the IEA, CCS will play a major role in achieving emissions reductions. In its ETP BLUE Map scenario, the IEA estimates that power generation with CCS will account for 11 000 TWh in 2050. With technology, solutions and storage capacity for CO_2, Norway is well-equipped to contribute to advancements in this area. The effort that has already been invested gives Norway and Norwegian players an early mover advantage that should be put to good use. The Norwegian supplier industry can draw benefit from this to develop cost-effective solutions, initially for cleaning up coal power internationally, and later for capturing CO_2 from gas power generation and industrial activities. In addition to competitive advantages in the form of potential storage sites and high-level research expertise, Norway also has substantial natural gas reserves. The value of these reserves may be affected by future carbon tax regimes.

The availability of viable solutions for gas power generation with CCS will modify the risk picture considerably. Research and development activities to realise CCS will therefore be of major significance to ensuring Norway's future value creation from its natural gas resources. Thus, the development of technology for gas power with CCS represents an important method of safeguarding value in Norway. Gas power may also play a vital role in balancing a large share of renewable energy in Europe and in replacing coal power. Norway and Norwegian players are expected to play a significant role in international cooperation with regard to CCS solutions.

Intensifying activities in carbon capture and storage is defined as most robust in relation to the two climate-active scenarios. International consensus on carbon pricing is crucial here, as are individual countries' continued efforts to decarbonise fossil energy carriers with the aim of reducing greenhouse gas emissions. A reversal of focus would weaken the market for CCS technology.

Flexible energy systems – smart grids

Achieving progress in all of the priority focus areas described in the strategy will require effective, flexible energy systems. Current grid designs and system solutions must be further developed to fulfil future requirements for technical solutions and functionality. The following aspects will have to be taken into account when designing the climate-friendly energy systems for the future:

- Greater integration of new renewable energy and future energy technology.
- New patterns of operation at Norwegian hydropower plants resulting from increased use of balancing services nationally and internationally.
- Subsea transmission grid to connect Norway to Europe, harvest offshore wind power and achieve electrification of petroleum activities.
- Adequate security of operation and supply in a common power system with a rapidly rising level of complexity.
- Energy restructuring and more parallel infrastructures that utilise heat and electricity.
- Higher degree of end-user flexibility.

Productive research and development is essential for achieving targets in this area. The development of effective knowledge and solutions entails the development of goods and services of intrinsic value in an international market in which there is demand for these. The development of flexible energy systems – smart grids – is called for in all four Energi21 scenarios. The degree of international integration will influence the nature of the problems that must be solved. Major system challenges already exist in all four scenarios that cannot be solved with the knowledge and technology available today.

Utilisation of energy – converting low-temperature heat into electricity

According to the IEA, raising energy efficiency is one of the most important solutions for meeting climate challenges. Raising energy efficiency in industry, industrial buildings and homes is therefore high on the energy policy agenda, and is a key component of national energy restructuring efforts. Encouraging increased use of low-grade heat for heating purposes, when possible, is a key task.

One important measure for raising energy efficiency in industry is the utilisation of waste heat from the process industry. A lack of infrastructure makes it difficult to utilise this thermal energy resource in Norway optimally. Special focus is therefore being directed towards the development of solutions for converting low-temperature heat into electricity. Utilisation of waste heat and conversion of low-temperature heat into electricity is a complex field characterised by many unsolved problems. Technology developed in this area will also be relevant for geothermal heat and solar heat. Thus, the development of technological solutions for utilisation of waste heat and conversion of low-temperature heat into electricity will be pivotal to the restructuring of the Norwegian energy system.

Intensifying activities to improve energy utilisation by increasing use of waste heat is defined as robust in relation to all four Energi21 scenarios. The solutions developed will all be of benefit. The greatest uncertainty is linked to the degree of profitability, which will be affected by energy prices.

