ENERGI 21

Strategy 2014

National strategy for research, development, demonstration and commercialisation of new energy technology

Part 2 of 2

energi21

ENERGI21

Strategy 2014

PART 2 Background, analysis and assessments

Preface

The Energi21 board presents in this document the third national strategy for research, development, demonstration and commercialisation of new climate-friendly energy technology. The strategy is targeted towards value creation and efficient utilisation of resources in the energy sector through investment in R&D activities and new technology to benefit society as a whole. Trade and industry has played a leading role in the strategy processes, and close cooperation with universities and research institutes has been emphasised.

Climate, security of energy supply, and economic competitiveness are the main drivers of the development of the national and international energy sector. Norway's energy situation is unique in that it has a power supply that is almost exclusively based on renewable forms of energy, excellent access to additional renewable energy resources, a well-established energy intensive sector, and plentiful oil and gas resources.

The Energi21 strategy addresses nationwide objectives for utilising renewable resources and developing an efficient, flexible energy system. It also deals with the objectives of enhancing both Norwegian industrial competitiveness and Norwegian expertise in the international energy market.

In the period from 2009 to 2011, in the wake of the Storting's (Norwegian parliament) first Agreement on Climate Policy from 2008, the authorities significantly increased research investments in the areas of renewable energy, raising energy efficiency and carbon capture and storage. The subsequent agreement from 2012 continued along the same ambitious lines and Norway's new government is keeping a strong focus on energy and climate initiatives. The availability of the clearly designated strategies developed in the Energi21 processes has proven very useful in the context of the operative research system. Plans have been in place for implementing the increased commitments approved by the authorities, and the business sector and research system have been prepared for the capacity increase needed to carry out the research.

Internationally, investment in R&D is rising sharply in the energy sector and this represents a major component of the EU initiatives under Horizon 2020, the new EU framework programme for research and innovation. Reliable, clean and efficient energy has been defined there as one of the seven Grand Challenges. It will be important for the Norwegian research community and trade and industry to gain a strong foothold in research cooperation within the EU.

In the view of the Energi21 board, this strategy lays the foundation for an even more targeted increase in public and private investments in RD&D towards new climate-friendly energy technology. A long-term, concentrated research drive will yield major advances in terms of effective utilisation of energy resources, development of a flexible and efficient energy system, and the expansion of internationally competitive industry.

We would like to take this opportunity to thank everyone who has provided input and taken part in the process, thereby making it possible to draw up a broadly-supported, integrated national R&D strategy for new climate-friendly energy technology. It is our hope that the recommendations provided here will be followed up and implemented by the Norwegian authorities and the national energy industry.

Oslo, September 2014

Sverre Aam
Chair of the Energi21 board

Summary

Energi21 is the Ministry of Petroleum and Energy's strategic body for research, development and demonstration (RD&D) in the energy sector.

The main purpose of the Energi21 strategy reports is to provide the Ministry of Petroleum and Energy with recommendations on future strategic priority areas for efforts to develop new climate-friendly, environment-friendly solutions in the renewable energy sector. The Energi21 strategy documents are drawn up in cooperation with the business sector, academia and the relevant authorities.

The guiding principles for national and international strategies in the energy sector revolve around the need to address climate challenges and safeguard both security of energy supply and competitiveness. These drivers, together with assessment of the potential to meet targets and of Norway's national competitive advantages, form the basis for the recommended strategic priority areas and proposed measures.

In the third strategy report, the Energi21 board recommends strong growth in public funding for research, development and demonstration within the following six areas:

- Hydropower
- Flexible energy systems
- Solar power
- Offshore wind power
- Raising energy efficiency
- Carbon capture and storage

These are areas in which Norway enjoys competitive advantages in future energy markets, thanks to its natural energy resources, substantial technology and competency base and industrial experience. Among these six priority focus areas, the Energi21 board recommends devoting special attention to Hydropower and Flexible energy systems. These two areas represent the very foundation of Norway's energy system and are vitally important for current as well as future value creation, nationally and internationally.

In addition, the board stresses the importance of maintaining and continuously developing the competency platform that underpins all the energy-related thematic and technology areas.

The Energi21 report recommends wide-ranging activities based on access to ample, predictable public research funding, beneficial market incentives and the commitment and active participation of the energy business community. The report highlights the following measures as essential for successful implementation of the strategy:

- Expanding efforts to create an integrated, harmonised incentive structure along the entire innovation chain;
- Adapting incentive structures to future climate-friendly energy systems;
- Strengthening innovation and renewal in the energy sector;
- Increasing the involvement of the business sector in research and innovation;
- Facilitating Norwegian participation in international testing and demonstration projects;
- Enhancing research and innovation cooperation in the EU arena;
- Increasing recruitment to strengthen Norway's position as a renewable energy nation;
- Developing dynamic research groups and a strong national technology and competency base;
- Promoting greater sectoral cooperation at the government administrative level to ensure effective implementation.

The Energi21 report is recommending a plan to step up funding over a four-year period, with overall growth of NOK 1 billion in public allocations.

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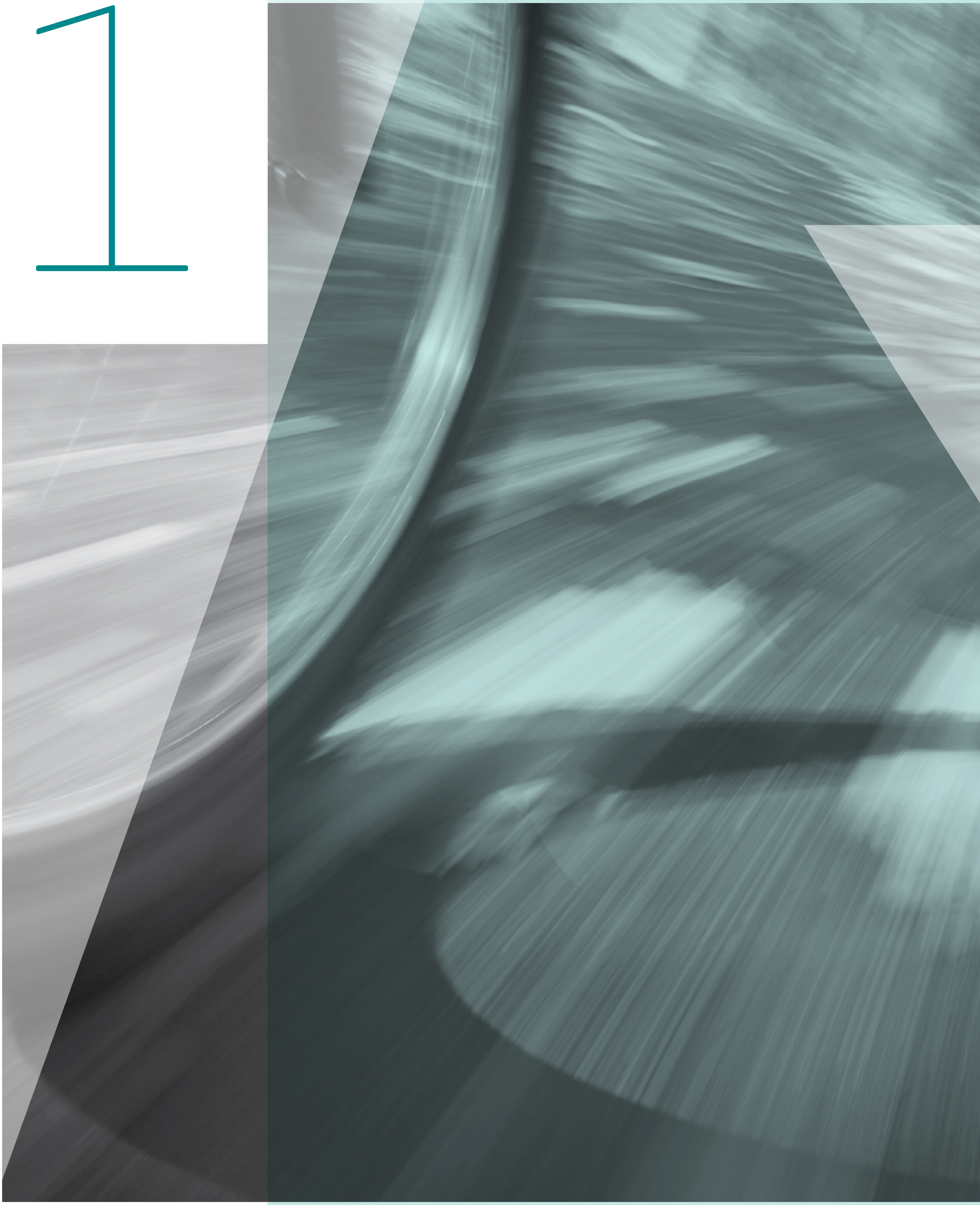