Implementing the strategic recommendations

10

Photo: Shutterstock

Implementing the strategic recommendations set out in the revised Energi21 strategy will require the investment of personnel resources as well as financial and knowledge-based capital. Dedication to meeting long-term objectives and use of effective short-term actions will be key factors for successful implementation. The need for financial or other instruments will vary according to the maturity of the technology and the market and the type of technology developer.

10.1 Coordination and cooperation

Future value creation in the energy sector must be based on multidisciplinary innovation and cross-sectoral cooperation. To realise the strategy's recommendations, it will be essential to ensure adequate coordination and cooperation between the authorities, the public agencies within the research and innovation system, research communities, educational institutions and, not least, industry – which in most cases will actually bring the newly-developed solutions into operation.

10.1.1 Ensure recruitment and long-term competence-building

Given the rapid pace of technology and market development, knowledge and capital are crucial to gaining a market position. Companies must employ highly-knowledgeable professionals to remain at the forefront of their field and successfully meet tomorrow's challenges. The industrial sector itself is responsible for long-term competence-building and recruitment to industrial activities. However, recruitment is a genuine problem in certain branches of industry, and competition for the most talented individuals is tough. Cooperation between trade and industry, research communities and educational institutions is essential to ensuring the education of an adequate number of professionals with the proper competence. Industry participation will promote the integration of practical and theoretical knowledge and the development of forward-looking, market-oriented expertise.

The Energi21 board recommends the following measures to strengthen cooperation between the various players and ensure long-term competence-building:

Increased coordination and cooperation between relevant sectoral ministries
Introduce a strategic approach and actions to achieve mutual influence and synergies.
Harmonise the development of knowledge, solutions and framework conditions.

Close cooperation between trade and industry and educational institutions
Train and recruit professionals with specialist knowledge in various disciplines to safeguard Norway's energy resources and energy systems.

Close cooperation between research communities and industry
Establish a knowledge platform that reflects the future needs of industry and society at large and promotes future value creation.

Close cooperation between trade and industry and the authorities
Implement RD&D instruments and projects to facilitate future value creation and commercialisation of research results.

Participation in the international knowledge arena
Participate in international research cooperation to foster a competitive knowledge pool and industry.

10.1.2 Industry involvement – a prerequisite for success

Industry-led initiatives and industry participation in RD&D projects are critical to the implementation of the strategy's recommendations. All phases of the innovation chain are dependent on the presence of trade and industry to commercialise results and create value. Public funding helps to reduce risk and increase the implementation ability of the commercial players involved, but the industrial sector itself must generate concepts and identify relevant research topics as well as provide the largest proportion of funding. Industry participation will be decisive in ensuring that RD&D activities have the proper focus and structure.

Innovation ability and willingness to engage in research-based activities

Industrial players' innovation ability and willingness to engage in research-based activities is also vital for success, and it is important to differentiate between the individual player's technology and market areas. The attitudes of commercial players towards participating in future-oriented technology and services development are shaped in part by their short-term focus on profitability and in part by company traditions and corporate culture. Their innovation ability is influenced by a number of factors, including financial resources, regulatory frameworks and other framework conditions that affect operations. The implementation of recommendations set out in the Energi21 strategy calls for innovation within technology and system technology disciplines. This in turn will require a long-term strategic focus on the part of the industry players and the creation of innovation arenas and active industrial clusters.

The Energi21 board recommends the following measures to promote industry involvement and innovation ability:

Regulatory instruments that reward research activities in industry
Establish framework conditions that strengthen companies' innovation ability and competitiveness.

Build innovation arenas
Develop and exercise active ownership in joint innovation arenas, such as FME centres and the like, and build infrastructure of benefit to many stakeholders.

Knowledge-sharing and network-building
Collaborate on joint research, development and/or demonstration projects to facilitate knowledge-sharing and knowledge refinement.

Dynamic, high-calibre, internationally competitive research communities
Cultivate internationally competitive research communities to attract international players and encourage them to conduct RD&D activities in Norway.