Norway as an energy nation

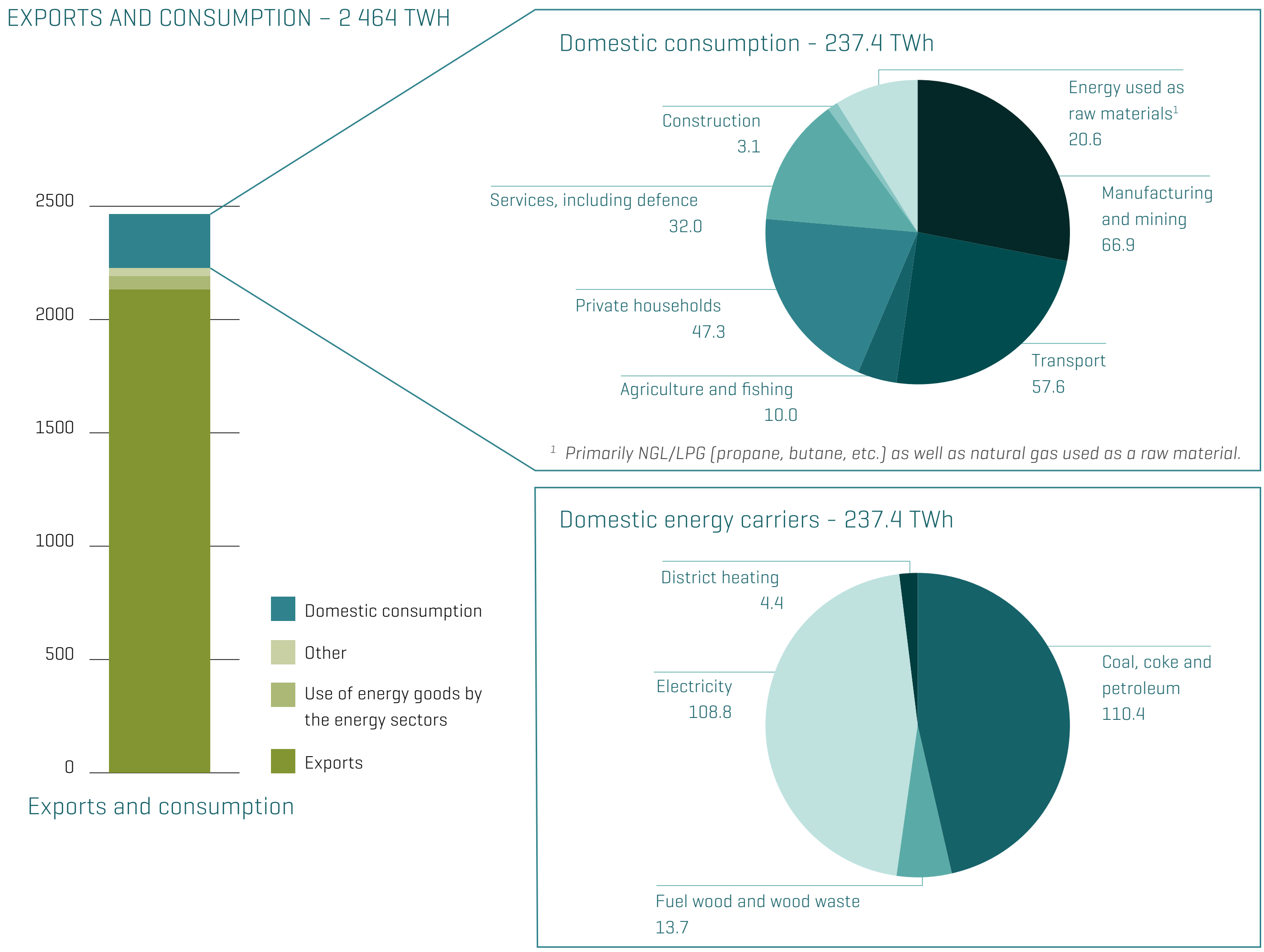
Norway's access to national energy resources, technological competence base and industrial experience gives it a competitive advantage in a number of energy-related areas. This provides a solid foundation for developing a profitable, internationally oriented energy industry with deliveries of climate-friendly energy technology to future markets.

1.1

Norway as an energy nation

Norway has an unique position, with an abundance of energy resources both from fossil sources such as oil and gas and from renewable sources such as wind, water and bioenergy. Norway's development into an energy nation began over 100 years ago, and the utilisation of its vast hydropower resources has been crucial to the development of industry and prosperity. Norway is the world's sixth-largest hydropower producer and the largest in Europe. The Norwegian hydropower system has a mean or normal annual production of 130 TWh from 1 250 power plants with an installed capacity of approximately 30 GW. Norway has over 800 hydropower reservoirs with a storage capacity equivalent to 85 TWh, or roughly 70% of mean production, accounting for some 50% of Europe's total reservoir capacity. Substantial storage capacity and high installed capacity give the unique Norwegian hydropower system great flexibility.

Norway's role as an energy nation is also linked to its production and export of oil and gas. Norway is the world's seventh-largest oil producer and the second-largest gas exporter. Oil and gas resources have been the basis for substantial value creation in the past 40 years. Norway is home to a renowned, world-leading supplier industry to the petroleum sector. The country also has an extensive technology and competency base in offshore activities, subsea technology and marine operations. In addition to its hydropower resources and oil and gas reserves, Norway also has significant wind power potential, both on land and offshore. This national energy framework entails a wide range of promising opportunities for future value creation based on resource utilisation as well as development of technology and knowledge deliveries.



Figur 1 Norwegian production, export, consumption and distribution in 2012, by energy carrier. Source: Statistics Norway, Energy account and energy balance for Norway, 2012

1.2

Energy in Norway

Electricity is the dominant energy carrier in Norway and covers approximately 50% of total consumption, including transport. Norway is thus in a class of its own when it comes to dependence on electricity, and the country has an extensive knowledge and technology platform relating to electricity in society. Of the electrical power produced in Norway in 2012, roughly 95.2% was based on renewable hydropower, 1% on wind power, and roughly 3.8% on fossil fuels.

1.3

Energy and climate challenges towards 2050

Global warming and climate change are among the most pressing challenges facing the world community. A temperature increase of over 2°C will lead to serious climate change as well as major negative impacts such as flooding, extreme weather events, sea-level rise, drought, etc. At the UN Climate Change Conference in Copenhagen in 2009, top-level world leaders agreed to limit the global temperature rise to 2°C, which will require reducing the world's greenhouse gas emissions by at least 85% by 2050. If this goal is to be achieved, we will need to decarbonise not just the energy sector, but also the transport sector and the industrial sector in the next 40 years. In reality, the most dominant issue guiding the development of national and international energy policy today is the climate challenge, along with security of energy supply and industrial competitiveness. This is also being reflected in energy research strategies.

1.3.1
PATH TO MEETING THE 2°C TARGET

Focused, long-term national and global investment in climate-friendly energy technologies is critical to meeting the 2°C target of the Intergovernmental Panel on Climate Change (IPCC).

Ambitious goals have been set internationally towards achieving a zero-emissions society, with targets for significant reductions in greenhouse gas emissions by 2050. Innovative solutions that are the fruit of international and multidisciplinary cooperation will be vital to achieving a zero-emissions society. In 2007 the Storting committed Norway to the goal of limiting global warming to 2°C, providing the basis for the cross-party agreement on climate policy in 2008. This entails that Norway will pursue a policy designed to help ensure that the global temperature does not rise by more than 2°C above pre-industrial levels.

1.3.2
ENERGY IS THE KEY PLAYER IN THE CLIMATE GAME

In its Energy Technology Perspectives (ETP) 2014, the International Energy Agency (IEA) states that 73% of the world's total CO_2 emissions stem from industrial activities, construction and electrical power production. Production of electricity alone accounts for 39% of this.

In the years up to 2030, it is estimated that the global need for energy will be 60% higher than it is today and that the world population will continue to grow. Emerging economies will account for two-thirds of this increase in energy demand. Strong economic growth in China and in the highly populated emerging economies is the main cause of the climbing demand for energy. Today, 1.2 billion people still lack access to electrical power. Reliable access to energy is critical to continued economic growth and welfare development in developing countries and to maintaining the standard of living in industrialised countries. However, the IEA's 2°C scenario in ETP 2014 confirms that global population and economic growth can be decoupled from energy demand. While the challenges are considerable, there is also a wide array of opportunities for developers of new technology and solutions.

1.3.3
FUTURE ENERGY SOURCES

Although renewable energy sources will play an increasingly important role in satisfying the global demand for energy, the IEA points out that fossil energy sources will continue to be important energy sources in the coming decades. In its New Policies Scenario, which takes account of various political commitments and measures, the IEA estimates an annual growth of 0.5–1.5% for fossil fuels, just over 2% for hydropower, 1.5% for bioenergy and 7.3% for other renewable sources in the period from 2012 to 2035. The development in this scenario is shown in Figure 2.

Renewable energy has experienced the highest growth in percentage. According to the IEA, at the end of 2013 some 132 GW of solar cells had been installed worldwide, with approximately 1 200 productive hours per year, this gives an overall production of roughly 160 TWh annually. This is nearly 25% more than the mean annual production from Norwegian hydropower. At the end of 2013, 318 GW of wind power had been installed, with an overall production of more than 500 TWh.

Fossil fuels are the locomotive of today's welfare society and will continue to play an important role 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 fuels. A green shift in development is not only

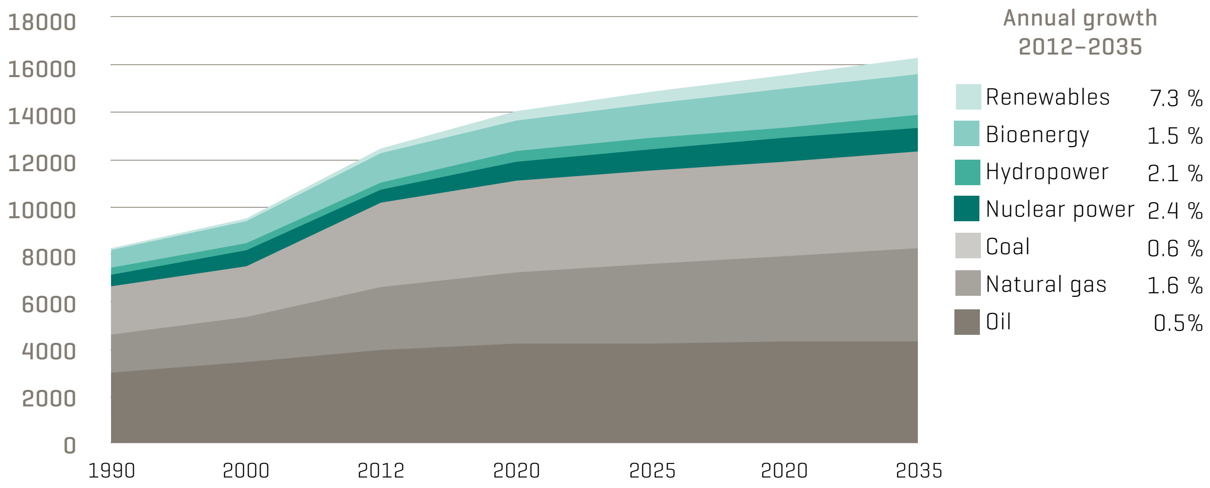


Figure 2 2 Development in primary energy demand (in megatonnes of oil equivalent (Mtoe)) according to the IEA's New Policies Scenario. Source: IEA – World Energy Investment Outlook 2014

critical, but also possible. Recent years' developments in new, renewable energy technology show that several energy carriers and technologies have the potential to contribute significantly to the overall energy mix in the years ahead, in combination with technology for decarbonising fossil energy resources. The IEA has also calculated that if the 2°C target is to be met, roughly two-thirds of the identified fossil energy resources cannot be exploited and may thus become worthless. Coal, oil and gas reserves represent much of the basis for valuation of the world's coal and petroleum companies. These companies account for a large share of the value on the world's stock markets, and if part of these reserves becomes worthless, the value of the petroleum sector will plummet, along with the value of the stock markets. This has been dubbed by many as the "carbon bubble". The carbon bubble threat may, on the other hand, provide strong motivation for Norway to accelerate the development of carbon capture and storage (CCS) technology, precisely to safeguard the value of the country's resources. Regardless, heavy investment in developing new industry and value creation in renewable energy technology and CCS will be a sound strategy for Norway to follow.