Increased participation of small companies in research, development and testing facilities
Establish framework conditions that lower the threshold for the participation of smaller, entrepreneurial companies in research activities and testing facilities for technology verification.

10.2 Integrated and harmonised system of instruments

Views regarding what is to be achieved must be founded on a common understanding of what the system of instruments comprises. Shared understanding on the part of the trade and industry players as to the function and purpose of the instruments will help to ensure optimal utilisation of public resources, enhance implementation ability and increase the number of viable project concepts. The goals of the broad-based political agreement on climate policy achieved in the Storting and the priority focus areas of the Energi21 strategy should form a common strategic foundation for the public agencies within the research and innovation system when designing and coordinating their objectives and instruments.

The Energi21 board recommends the following measures to achieve a more integrated and harmonised system of instruments:

Common strategic foundation for the public agencies within the research and innovation system – coordinated objectives and instruments
The broad-based political agreement on climate policy and the Energi21 strategy should be used as a common strategic platform.

Top-level management forum for the public agencies within the research and innovation system
Two meetings a year should be held at which the top-level management of the public agencies within the research and innovation system harmonise the strategic foundation for funding announcements and allocation of project funding. In addition, information about trends, the number of applicants and measures to promote interest in areas in which there are knowledge gaps should be exchanged.

Differentiated instruments in relation to the type of technology developer and position in the innovation chain
The system of instruments should be broad enough to encompass all types of technology developers – from smaller-scale entrepreneurial companies to larger-scale capital-intensive companies.

Meeting-place for the stakeholders within the research and innovation system and project developers
The Research Council of Norway, Innovation Norway, Enova and Gassnova should cooperate on establishing a meeting-place at which project and technology developers can gain an understanding of the purpose, structure, function and use of available instruments. Steps should also be taken to promote productive dialogue between the stakeholders within the research and innovation system and their users.

10.3 Incentives for realising objectives

Each phase of the innovation chain is vital for generating, realising and commercialising research results. The system of instruments must follow the entire innovation chain and be flexible enough to respond to changing challenges and needs.

The Research Council, Innovation Norway, Enova and Gassnova are the public sector stakeholders with the greatest influence on the realisation of the ambitions and objectives of the Energi21 strategy. Other players in the public sector also have substantial influence, for example in the context of requirements, regulations and the statutory framework.

It is imperative to avoid situations in which a certain technology is given priority in an early phase of the innovation chain only to be stopped as it comes close to fruition because the objectives of the various instruments have not been harmonised or the thematic priorities are different. Ensuring adequate support for projects in the energy sector that have reached the pilot and testing phase is currently a challenge.