1.4

Future markets for climate-friendly energy technology and services

In ETP 2014, the IEA shows 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. 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.

In World Energy Investment Outlook 2014, the IEA estimates that investment costs for achieving the 2°C target will total USD 53 000 billion for the 2015–35 period (the 450 Scenario), or USD 2 500 billion per year on average. Roughly 75% of this amount will go to energy supply and 25% to raising energy efficiency. This must be viewed as a genuine investment, not a bundle of costs, and while it represents a considerable challenge, it also represents major market opportunities for energy companies, equipment suppliers and service providers.

The IEA also points out that technology transfer to emerging economies and wide-reaching energy policy instruments will be crucial to carrying out the "green energy revolution" we need.

Climate-friendly technology is now one of the world's fastest-growing technology markets. Nevertheless, segments of today's market still comprise new and immature technologies, and the potential is therefore great. Continued high global growth is expected, and the prognoses vary from technology to technology.

International investment in energy restructuring will open up opportunities for technology suppliers and service providers. The European Commission, for example, has estimated that EUR 400 billion will be invested in distribution grids and EUR 200 billion in transmission grids in the years up to 2020. The Commission's in-house science service, the Joint Research Centre, estimates in its analysis that EUR 56 billion (NOK 450 billion), or some 10 per cent of the total investment in the electricity network, will be used by 2020 in Smart Grid solutions. This is an indication of a growing focus on stronger and smarter grids in the EU, also from an investment perspective.

The Norwegian business sector has competitive advantages in many areas and is well equipped to gain a foothold and play a role in emerging international markets. Norway's competitive advantages are presented in Part 1, Chapter 3.5.

1.5

Norway as an energy nation towards 2050 – key challenges

The importance of the power sector for society is growing, and an interruption of the energy supply can paralyse vital functions and processes. The power system as a whole is a key infrastructure for general value creation in society, and safeguarding the security of supply is the utility sector's responsibility to society and its primary objective. The main challenge in the years up to 2020 will be to maintain both the security of supply and the owners' required rate of return – a dual goal that may be difficult to achieve, given the power industry's operational challenges.

The power system is far more complex than other infrastructure in society. Electricity cannot be stored in a volume of any scope, and the power system must continually secure an immediate balance between production and consumption. All of these factors make the day-to-day operation of the power system a demanding task.

Grid companies and power companies are facing extensive new investments and reinvestments. Ageing plants are an important driver of reinvestments, while climate-related issues create a need for new investments in power plants and power grids. Below is a list of some of the most important reasons underlying the energy industry's need for investments and reinvestments in the years up to 2030:

- The EU's Renewables Directive and the Norwegian-Swedish market for green electricity certificates will lead to the phasing in of large amounts of intermittent renewable energy, creating the need for grid enhancements in many places.
- The electrification of the Norwegian continental shelf and road transport will require grid enhancements and adaptation of infrastructure.
- Society's dependency on a well-functioning power system is rising steadily, which means that requirements relating to security of supply and preparedness will become more stringent.
- Large segments of the Norwegian regional and distribution grid were built in the period from 1960 to 1990. These facilities have now reached or exceeded their expected service life, which varies from 35 to 50 years. The same is the case for hydropower plants. The energy industry is therefore facing substantial investment and reinvestment needs.
- More extreme weather events are expected in the years ahead, so robustness requirements will become more stringent both for electrical power equipment and in relation to preparedness.
- New, comprehensive government directives relating to dam facilities, power plants and grid facilities. These encompass security measures as well as introduction of new functions such as advanced monitoring and control systems.

All of these require an increased pace of reinvestment in the power system. In addition, new power lines and power plants must be erected on a much larger scale than previously. This may provide a window of opportunity for testing, demonstration and integration of new technology and innovative solutions.

In addition to future challenges relating to production and distribution of electrical power, Norway is also facing major challenges relating to thermal energy and fuel as well as the use of energy goods as raw materials in industrial production and future CCS.

Although most of the 50 TWh in fossil heating oil (1970 figure) in the heating sector has now been replaced with electricity or bioenergy, there is still an annual consumption of roughly 7 TWh of fossil heating oil. In addition, a good deal of fossil gas is used for heat production in industry and buildings. A new dimension in the area of thermal energy is the steadily growing market for cooling for buildings, ICT facilities and industrial facilities.

Energy restructuring has come less far in terms of fuel use for motor vehicles. Conventional fossil fuels still account for over 80 TWh of energy consumption, while biofuels and electricity account for only around 2 TWh.

With regard to CCS, the capacity to store CO_2 from the Continent is also an important topic that will help to set the course for the research activities of energy stakeholders.

There are several other issues in the European arena that are of principal importance for Norwegian energy stakeholders and will guide the direction of research activity:

- The use of Norwegian natural gas and hydropower for power system balancing services;
- Natural gas power production with CCS as a component of the EU's baseload supply and for power system balancing services; Storage capacity on the Norwegian continental shelf for CO_2 from the Continent.

[1] *Official Norwegian Report NOU 2012:9 on energy (Energiutredningen – verdiskaping, forsyningssikkeret og miljø, in Norwegian).*
[2] *IEA – Energy Technology Perspectives (ETP) 2014.*
[3] *World Energy Outlook 2013.*
[4] *IEA – Energy Technology Perspectives (ETP) 2014.*
[5] *Global Wind Energy Council (GWEC).*
[6] *Wasted capital and stranded assets. CarbonTracker/London School of Economics/Grantham Research Institute.*
[7] *Wasted capital and stranded assets. CarbonTracker/London School of Economics/ Grantham Research Institute*
[8] *EU - Energy infrastructure priorities for 2020 and beyond*
[9] *Assessing smart grid benefits and impacts, 2012, s. 9*

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International research cooperation

2.0

International research cooperation

Tomorrow's climate-friendly energy systems will require innovative solutions developed through multidisciplinary national and international cooperation. Targeted research and innovation activity, on the part of both 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, internationally oriented, knowledge-based industrial sector in Norway.

Norway's presence in the international R&D arenas is critical if the country is to assume a position at the international research front. It is important that Norway maintains its role in international cooperation efforts and enhances this role in the areas where this will have the greatest impact. Priority should also be given to bilateral cooperation with rapidly emerging research nations outside Europe in areas in which this will boost research quality, expand the knowledge base and cultivate opportunities for Norwegian trade and industry in international markets. North America and the rapidly emerging economies of Asia are particularly relevant partners for cooperation in developing new solutions adapted to the countries in which they will be used.

2.1

Research and innovation cooperation in the EU

The Europeaen framework programme is the main arena for international cooperation and a priority for Norwegian research. Since 1994 Norway has participated in and benefited greatly from the EU framework programmes for research. Norway is an active participant in several initiatives under the SET Plan and has participated in many 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. The new EU Framework Programme for Research and Innovation, Horizon 2020, has now been launched, and there are many opportunities for Norwegians to participate in its various areas.

HORIZON 2020 – CHANGES AND FEATURES

Horizon 2020 is the EU Framework Programme for Research Innovation for the 2014–20 period, and the successor to the EU Seventh Framework Programme for Research and Technological Development (including demonstration activities) (FP7). Horizon 2020 is a financial instrument for advancing the objectives of the European growth strategy, Europe 2020, including the Innovation Union flagship initiative, as well as for further developing the European Research Area (ERA).

Horizon 2020 is designed to create jobs and drive economic growth with the aim of tackling societal challenges and strengthening Europe's position in the research, innovation and technology sphere. With a budget of some EUR 77 billion, Horizon 2020 is the world's largest research programme and roughly 30% larger than FP7.

Horizon 2020 distinguishes itself from previous framework programmes in the following ways, among others:

- Research and innovation are combined into a single framework programme. For the energy area, this entails that activities under the Intelligent Energy Europe (IEE) programme, which belonged under the Competitiveness and Innovation Framework Programme (CIP) in the previous period, will be integrated into the Energy Challenge under Horizon 2020.
- The programme encompasses the entire innovation chain ("taking great ideas from the lab to the market").
- The programme is challenge-based to a much greater degree than FP7. Calls for proposals will have their basis in societal challenges in Europe, e.g. with regard to sustainable energy, while Horizon 2020 will do more to emphasise the importance of research and innovation for society.
- Calls for proposals are less detailed and give actors more freedom to propose solutions, while at the same time requiring more interdisciplinary collaboration between researchers and other actors.
- Horizon 2020 places much greater emphasis on innovation and demonstration activity, for instance by providing support for various types of innovation and market-oriented activity that promote value creation and by incorporating an innovation dimension into calls across the programme.
- Many calls will employ Technology Readiness Levels (TRLs) to assess technological maturity. Horizon 2020 also encompasses activities with high TRLs (i.e. solutions approaching commercialisation).
- Greater importance is attached to the participation of

and benefit to trade and industry than previously. New measures will encourage increased participation of small and medium-sized enterprises (SMEs) and various funding instruments will support the research and innovation activities of SMEs. The objective is for 20% of the budget for Societal Challenges and segments of Industrial Leadership to be allocated to SMEs.