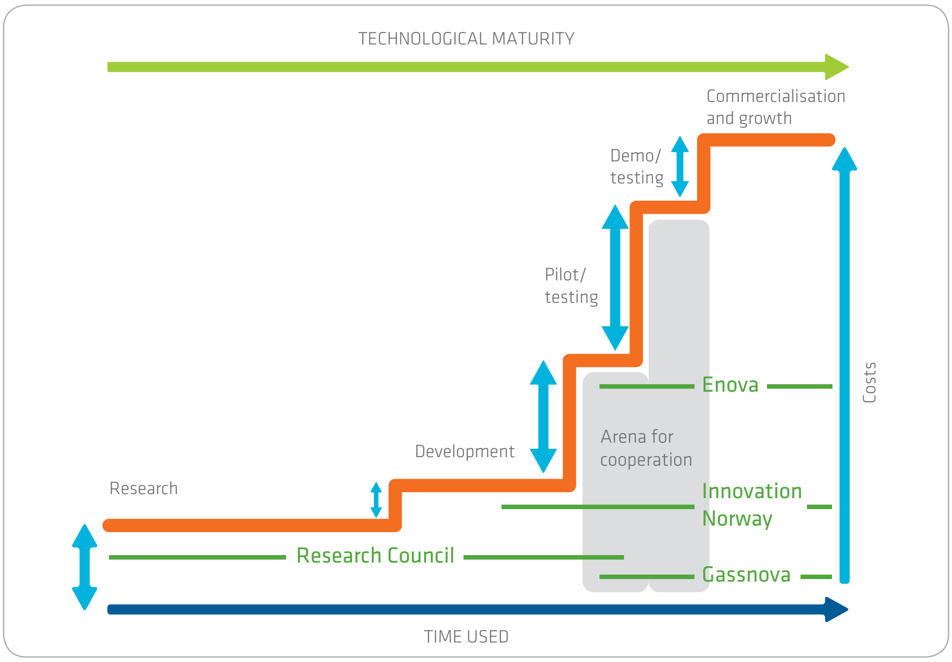

Figure10.1. There must be integration and continuity between the public players providing support to trade and industry in order to generate new value creation as well as fulfil the objectives of the various instruments.

There is a need for testing and demonstration facilities in many of the Energi21 thematic and technology areas. Such facilities are essential tools for realising industry ambitions and objectives.

The costs of such facilities and projects are significantly higher than for R&D projects, but it is vital to demonstrate the effectiveness of a technology to motivate further implementation. There is therefore a need to close the gap between research and development on the one hand and instruments for market introduction on the other. The programmes and instruments now in the portfolios of the Research Council, Enova, Innovation Norway and Gassnova appear to cover the entire innovation chain.

This, however, is not necessarily enough. It is also of the utmost importance that the objectives of the various instruments are coordinated. Current instruments, such as the Research Council's RENERGI programme and the FME centre scheme, have been established with a dual objective involving: 1) energy supply and energy restructuring and 2) industrial development in the energy sector.[1] Innovation Norway's funding scheme for environmental technology also has a clear focus on industrial development. This means that it will be harder to carry out projects to develop and realise solutions for improving the Norwegian energy system when these do not involve a component of industrial development. This may have an impact on, for example, projects relating to energy system development, important environmental projects or projects that generate indirect value creation that does not "belong" to a specific commercial player.

Sufficient resources is another critical factor. When technologies reach the pilot, testing and demonstration phases, costs climb significantly. There must be adequate capital available – both in terms of public funding instruments and industry funding – to finance the step up to the next phase.

The Research Council, Enova and Innovation Norway have recently taken the initiative to enhance the profile of and coordinate their respective instruments for testing and demonstration. This is an excellent initiative which should be further developed to ensure optimal utilisation of public funding and clarify the interplay between the various instruments.

It is important that technologies have come as far as possible in the R&D phase before investing in testing and demonstration facilities. Costs tend to rise after a longer period of R&D, so it is imperative that all the relevant public agencies and industry players involved engage in closer dialogue and make more of an effort to harmonise their objectives than previously. It is very unfortunate when projects that are granted public funding in an early phase of the development chain are stopped because they do not fit the current thematic orientation despite the fact that they fulfil all the eligibility criteria for public risk mitigation.

1 The focus on energy supply and energy restructuring reflects the responsibility of the Ministry of Petroleum and Energy to develop effective knowledge and solutions that ensure adequate management of the Norwegian energy system and energy resources.

The Energi21 board recommends the following measures for establishing a complete incentive structure for the energy sector:

Support for testing and demonstration facilities – funding scheme and regulatory measures
Targeted activities in the field of climate-friendly energy technology have led Norwegian industrial players in cooperation with research groups to develop promising solutions with great potential for use both domestically and internationally. This success brings with it a need to support testing and demonstration facilities in order to verify and test technology solutions and systems at a large scale. The Energi21 board recommends that support be given for testing and demonstration facilities within the following thematic and technology areas:

Close cooperation between industry and educational institutions. Train and recruit professionals with specialist knowledge in various disciplines to safeguard Norway's energy resources and energy systems.