- New instruments will ensure access to risk capital and boost commercialisation and innovation activity.
- The public sector has been given a more significant role under Horizon 2020 than under FP7, both as a user of results and as a key participant in and a supplier of the frameworks for projects. New measures on the demand side will, for example, encourage increased research and innovation activity and improve public procurements.
- Measures have been taken to simplify the rules for participation, including flat rates for reimbursement of costs, simpler control and auditing routines, and reduced application processing times.
- The programme has a longer overall planning horizon, with two-year work programmes and a three-year strategic planning framework.

SET PLAN

The Strategic Technology Plan (SET Plan) is the EU's cooperation arena for accelerating the development of strategically important energy technologies and a key element of EU energy and climate policy.

Research cooperation is an important component of the SET Plan, under which relevant financial tools and instruments in the area of energy technology, among other things, are coordinated based on unified plans for research, development, demonstration and early market introduction.

The SET Plan consists of four main elements: the SET-Plan Steering Group, European Industrial Initiatives (EIIs), the European Energy Research Alliance (EERA) and the SET-Plan Information System (SETIS). Norway participates in the SET Plan and plays an active role in the EIIs on wind power, CCS, bioenergy and smart grids.

There is an increasingly direct link between the priorities of the EIIs and the priorities of the Horizon 2020 calls for proposals.

[10] *SET-Plan: Strategic Technology Plan (SET-planen) er EUs strategiske rammeverk for utvikling og innfasing av klimavennlig energiteknologi*

PARTICIPATION IN HORIZON 2020

"Secure, Clean and Efficient Energy" is one of the seven Societal Challenges under Horizon 2020. The Energy Challenge has three focus areas:

- Energy Efficiency
- Low Carbon Technologies
- Smart Cities & Communities

Calls will be issued within each of these focus areas, featuring topics described in the work programme for Horizon 2020. Depending on the call topic, support will be provided for various types of action, including Research & Innovation Actions, Coordination and Support Actions, and the SME Instrument.

There are also various measures to promote cooperation between research programmes and the development of the ERA. The ERA-NET Cofund Action is a funding instrument for coordination and cooperation between research programmes and activities in different countries. Countries cooperating under the scheme work together to define the research challenges and area of cooperation, and Horizon 2020 provides co-funding under joint calls.

The Research Council of Norway's participation scheme provides support to Norwegian actors to take active part in important, high-level EU fora and to advance Norway's priorities.

FINANCIAL SUPPORT

Horizon 2020 has new funding rules that are more attractive for trade and industry. Participants in Research & Innovation Actions will receive 100% coverage for approved direct costs related to the project. Direct costs include salary and social security costs, travel expenses, meeting expenses and other costs that are directly connected to the project. For participants in full Innovation Actions there is a flat funding rate of 70% for approved direct costs, while public sector organisations and private non-profit entities are eligible for 100% funding of direct costs in Innovation Actions as well.

In addition, indirect costs, such as rent, electricity, office expenses, etc., are covered by a flat rate of 25% of the approved direct costs.

VALUE OF EU COOPERATION

Active participation in the EU arena opens the door to European cooperation, builds strategic competence and helps to strengthen competitiveness and enhance innovation capacity. Benefits include:

- More and stronger international networks that can be drawn upon again;
- Enhanced internationalisation of own activities;
- International visibility and profiling of activities and individuals;
- International recruitment;
- Access to advanced research infrastructure;
- Access to competent and demanding international clients;
- Access to new knowledge;
- Enhanced scientific prestige.

OBJECTIVES FOR NORWEGIAN PARTICIPATION IN HORIZON 2020

In its national strategy for research and innovation cooperation with the EU, the Norwegian Government sets out four primary objectives for Norway's participation in Horizon 2020 and the ERA:

- Participation will enhance the quality of Norwegian research and innovation and the country's ability to compete internationally.
- Participation will enhance innovation capacity, value creation and sustainable economic development.
- Participation will promote better welfare and more sustainable societal development through research and innovation that equips Norway to deal with major societal challenges.
- Participation will promote the development of Norway's research and innovation sector, both through further development of policy and instruments and through new patterns of cooperation across national, sectoral and scientific boundaries.

3

Energi21 – strategic analysis

3.1

Description of method for strategic comparison of thematic and technology areas

3.1.1
STRATEGIC REVIEW OF 11 THEMATIC AND TECHNOLOGY AREAS

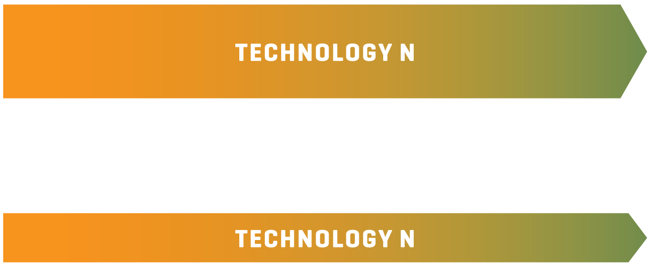
The Energi21 board's selection of priority focus areas and recommendations for measures to be implemented are based in large part on an analysis of 11 thematic and technology areas. The assessment encompasses factors deemed to be of importance for designating the priority focus areas. The strategic review of thematic and technology areas is presented in Section 3.2.

In its strategic analysis the Energi21 board describes the factors it considers particularly relevant for Norwegian actors, the country's energy supply, and industrial development. In addition, it identifies the following key elements:

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

Each thematic and technology area has been analysed in relation to how much it contributes towards achieving the Energi21 strategy's primary objectives, its state of technological maturity, and the estimated time period needed for its realisation on the market. A simplified diagram has been prepared for each thematic and technology area following the set-up in Figure 3 below. The colours of the technology arrows indicate the degree of a technology's maturity, i.e. whether a given technology can be implemented by 2025 (green arrow) or whether current research challenges will delay implementation of the technology until after 2025 (orange arrow). The relative thickness of an arrow represents a technology's potential contribution towards achieving the Energi21 strategy's primary objectives. A thick arrow corresponds to high potential, a thinner arrow indicates moderate potential.

At a Sira Kvina hydropower plant. *Photo: Sira Kvina kraftselskap*



Objective 1	Increased value creation on the basis of national energy resources and utilisation of energy
Objective 2	Energy restructuring through efficient use of energy and increased flexibility in energy systems
Objective 3	Development of internationally competitive industry and expertise in the energy sector

Figure 3 Technology area's contribution towards achieving the Energi21 strategy's primary objectives. Maturity is indicated by colour: green means mature, orange means implementation is delayed by technological advances still needed. Arrow thickness reflects potential contribution, with thick indicating high potential towards achieving the objectives.

This schematic representation is an oversimplification, of course. Even for technologies that are already mature and competing in the market, it will normally be research challenges and room for improvement. In such cases research activities are typically driven more by technological advances and further cost cutting more than market implementation. Research activity to enhance industrial competitiveness in existing markets can lead to significant value creation. Moreover, political decisions and changes to instruments can either shorten or lengthen time to market.

3.1.2
METHOD OF COMPARATIVE ANALYSIS

With the strategic review of thematic and technology areas as its starting point, the board has thoroughly analysed each area in relation to its potential to achieve relevant Energi21 objectives, its degree of technological maturity, and the estimated time period needed for its market implementation. In addition, each area has been analysed in relation to its overall significance for the further development of Norway as an energy nation and the country's competitive advantages (natural resources, business sector and competency) in future energy markets. The board's method of analysis is illustrated below.

Each phase of the innovation chain is vital for achieving successful commercialisation of results, and 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 may be needed here is market-oriented instruments. This means that these thematic and technology areas may not be given highest priority for research activities.

Technological maturity illustrates potential for advances in technology, which in practice often means potential for cost reductions and increased efficiency.

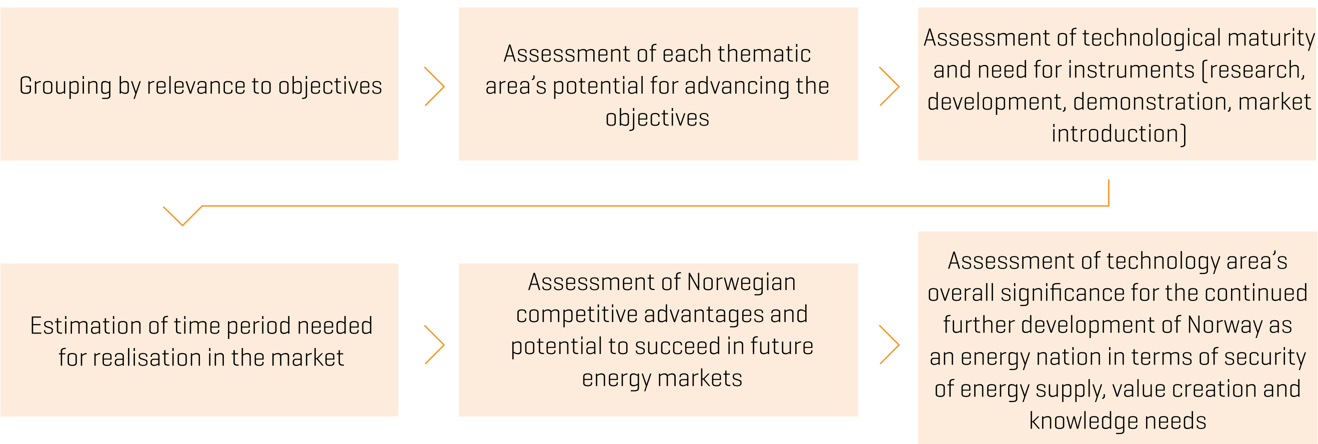


Figure 4 The process and assessment criteria applied in the overall strategic comparison of thematic and technology areas.

COMPETITIVE ADVANTAGES

Throughout the analysis process the Energi21 board has attached great importance to the extent to which Norwegian actors have specific competitive advantages that enhance the potential and probability of success. This is essential to achieving success in international markets, and efforts should target the areas where such advantages exist. This is reflected in the analysis of each thematic and technology area and has been incorporated into the designation of priority focus areas.

Strategic diagrams

The results of this strategic analysis are depicted in diagrams showing each thematic and technology area's position in terms of the various assessment criteria. A separate diagram has been compiled for each of the three primary objectives of the Energi21 strategy:

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

The diagrams illustrate the following criteria:

- *Potential: This indicates a technology area's potential (high or moderate) 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 in the diagram) may still be in need of research activity to strengthen their competitiveness by cutting costs and optimising performance. One example is Norway's 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. Another example is technology for hydropower, whose market is one of mature technology but where there is a need for enhanced efficiency and capacity due to changing requirements and new patterns of operation at power production facilities.

The following section presents the results of the overall comparison of thematic and technology areas, with strategic diagrams and explanations for each of the three primary objectives of the strategy.

Meltwater near the Seljestad tunnel, western Norway. *Photo: ABB*

OBJECTIVE 1.
INCREASED VALUE CREATION ON THE BASIS OF NATIONAL ENERGY RESOURCES AND UTILISATION OF ENERGY

Norway is an energy nation. Utilisation of national energy resources represents an important source of value creation both today and well into the future. There is major resource potential as well as promising opportunities for satisfying national energy needs, supplying energy and system services internationally and developing technology products in which renewable energy input is an important factor in the production process.

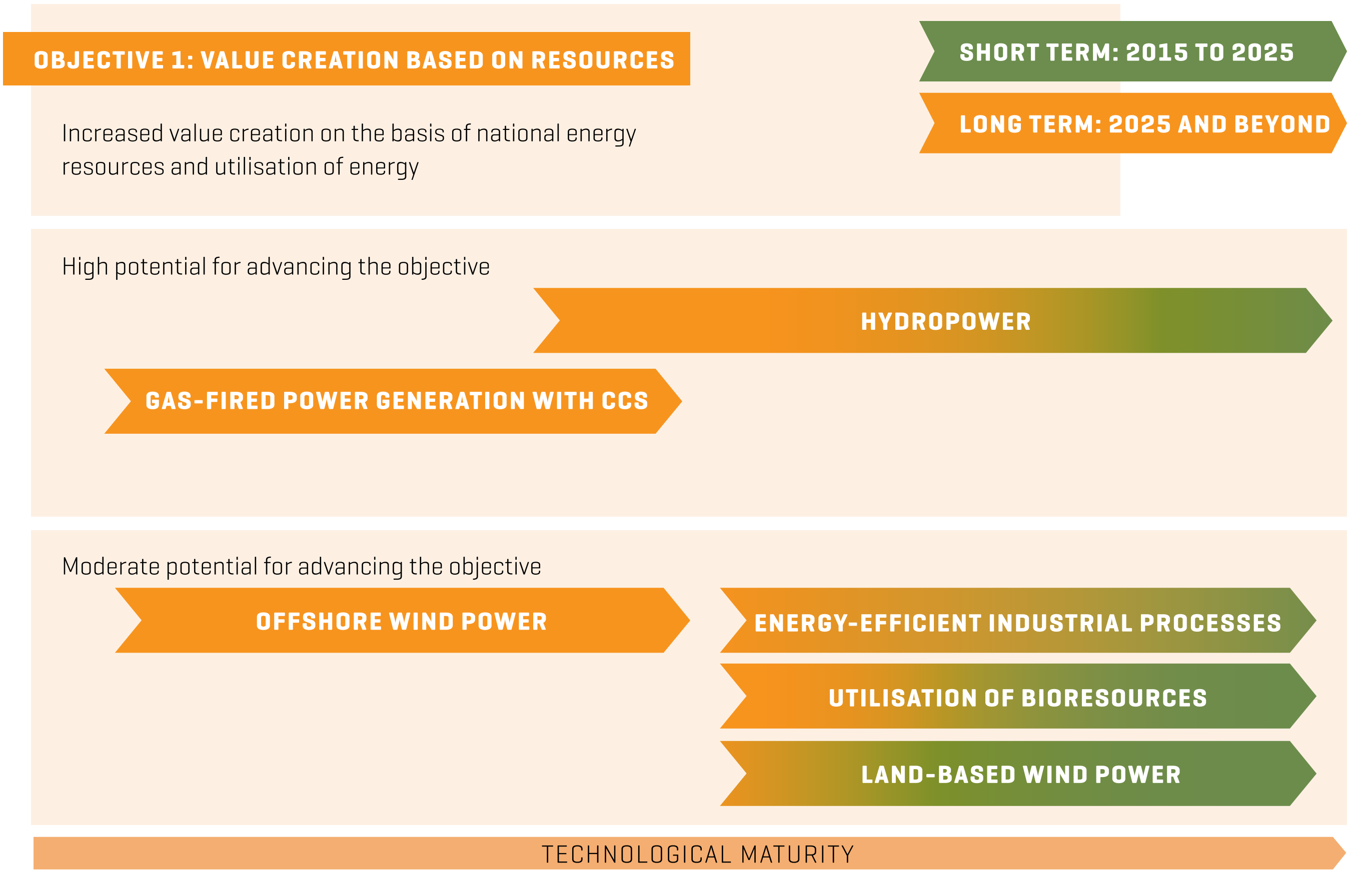


Figure 5 National energy resources: anticipated significance for value creation is indicated vertically in two categories. Horizontal placement indicates the maturity and current development phase of each technology. Arrow colour indicates the estimated time period needed for the technology area to develop into a competitive industry (green arrow = short term, orange arrow = long term).

OBJECTIVE 2.
ENERGY RESTRUCTURING THROUGH EFFICIENT USE OF ENERGY AND INCREASED FLEXIBILITY IN ENERGY SYSTEMS

Climate challenges will have to be taken into consideration when meeting the need for energy and transport services in the years ahead. The solutions that will ensure adequate security of supply and at the same time are effective in the context of a climate strategy will entail the restructuring of current energy systems, also in Norway. Energy restructuring comprises the phasing out of fossil energy sources and phasing in of energy- and climate-efficient solutions such as new renewable production capacity, raising energy efficiency and enhancing flexibility and efficiency in the end-user segment. There will also be closer integration between the energy and transport sectors in the transition to more sustainable transport solutions. A robust Norwegian climate strategy will include the reduction of greenhouse gas emissions from industry as well. In addition to technology, the ability of the individual and society as a whole to integrate new systems and solutions will be crucial to the effective development of energy- and climate-efficient energy systems.

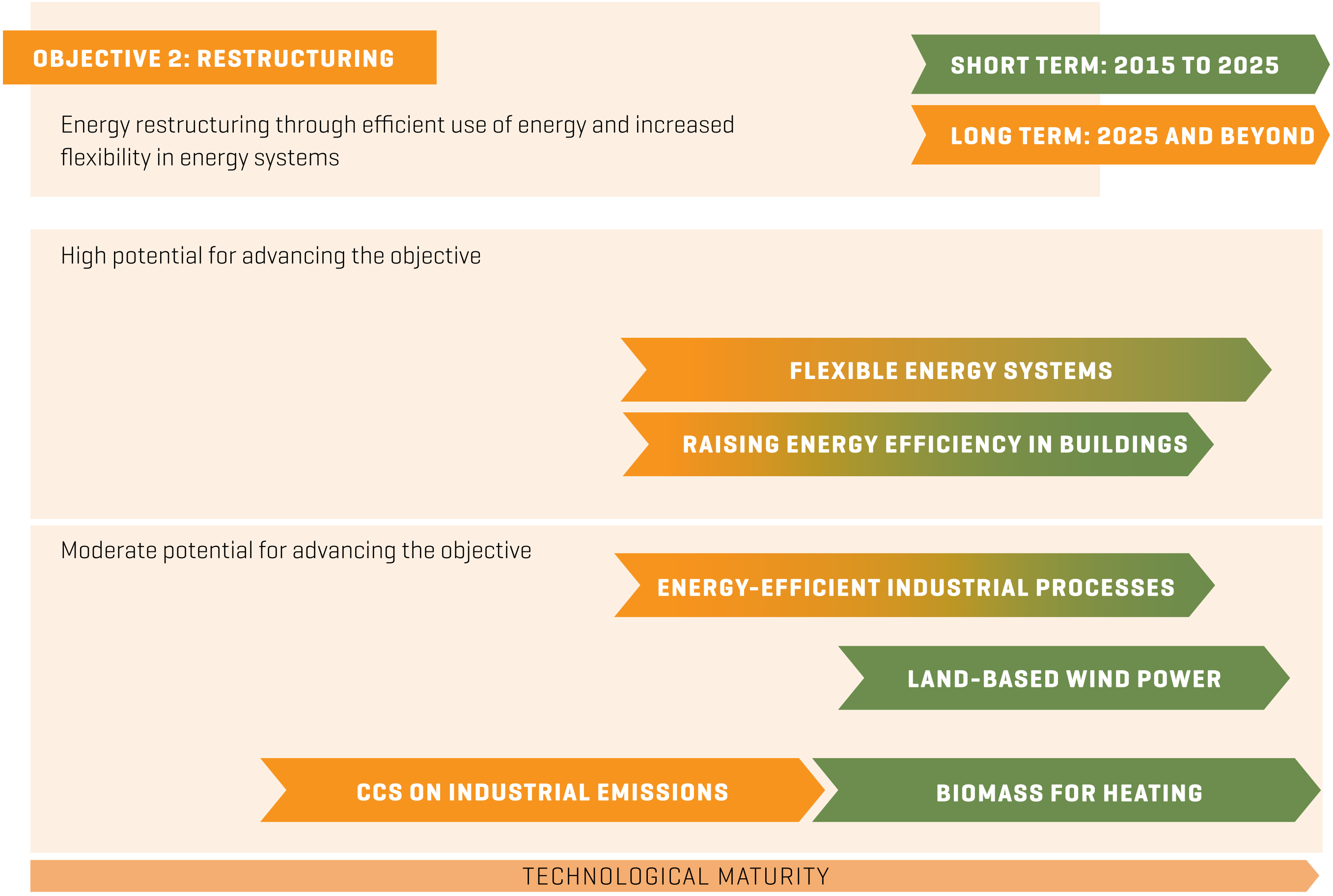
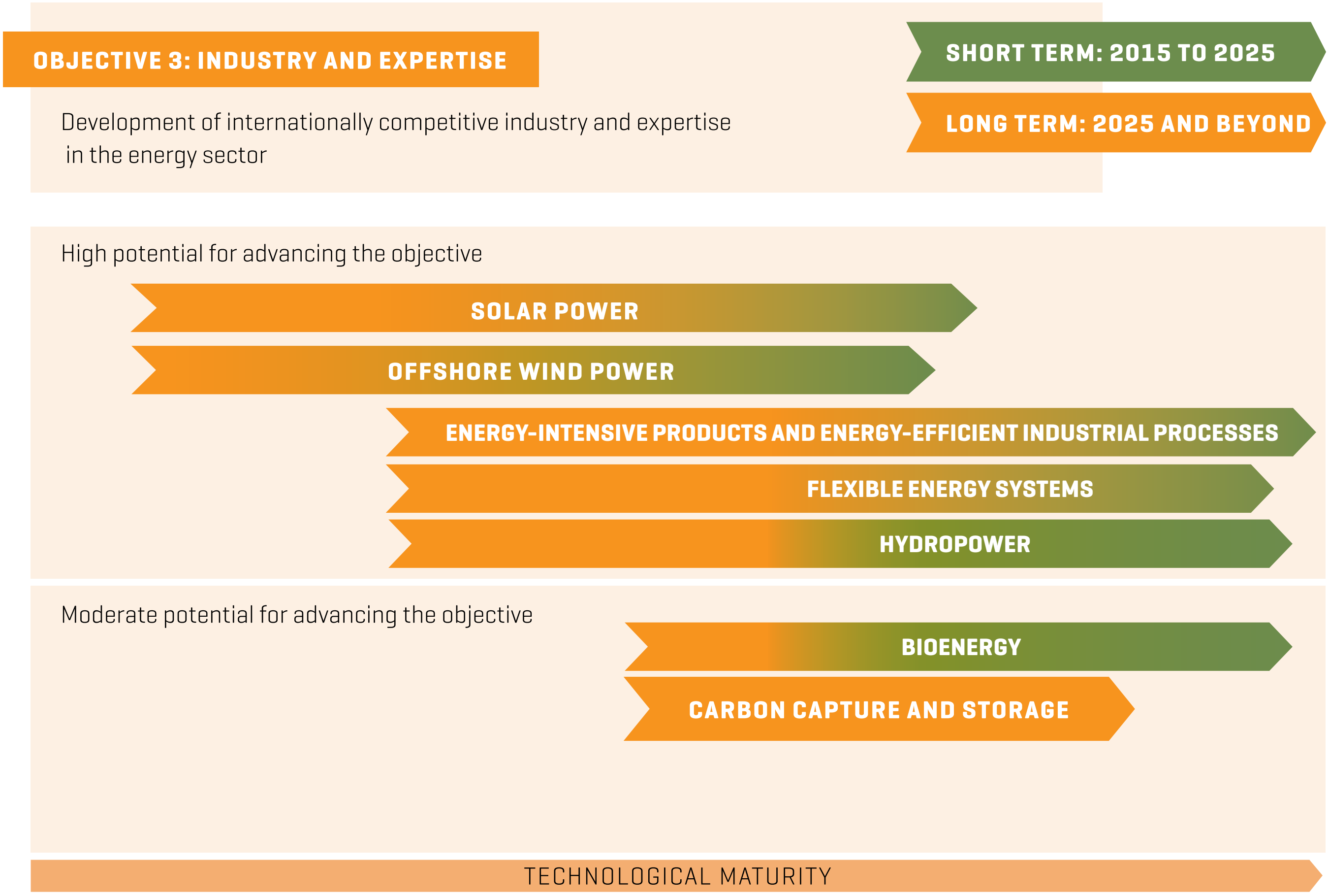