- Offshore wind power
- Hydropower/pumped-storage hydroelectricity
- Future transmission and distribution grids – smart grids

Increase in the number of R&D projects within the Energi21 strategy's priority focus areas
Three years have passed since the publication of the initial Energi21 strategy. Research groups and industry have collaborated well, and the authorities have contributed their share to this wide-ranging cooperation in the form of a substantial increase in funding. The industry has now achieved a knowledge base, a momentum and a high level of involvement, providing an excellent basis for stepping up activities in the priority focus areas and realising the potential for value creation that has been identified.

The activities launched in the wake of the initial Energi21 strategy report must be continued. The revised strategy narrows the definition of the priority focus areas, making them more action-oriented. Commitments relating to climate issues and the need to ensure security of supply have emerged as key drivers in the energy sphere during the period since the publication of the initial strategy, and the areas in which Norwegian players can take on a leading international role have been more clearly highlighted. These form the basis for the revised strategy, and it is important that stable, reliable research funding remains available.

The Energi21 board recommends increasing the number of R&D projects in the following strategic thematic and technology areas:

- **Offshore wind power**
  - Optimal foundation designs for different seabed conditions.
  - Improved installation of and anchoring foundations for offshore turbines.
  - Cost-effective systems for operation and maintenance.
  - Methods and systems for condition-based maintenance.

- **Flexible energy systems for the future**
  - Transmission and distribution grids:
    Primary and secondary technologies, electrotechnical components and system solutions.
  - Smart grid technologies and transition strategies.
  - Infrastructure solutions.

This table is continued on the next page >

- **Raising energy efficiency in industry**
  - Conversion of low-grade heat into electricity.

- **CO_2 capture, transport and storage**
  - Technology for secure, cost-effective storage and monitoring of CO_2.
  - Cost-cutting technologies for CO_2 capture from power generation and the process industry.
  - Methods and service concepts for assessing storage sites for CO_2.

- **Solar electricity**
  - Silicon as a material for solar cells.
  - Next-generation solar panels based on silicon and other materials.
  - Incentives and market development

Establishment of a new FME centre
There is a need for targeted activities in the area of flexible energy systems for the future, with focus on flexibility and creating favourable conditions for balance power. This is a suitable area in which to establish a new Centre for Environment-friendly Energy Research (FME). The Research Council currently has a large portfolio of Knowledge-building Projects for Industry in the energy system area. A natural approach would be to base the FME centre on certain of these ongoing activities. In addition, activities need to be launched in connection with solving the technological and regulatory challenges involved in achieving the desired level of balance power. In this context it would also be natural to explore the possibility for close integration with the newly established Centres for Social Science-related Energy Research (FME Samfunn) in order to research the market-related challenges linked to increased use of Norwegian hydropower as balance power.

Market-based instruments
This strategy report has presented a diverse array of technologies and solutions that have already reached an adequate degree of technological maturity and can help to meet targets and achieve the objectives of optimal utilisation of national energy resources, energy restructuring and increased value creation. Market-based instruments are key tools in this context and must continue to be refined. The introduction of the green electricity certificates is an example of such an instrument.

Research infrastructure
Funding for research infrastructure such as laboratories, testing equipment and testing facilities is of great importance. One criteria for allocation of such funding to research groups must be that research infrastructure is made accessible to all relevant players in Norway, and that access rights are not limited to a single industrial partner.

10.4 Funding

Funding needs vary according to the position of the technology in question along the innovation chain. The need for capital increases the closer the technology moves towards market introduction and commercialisation.

10.4.1 Current funding landscape

The public agencies within the research and innovation system provide support within different segments of the technology development chain through to market introduction. NOK 600 million is available in 2011 for allocation to research and development projects via the RENERGI and CLIMIT programmes and the FME centre scheme under the Research Council of Norway.

Enova has a budget of NOK 400 million for 2011 for support for demonstration projects. NOK 250 million is earmarked for offshore wind power and other renewable marine energy production. In several of the Energi21 priority focus areas there is sufficient market pull to provide industry with the incentive to invest heavily in upscaling and pilot demonstrations (for example, in the areas of hydropower, land-based wind power and solar cells.) Support schemes for pilot and demonstration projects have been launched in several areas in which there are too few incentives for industry to invest in these types of projects on its own (for example, in the areas of natural gas power with CCS and offshore wind power, wave energy and energy from ocean currents, for which Gassnova and Enova, respectively, have established support schemes).