Figure 6 National energy restructuring: anticipated significance for energy restructuring is indicated vertically in two categories. Horizontal placement indicates the maturity and current development phase of each technology.

OBJECTIVE 3: DEVELOPMENT OF INTERNATIONALLY COMPETITIVE INDUSTRY AND EXPERTISE IN THE ENERGY SECTOR

Climate- and energy-policy objectives are paving the way for a radical restructuring of the international energy system. Sustainable development in emerging economies will in addition require a considerable increase in energy production and capacity and energy services. Together, these represent the main drivers of the rapidly growing markets for climate-friendly energy technologies. The Norwegian business sector is in a good position to gain a foothold in emerging energy-related markets, both nationally and internationally.

Access to knowledge is a vital competitive advantage for Norwegian business, and dynamic educational and research environments are critical factors for recruitment and innovation in the energy sector. Norway must have strong, competitive, internationally recognised research and educational communities that can take the lead in international research cooperation.



Figur 7 Development of a competitive business sector and expertise: anticipated potential for developing competitive expertise or business activities is indicated vertically in two categories. Horizontal placement indicates the maturity and current development phase of each technology.

3.2

Review of thematic and technology areas

HYDROPOWER

- Plans are being made to construct major hydropower facilities around the world. According to the IEA, hydropower accounted for the largest share of renewable electricity production in 2013, with roughly 3 500 TWh worldwide. Hydropower development is on schedule for the 2°C scenario targets, with production projected to be 5 500 TWh in 2025. Nearly all this growth is occurring in non-OECD countries, representing a large market for the expertise of Norwegian energy companies, consultants and supplier industry.
- The average age of Norway's hydropower plants is 45 years. A high proportion of this infrastructure will be renovated and upgraded in the coming decades, which offers a wealth of opportunity for integrating new technology and solutions and creating added value from better utilisation of energy resources.
- In Norway, hydropower activities are mainly concentrated on renovation, expansion, environmental adaptation, small-scale hydropower, and assessing hydropower for supplying power system balancing services.
- The justification for public funding for research, development and demonstration to a large degree lies in:
  – increased value creation on the basis of national energy resources and utilisation of energy;
  – development of internationally competitive industry and expertise in the energy sector.

3.2.1 HYDROPOWER

Market development and anticipated significance internationally and in Norway – relevance and potential

Internationally, hydropower is expanding greatly. Major hydropower projects are relevant in Asia, Latin America, the Balkan states and in time in Africa as well. The European hydropower projects are mainly concentrated on renovation and reconditioning/refurbishment, among other things for adapting facilities to interact dynamically with renewable sources of energy such as wind and solar. In Norway the focus ahead will be on providing a basis for hydropeaking, further expanding the role of small-scale plants, rehabilitating existing facilities (UE) and more environmentally adapted hydropower production.

Norwegian stakeholders

Norway is home to a large number of operative energy companies with hydropower in their portfolios, as well as some technology suppliers and highly-knowledgeable consultancy firms. There are opportunities for Norway's industrial and energy sector to play a part in the expansion of international large-scale hydropower development. With over a century of experience in the construction and operation of hydropower facilities, Norway possesses a solid knowledge and experience base and has clear competitive advantages.

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.

Norwegian challenges, advantages and opportunities

Large-scale hydropower > 10 MW

The average age of Norway's hydropower plants is 45 years. Major renovation projects are needed, which will have a profound impact on the industry for the next several decades. Existing facilities must also be adapted to new conditions resulting from changes in both climate and regulatory regimes. Another 130 TWh is to be developed in Norway, representing a potential for further value creation as well as great opportunity for integrating new technology and solutions. New knowledge regarding environmentally adapted development and operation should help to further expand this potential.

HYDROPOWER	Objective 1	Increased value creation on the basis of national energy resources and utilisation of energy
	Objective 2	Energy restructuring through efficient use of energy and increased flexibility in energy systems
HYDROPOWER	Objective 3	Development of internationally competitive industry and expertise in the energy sector

[11] *Upgrade and expansion (UE).*

The average age of hydropower industry personnel is high. Future value creation and business development in the hydropower segment will require extensive experience and expertise in hydropower technology. In light of this, it is necessary to reinforce and further develop the country's educational institutions to ensure adequate recruitment to all segments of the hydropower value chain. Further developing the Norwegian Hydropower Center will be a central component of this work.

There are opportunities for Norway's industrial and energy sector to play a part in the expansion of international large-scale hydropower development, i.e. installations with more than 10 MW installed capacity. With over a century of experience in the construction and operation of hydropower facilities, Norway has a solid knowledge and experience base. It is important that the country nurtures and strengthens its position in the field of hydropower in order to maintain and continue developing Norwegian expertise in environment-friendly hydropower technology and management.

Small-scale hydropower

Over the past five years, interest in developing small-scale hydropower has risen significantly. The main challenges involve environmental impact, grid connection and the competency of small developers.

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 during the development phase, followed by reliable, long-term revenues over the plants' lifespan. Experience has shown that the lack of a clear picture of future watershed runoff poses a substantial financial risk. Historical hydrological time series are normally used to forecast future production, but where there is insufficient historical record available, the financial uncertainty and risk can be high.

Power system balancing services

Norway alone houses nearly 50 per cent of Western Europe's total hydropower reservoir capacity. This puts the country in a unique position to supply power system balancing services such as balancing power. The European energy system is undergoing a transition, and in recent years a great deal of wind and solar power has been integrated into the grid. This rising proportion of intermittent electricity production entails a need for balancing power and production capacity that can compensate for the output fluctuations that have already increased substantially and will continue to do so in the years ahead. In this context the Norwegian hydropower system can deliver power as well as store potential energy. Seizing this opportunity will require a mutually agreed understanding of this potential with the UK, Germany, the Netherlands, Denmark and Sweden.

For Norway to capitalise on these opportunities to supply power system balancing services 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 reinforcing Norway's main grid, installing more DC cable capacity and possibly developing masked grid for the North Sea. Market mechanisms to provide payment for such deliveries need to be developed. Power system balancing services represent 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.

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, with ordinary revision, 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 and raising international cable capacity.
- *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, significantly reinforce the grid and establish more new international connections.

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 balancing 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 3.2.9 Flexible energy systems. It will also be important to exploit the possibilities for greater interaction between the electrical grid and the thermal system.