10.4.2 Future funding needs

It is recommended that funding for research programmes and research centres continue to be increased in order to realise the possibilities identified through the process of drawing up this strategy and made concrete in the priority focus areas. Public funding must also be made available for technology and solutions nearing the testing and demonstration phase.

The table below provides a summary of the Energi21 board's recommendations for funding for the various public agencies in relation to the priority focus areas.

		Current annual funding (In NOK million.)	Energi21s recommendation	Notes
The Research Council				
	RENERGI programme	350	500	Increase funding for R&D without thematic limitations to improve recruitment and ensure future innovation. Strengthen priority research areas.
		0	100	New initiative as a result of extensive industry involvement in the FME centres.
	CLIMIT programme	100	150	
	FME scheme	150	220	New FME centre: future energy systems.
Enova				
	Funding scheme for demonstration	400	550	
	Support for testing and demonstration facilities (new)	0	300	
Innovation Norway				
	Miljøteknologiprogrammet	250	Should be continued	Funded by the Ministry of Trade and Industry.

ATTACHMENT A

Mandate for the board of Energi21 from

THE ROYAL NORWEGIAN MINISTRY OF PETROLEUM AND ENERGY – July 2008

The objective of the Energi21 strategy
The Energi21 strategy is to comprise an integral component of Norwegian energy policy and promote the achievement of the following primary objectives set out by the authorities for R&D in the energy sector:

- To increase value creation on the basis of national energy resources and utilisation of energy.
- To facilitate energy restructuring with the development of new technology to limit energy consumption and increase the efficient production of environment-friendly energy.
- To cultivate internationally competitive expertise and industrial activities in the energy sector.

The objective of the strategy is to ensure sustainable value creation and security of supply by improving coordination of and energy industry participation in research, development, demonstration and commercialisation of new energy technology. The strategy should also help Norway to become a major supplier of environment-friendly energy to Europe.

The strategy should foster integrated thinking around the development of new energy technology by bringing the authorities, trade and industry and research communities closer together. Another aim is to generate greater support for energy research in general and encourage industry to increase its investment in R&D activities.

The tasks of the board

The Energi21 board is to organise and lead the process of drawing up and implementing the revised Energi21 strategy in accordance with the strategy's objective.

The strategy must be drawn up in communication with and based on needs of the relevant stakeholders, such as energy companies and supplier companies, research communities, allocating authorities, the Research Council of Norway, Enova and Innovation Norway.

The board is to make the revised strategy more concrete, targeted and action-oriented.

Working groups are to be established in the priority research areas and their work followed up.

The board must remain abreast and take adequate account of national strategies and activities of significance for the Energi21 strategy. These include, for example, the Government's bioenergy strategy, the Norwegian Hydrogen Strategy and the authorities' carbon capture and storage (CCS) initiatives.

The board is to provide input to the allocating authorities (including the Research Council, Enova and Innovation Norway) and the energy industry regarding research priorities in relation to the Energi21 strategy.

The board is to assist the research communities by determining what type of expertise will likely be required by energy companies and the supplier industry.

The board is to help to coordinate research activities and motivate energy companies (their boards and management) to increase investment in R&D activity in accordance with the Energi21 strategy.

The board is to conduct an annual internal evaluation of its activities.

The strategy is to be revised two to three years after its publication.