The extent to which Norwegian actors are willing to supply power system balancing services will to some degree depend on how much Norway develops its own new renewable energy resources such as wind power. Any ambitious plans to utilise these intermittent energy resources will necessarily take up a share of the Norwegian energy system's regulating and balancing reserves. Norway's role as a major exporter of renewable energy may therefore conflict somewhat with the role of exporter of balancing power to Europe. More insight into perspectives related to supplying renewable energy or power system balancing services will be valuable in the years ahead.

Need for knowledge development

Hydropower technology is mature and there are no real technological obstacles to harnessing the potential energy of water. Nonetheless, due to future requirements for production planning, efficient operation and environmental considerations, as well as the effects of climate change on hydropower plant design, there is still a need to further develop the hydropower knowledge base.

AMBITIONS

- Increase the value of hydropower by better utilising the unique storage facilities of reservoirs in the context of the national and European power systems.
- Promote the environment-friendly, cost-effective construction of new hydropower capacity in Norway and internationally.
- Optimise operations, maintenance and renewal of the hydroelectric system, adapting to future changes in markets, climate and environmental requirements.
- Further strengthen Norwegian hydropower-related expertise and industry to achieve national objectives and be an attractive partner for owning, constructing and operating facilities internationally.

STRATEGIC RESEARCH TOPICS

- Hydrology and watershed runoff: Enhanced data on drainage basins, improved models for unmeasured areas and with short time resolution that take into account the expected effects of climate change on runoff.
- Further developing Norwegian specialist expertise in tunnelling and underground facilities, including drilling technology for environment-friendly waterways with minimal visible impact and optimal upgrading/expansion of waterways to meet updated requirements for operation and for health, safety and the working environment (HSE).
- Models/methods for optimising operation and maintenance of existing hydropower facilities while considering impacts on the environment and local communities.
- Renewal of the Norwegian hydropower system with an eye to improving cooperation with other renewable energy technologies such as wind and solar power. Increased installed generator power capacity, changed usage of reservoirs, etc.
- Technological solutions and systems for upgrading existing pumped storage plants for off-peak pumping (short term).
- Enhancing understanding of turbine and electromechanical stresses from increased power output and dynamic operation.
- Assessing the consequences of climate change, directives concerning water and flooding, and other regulations with respect to changed potential, dam safety and river system environment.
- Addressing international issues related to hydropower, including: erosion and sediment transport; greenhouse gas emissions from reservoirs; water consumption, "water footprint"; and other local environmental, societal and social issues.
- Devising models for determining the environmental impacts of short and long-term balance power.

ACTIONS TO BE TAKEN

- Establish measures specifically targeted towards master's and doctoral-level education and ensuring researcher recruitment, particularly through further developing the Centre for Environmental Design of Renewable Energy (CEDREN) and the Norwegian Hydropower Center.
- Provide funding for testing and demonstration facilities as well as a large-scale laboratory for testing and verifying new technology and environmentally adapted solutions. Such a facility would also function as a training centre for competencies in hydropower, with an emphasis on short and long-term balancing power.
- Provide funding for initiatives from industry which may have potential for value creation.
- Launch knowledge-building projects and researcher projects within the identified strategic research areas.

3.2.2
SOLAR POWER

SOLAR POWER

- Solar power is one of the fastest-growing renewable energy technologies. In its ETP 2014, the IEA reports that solar cells are advancing faster than expected. System prices have fallen 40% since the ETP 2012 report. Due to this dramatic price drop and high growth rate over many years, end users in many markets are beginning to see electricity from solar cells as competitive with conventional power. Solar electricity is starting to play an increasingly meaningful role in supplying energy throughout the world, including in emerging economies.
- Advances and the market will provide openings for suppliers and other companies looking to supply technology or solutions to larger or smaller segments of this value chain.
- The justification for public funding for research, development and demonstration thus to a large degree lies in development of internationally competitive industry and expertise in the energy sector.

Market development and anticipated significance internationally and in Norway – relevance and potential

Solar (photovoltaic) power is already emerging as a significant source of energy as end users are beginning to see it as competitive with conventional energy carriers. This will have a major impact on the world's energy markets in years to come – and the effects are already manifesting themselves. The energy supply of Europe and the rest of the world is in transition, best illustrated by Germany's Energiwende, a radical restructuring of the country's energy sector towards renewable sources. Corresponding changes are taking place all across Europe, made possible by the substantially strengthened competitive positions of wind power and particularly solar power.

This is dramatically changing business models as well, and ultimately entire energy systems. Companies seeking to secure a position as a long-term energy supplier must shift their focus. These developments are affecting Norway and the Norwegian business sector with regard to prices in the European power market, presenting challenges and offering opportunities.

Solar power has grown rapidly over the past 20 years. Annual growth in installed capacity was 48% from 2000 to 2007 and 72% from 2007 to 2011. In 2013 total installed capacity was roughly 132 GW, corresponding to annual production of roughly 160 TWh. By comparison, Norway's annual hydropower production averages 130 TWh. While many people regarded solar-cell price reduction projections presented in

SOLAR POWER TECHNOLOGY

Objective 1	Increased value creation on the basis of national energy resources and utilisation of energy
Objective 2	Energy restructuring through efficient use of energy and increased flexibility in energy systems
Objective 3	Development of internationally competitive industry and expertise in the energy sector

[12] *IEA World Energy Outlook 2012.*

2008 as far too optimistic, those estimates have in fact been surpassed. The market for solar power has also grown more than projected, and there is broad consensus that this trend will continue. Analyses by McKinsey predict annual growth of 35–50 GW. Deutsche Bank estimates that 45 GW of new solar capacity will be added in 2014. This development and its projections constitute the beginnings of a self-driven market.

International growth can be grouped into two types of markets, centralised (large-scale) solar power farms and distributed solar power stations. These markets are developing differently in various parts of the world, but both are undergoing rapid growth.

European demand for distributed solutions in residential and commercial buildings (BIPV/BAPV) has comprised a large proportion of the market growth and total, a trend expected to continue. In the UK there is strong growth (6 000 new installations per week in summer 2013), and in Germany distributed solar power now comprises 70% of the country's total installed PV capacity.

The market for both BIPV and BAPV systems is expanding modestly in Norway, where there is less incentive than in the rest of Europe. Coming changes in building codes towards passive house standards, and eventually zero-energy and plus-energy standards, will create a need for localised electricity production. In practice, solar cells are currently the best technology for this purpose. The Norwegian solar power market itself will not constitute a large market for supplying solar panels, but solar power will play a significant role in Norway's energy restructuring and realising zero-energy and plus-energy buildings.

Norwegian stakeholders

The rapid development and successful industrialisation of the solar cell industry has led to tremendous growth in the supply of renewable energy worldwide. The fact that end users now see electricity from solar power becoming competitive in many unsubsidised markets means that the industry has entered a new phase. Whereas the Norwegian solar cell industry used to consist primarily of companies in the module manufacturing chain (producing solar-grade silicon, ingots, wafers and panels), the scene now emerging is one of new value chains, increasing specialisation, and the development of new business areas and business models. Changes are taking place downstream in particular, where new companies are investing in and developing solar power stations of varying sizes. An installation industry is also emerging, targeting project development and expansion. As new stations are completed, the market for their financing, service and operation grows.

Even though REC has ceased production activities in Norway and some other companies have been confronted with major challenges, the number of companies active in Norway's solar industry has not declined. When the Energi21 forum invited industry input for the solar power working group in 2010–11 there were five participants. In the working group established in 2013 there were 14 participants. The number of involved companies in Norway is on the rise and they are targeting a variety of segments in the value/business chain. In 2005 there were 21 companies classified as solar energy enterprises in Norway. By 2010 that number had nearly doubled, reaching 40, and that does not include consultancy firms

75 MW i Kalkbult, norske Scatec Solars solkraftanlegg i Sør-Afrika. *Foto: Scatec Solar*

and research institutions. By 2013 still more companies had joined the list. The economic volume of solar-related activity has fluctuated but now is rising again.

Norwegian advantages and opportunities

Changes in the structure of the industry are taking place now, mainly the emergence of downstream companies with activities revolving around solar power plants. An important point in this context is that this development is creating opportunities within niches, where it is substantially easier to exploit advantages and sustain competitiveness. In large-volume markets, niches and subcontractor deliveries, too, can represent significant value creation. Existing subcontractors can shift focus and customise their activities and deliveries to the international solar power market.

Over the past 10–15 years Norway has established a level of research capacity and competency that provides an excellent knowledge platform for further development towards what is now a new phase for the solar power industry. Flexible, sound research infrastructure has been a one of the pillars supporting this platform. The industrial success achieved in the solar energy field means that Norway already has a strong industry on which to build, and which, as has been amply demonstrated, can also generate spin-offs and new initiatives. Norway has acquired wide-ranging expertise in materials and process industries over the past decades as well. The manufacture of high-grade silicon and the first segments of the silicon value chain requires electricity and cooling water, which are in abundant supply in Norway and will remain so, according to energy projections. Low electricity prices can be expected. The processes are not labour-intensive, and a proper degree of automation should yield profitability and value creation.

AMBITIONS

- Build up a silicon-based solar industry for the future – an upstream industry that is at the European forefront in quality and innovation.
- Develop business within multiple segments of the value chain, including applications for solar power internationally and in Norway.
- Cultivate prominent research and educational institutions that are attractive as international partners.
- Generate a knowledge base for further developing Norway's solar cell cluster and new industry based on existing and new business areas.

STRATEGIC RESEARCH TOPICS

- Development and demonstration of the high-efficiency, cost-effective, environment-friendly, silicon-based solar cells of the future.
- The role of solar power in the energy system, in terms of both technology and the market, and the basis for supplying components and services.

ACTIONS TO BE TAKEN

- Develop instruments that make it easier to include international partners in research projects.
- Provide funding for establishing pilot and demonstration facilities.
- Help to unify and coordinate the FME centres in order to enhance expertise in the use of solar power in the energy system. Relevant candidates include the Norwegian Research Centre for Solar Cell Technology (Solar United), the Research Centre on Zero Emission Buildings – ZEB, the Centre for Sustainable Energy Studies (CenSES) and the Norwegian Smartgrid Centre.