ATTACHMENT B

LIST OF TECHNOLOGY TARGET AREA (TTA) WORKING GROUPS AND PARTICIPANTS

TTA working group: Renewable energy production

Working group leader: Ragne Hildrum, Statkraft

Wind power

Sub-group leader: Arne Aamodt, Lyse Produksjon
Secretary: Trond Moengen, Energidata Consulting

Mats Sjøberg	Fred Olsen Renewables
Nils Arne Nes	Nord Trøndelag Elektrisitetsverk (NTE)
Øyvind Kristiansen	Statkraft
Elly Karlsen	Statoil
Stig Svalheim	Vestavind Kraft
Hans Axel Bratfors	DNV
Erik Olav Bærug	DNV
Christopher Kjølner	GE
Tore Tomter	Siemens Norway
Sigurd Øvrebø	Smartmotor
Ivan Østvik	Norwind
John Olav Tande	SINTEF Energy Research/ Norwegian Research Centre for Offshore Wind Technology (NOWITECH)
Terje Nøstdal	Belief
Solgun Furnes	Energy Norway/Energiakademiet

Hydro power

Sub-group leader: Erik Høstmark, Statkraft
Secretary: Trond Moengen, Energidata Consulting

Ånund Killingtveit	Norwegian University of Science and Technology (NTNU)
Siri Stokseth	Energy Norway/Energiakademiet
Svein Haugland	Agder Energi
Jan Helge Mårdalen	Hydro
Sigve Næss	BKK
Atle Harby	SINTEF Energy Research/ Centre for Environmental Design of Renewable Energy (CEDREN)
Steinar Faanes	Rainpower
Torodd Jensen	Norwegian Water Resources and Energy Directorate (NVE)

Solar power

Sub-group leader: Anne Jorun Aas, Scatec

Ragnar Trondstad	Elkem
Erik Stensrud Marstein	Institute for Energy Technology(IFE)/ Norwegian Research Centre for Solar Cell Technology
Anders Elverhøi	University of Oslo

Participants from Energi21:,
Kjell Olav Skjølsvik, Enova, Energi21 board member and support person
Lene Mostue, Director, Energi21

TTA working group: Energy systems

Working group leader: Terje Gjengedal, Statnett

Transmission grid (offshore/onshore)

Sub-group leader: Jan Ove Gjerde, Statnett
Secretary: Trond Moengen, Energidata Consulting

Georg Ballog	Nexans
Øyvind Bergvoll	Statoil
Arne Dybdal	Statnett
Nils Martin Espegren	Norwegian Water Resources and Energy Directorate (NVE)
Anen Sofie Risnes	NVE
Lars Audun Fodstad	Statkraft
Olav Bjarte Fosso	Norwegian University of Science and Technology (NTNU)
Albert Leirbukt	ABB
Petter EgilRøkke	Sintef Energy Research
Kjetil Uhlen	NTNU
Anne Johanne Kråkenes	Ministry of Petroleum and Energy
Laila Berge	Ministry of Petroleum and Energy

Distribution grid (onshore/offshore)

Sub-group leader: Ketil Sagen, Energy Norway/Energiakademiet

Eilert Bjerkan	Nortroll
Karstein Brekke	NVE
Per Bjørn Larsen	Nexans
Bjørn Lauritzen	Småkraftforeningen (Norwegian Association of Small Hydropower Plants)
Rolf Pedersen	Aidon
Knut Samdal	Sintef Energy Research
Jens Skår	BKK Nett
Eva Solvi	Transnova
Bjørn Utgård	Helgelandskraft
Trond Østrem	Narvik Universtiy College

Policy structures, framework conditions, and power market

Sub-group leader: Audun Ruud, Sintef ER

Magnus Korpås	Sintef Energy Research
Mette Bjørndal	Norwegian School of Economics (NHH)
Erlend Broli	Statkraft
Øystein Galaaen	NORWEA
Bernt Anders Hoff	Statnett
Hans Olav Ween	Energy Norway

Participants from Energi21:,
Lars Kristian Vormedal, Statnett, Energi21 board member and support person
Petter Støa, SINTEF Energy Research, Energi21 board member and support person
Lene Mostue, Director, Energi21

TTA working group: Raising energy efficiency in industry

Working group leader: Are-Magne Kregnes, Siemens

Secretary: Benedicte Langseth, Xrgia

Aluminium, ferrolegeringer, papirmasse, papir og papirvarer

Sub-group leader: Hans Petter Lange, Hydro Aluminium

Alf Tore Haug	Elkem Thamshavn
Gunnar Vegge	ABB
Johan W.Brekke	Statkraft
Olav Dehli	Norske Skog
Petter Nekså	Sintef Energy Research

Chemical products and refineries

Sub-group leader: Anne Karin Hemmingsen, Sintef Energy Research

Birger Bergesen	Norwegian Water Resources and Energy Directorate (NVE)
Knut Grande	Statoil
Steinar Kvisle	Ineos

Food industry

Sub-group leader: Trygve Magne Eikevik, Norwegian University of Science and Technology (NTNU)

Stein Rund Nordtvedt	Institute for Energy Technology
Torbjørn Kvia	TINE dairy cooperatiive Sør Jæren
Marit Sandbakk	Enova
Arne Norland	Felleskjøpet Rogaland
Hans Even Helgerud	NEPAS

Participants from Energi21:,

Arne Bredesen, NTNU, Energi21 board member and support person
Lene Mostue, Director, Energi21

TTA working group: Renewable thermal energy

Working group leader: Mats Eriksson VKE- Ventilasjon Kulde Energi /Norsk

Secretary: Benedicte Langseth, Xrgia

Geotermal energy

Sub-group leader: Jan Evensen, Rock Energy

Håkon Bergan	TTS Sense
Per Håvard Kleven	Kongsberg Decotek
Rune Helgesen	Geoenergi
Jane Nilsen Alshus	Statoil
Odleiv Olesen	NGU
Inga Berre	University of Bergen
Erling Næss	Norwegian University of Science and Technology (NTNU)

Bioenergy

Sub-group leader: Morten Fossum, Trondheim Energi Fjernvarme

Lars Sørum	Sintef Energy Research
Erik Trømborg	Norwegian University of Life Sciences
Per ArneKarlsen	Akershus Energi
Anette Solheim	Dovre
Tone Knudsen	Bellona
Helle Grønli	Enova
Bjørn Håvard Evjen	Norwegian Forest Owners' Federation
Arnold K. Martinsen	Norwegian Bioenergy Association (NoBio)
Rune Dirdal	Waste Management Norway
Jon Iver Bakken	Hafslund

Distributed heating and cooling solutions

Sub-group leader: Tom Erik Hole, Buskerud Kulde AS

Lars Haua	Johnson Controls Norway AS
Daneil M.Kristiansen	ABK
Jørn Stene	COWI
Ole Jørgen Veiby	GK Norge
Jens Petter Burud	YIT
Stein Terje Brekke	Teknotherm Industri AS
Per G. Vemork	VKE
Helge Folkestad	Ener-Produkt AS

Participants from Energi21:,

Monica Havskjold, Xrgia, Energi21 board member and support person
Lene Mostue, Director, Energi21

TTA working group: CO_2 capture, transport and storage (CCS)

The OG21 and Energi21 strategic bodies collaborated to serve as the CCS working group. The CLIMIT programme board functioned as a resource group when drawing up recommendations and objectives for CO_2 capture, transport and storage.

Secretary: Lars Ingolf Eide
Representative of the Energi21 board: Svein Eggen, Gassnova

Climit programme board:

Board chair Kjell Bendiksen	Institute for Energy Technology (IFE)
Olav Kårstad	Statoil
Åse Slagtern	Aker Solutions
Marianne Holmen	Statkraft
Niels P. Christensen	Vattenfall, Denmark
Nils A. Røkke	SINTEF Energy Research
Guttorm Alendal	University of Bergen
Kristin Margrethe Flornes	International Research Institute of Stavanger (IRIS)
Marit Larsen	Tel-Tek
Juergen Mienert	University of Tromsø

TTA working group: Frameworks and social analysis

The Energi21 board served as the Frameworks and social analysis working group.

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