[13] *BIPV: Building Integrated Photovoltaic (PV materials used in new construction) and BAPV: Building Adapted Photovoltaic (retrofitted PV materials).*

3.2.3
OFFSHORE WIND POWER

OFFSHORE WIND POWER

- In ETP 2014, the IEA states that the growth trajectory of offshore wind power is lagging behind for the 2°C scenario, underscoring the need for intensified RD&D activity.
- Current development is targeted at an international market where suppliers of technology can gain a position. Norwegian expertise and experience in oil, gas and maritime activities provide a strong basis.
- The theoretical energy potential from Norwegian offshore wind power is so large that utilising it must be based on supplying power to an international market with adequate infrastructure. This scenario is far into the future.
- The justification for public funding for research, development and demonstration lies:
  – ***to a large degree*** in development of internationally competitive industry and expertise within the energy sector;
  – ***to some degree*** in increased value creation based on national energy resources and utilisation of energy – at least in the long term.

As of the end of 2013, just over 6 600 MW of offshore wind power capacity had been installed, roughly 30% more than in 2012, and continued strong growth for the offshore wind power market is expected. The average turbine generates roughly 4 MW and the average capacity of an offshore wind farm in 2013 was 485 MW, which is 78% more than the previous year. The trend is clearly towards larger wind turbines and farms. Worldwide, offshore wind power now accounts for roughly 2.2% of installed wind power capacity, up from just 1% in 2010. Few Northern European countries have established activities in this area. Strong political 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.

The market for offshore wind power is outside Norway and will remain so for quite some time. Still, there is good potential for high production on the Norwegian continental shelf thanks to favourable wind conditions, which could enhance profitability and thus speed up development.

Norwegian stakeholders
Norway's supplier industry is currently involved in both offshore and onshore wind farms. In 2012 roughly 160 companies in Norway supplied technology and services to the offshore wind power market. A large number of these had origins in the petroleum and maritime sectors. 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.

Norwegian challenges, opportunities and advantages
Norwegian companies have acquired a considerable competency 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.

The bridge from R&D to markets is lacking in Norway, in part because the market is found outside the country's borders. Knowledge production is proceeding in Norway, but without the presence of large-scale national investments and projects, the national industry dynamic develops more slowly. This affects the industrial structure, which is largely comprised of companies concentrating on international opportunities. Thus it is essential to target Norway's instruments towards assisting Norwegian companies in this context. This applies not least to instruments and funding far along the innovation chain.

OFFSHORE VIND POWER

OFFSHORE VIND POWER

Objective 1	Increased value creation on the basis of national energy resources and utilisation of energy
Objective 2	Energy restructuring through efficient use of energy and increased flexibility in energy systems
Objective 3	Development of internationally competitive industry and expertise in the energy sector

New, improved methods and technology for installing 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.

Technological challenges

The costs of offshore wind farms are high compared to production using conventional energy sources. An important objective of technology development and R&D activities must be to reduce costs through the entire service life of wind power facilities. One of the primary factors for cutting costs involves developing larger turbines with higher capacity, lower weight and greater reliability.

AMBITIONS

- Develop a Norwegian supplier industry for the offshore wind power market.
- Build up Norwegian companies' technological and industrial expertise and develop solutions that:

– increase energy production from wind farms;
– cut costs throughout the entire value chain, from design to decommissioning.

STRATEGIC RESEARCH TOPICS

- Optimal foundations for both seabed-based and floating turbines and different seabed conditions.
- Concepts and systems for reliable electric infrastructure (offshore subsea solutions).
- Cost-effective, time-saving assembly and installation of offshore wind farms.
- Efficient concepts for marine logistics (heavy maintenance) and robust solutions for access.
- Concepts and systems for reducing operational and maintenance costs and increasing energy conversion ratios.
- Enhanced knowledge about offshore wind power's environmental and societal impacts.

ACTIONS TO BE TAKEN

- Contribute to EU demonstration programmes seeking to reduce the costs of offshore wind power. The Norwegian authorities must assume an adequately active role in these processes. Strategic cooperation with other countries on development and testing of technology should be considered.
- Facilitate and set aside resources for Norwegian actors seeking to invest in these processes.
- Provide funding for initiatives from industry which may have potential for value creation.
- Launch knowledge-building projects and researcher projects within the identified strategic research areas.

[14] *European Wind Energy Association (EWEA).*
[15] *Norwegian Renewable Energy Partners (INTPOW).*

3.2.4
LAND-BASED WIND POWER

LAND-BASED WIND POWER

- Installed wind power capacity has increased by roughly 25% annually over the past decade (ETP 2014).
- Norway has some of Northern Europe's best wind resources.
- Land-based wind power is a mature technology yet continual advances will further enhance its cost-effectiveness and energy output.
- The Norwegian-Swedish market for green electricity certificates is and will be a key driver for expanding land-based wind power in Norway.
- Norwegian companies with reliable solutions have opportunities as subcontractors in this market, and some exist already.
- Norwegian companies are looking to become owners of wind power farms in Norway and abroad.
- The justification for public funding for research, development and demonstration targeting land-based wind power lies:
  – ***to some degree*** in increased value creation based on national energy resources and utilisation of energy;
  – ***to some degree*** in energy restructuring through efficient use of energy and increased flexibility in energy systems.

Market development and anticipated significance internationally and in Norway – relevance and potential

More than 80 countries now have installed wind power. At the end of 2013 total installed capacity was 318 GW with a total production exceeding 500 TWh. This amount is projected to double every 3–4 years, with global installed capacity reaching roughly 1 000 GW in 2020, equivalent to production of some 1 500 TWh. There is great potential for utilising land-based wind power in Norway. At the end of 2013 Norway had roughly 800 MW of installed wind power capacity, with production of some 2 TWh. The potential is significant and can be realised without requiring new research. The common Norwegian-Swedish market for green electricity certificates will help to promote the expansion of land-based wind power. The Norwegian Wind Energy Association (NORWEA) estimates wind power production in Norway will reach 7 TWh in 2020. 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.

Norwegian stakeholders

Companies can be classified into two groups: energy companies that construct and utilise wind power, and suppliers of related technology and services. There are currently no Norwegian full-service suppliers but rather companies operating as subcontractors. Several Norwegian companies are positioning themselves for wind power development internationally.

LAND-BASED WIND POWER	Objective 1	Increased value creation on the basis of national energy resources and utilisation of energy
	Objective 2	Energy restructuring through efficient use of energy and increased flexibility in energy systems
LAND-BASED WIND POWER	Objective 3	Development of internationally competitive industry and expertise in the energy sector

Norwegian challenges, opportunities and advantages

Norway has some of Northern Europe's best wind resources. However, there are certain challenges to utilising this potential, such as the technology's cost level compared to hydropower and environmental issues. Market opportunities will still be available for delivery of components and services for specific development projects and for subcontracting within the value chains of the major wind turbine producers. New solutions within these chains could create significant value due to the large market size.

Technology development

Although land-based wind power may be considered as a mature technology, further technology development is still needed to raise cost-effectiveness and energy production. The technology areas involve wind turbine technology, meteorology and forecasting, concepts and designs of wind farms, efficient integration into the power grid, and condition-based operation and maintenance for increased reliability.

AMBITIONS

- Increase the cost-effectiveness of utilising available wind resources.
- Make land-based wind power profitable without subsidies by 2020.

STRATEGIC RESEARCH TOPICS

- Wind resources (prognoses)
  – Enhance methods and models for estimating wind and power production.
- Cost-effective operation and maintenance and technology
  – Optimise operation and maintenance, methods and tools.
  – Estimate and enhance reliability, service life and efficiency of primary components and systems.
- Environmental and societal issues
  – Generate knowledge about wind power's impacts on the environment and local communities.
  – Develop cost-effective solutions and measures for reducing negative impacts on the environment and land areas.

SPECIFIC ACTIONS TO BE TAKEN

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

[16] *Global Wind Energy Council (GWEC).*

3.2.5
UTILISATION OF BIORESOURCES

BIORESOURCES

- Roughly 18 TWh of bioenergy is utilised in Norway annually. The potential for increased felling in Norwegian forest area is roughly 6 million m3 annually, and some of this could be used for biofuels and bioenergy. The Norwegian Water Resources and Energy Directorate (NVE) estimated in 2014 that a realistic resource potential is 20–22 TWh. Access to additional biomass may be realised if efforts to cultivate marine biomass are successful.
- The utilisation of bioresources depends mainly on two main factors:
  1) The forest as a bioresource and carbon sink.
  2) Proper application, including the phasing out of fossil energy sources by using biofuels and bioenergy.
- For profitable, sustainable utilisation of biomass, the entire value chain must be considered as a whole, with biorefineries at the core of such an approach. Bioenergy for biofuels and stationary applications will be derived from different biorefinery-converted fractions.
- The justification for public funding for research, development and demonstration lies:
  – ***to some degree*** in increased value creation based on national energy resources and utilisation of energy;
  – ***to some degree*** in energy restructuring through the development of new technology and production of environment-friendly energy;
  – ***to some degree*** in development of internationally competitive industry and expertise in the energy sector.

Market development and anticipated significance internationally and in Norway – relevance and potential

Fuelwood is the main form of bioenergy utilised in Norway in terms of annual energy volume (6–7 TWh) and installed capacity (10 GW). Norwegian producers of wood-burning stoves and fireplaces and R&D groups have taken active part in and are carrying out ground-breaking work on developing more efficient and clean-burning stoves. It is important that these efforts are continued, both to enhance the adequacy of fuelwood burning as an environment-friendly form of energy and to promote continued Norwegian value creation in this area.

Internationally there is rising awareness that biomass is a finite resource that must be managed and utilised sustainably. This is a key point of the IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, to which Norway contributed. Biomass growth is limited internationally. This is also the case in Norway, although usage here is currently less than the yearly increment. With regard to international utilisation of biomass, trends and developments are towards the "cascade" principle of more complete utilisation of the biomass for the purposes of contributing to a sustainable economy and using resources efficiently. In light of this, there will be fewer solutions that utilise biomass solely for stationary energy purposes. More and more this energy will come from a fraction of the biomass cascade or a by-product of another form of biomass processing. In this way, bioenergy for stationary purposes will increasingly become an element within an energy system that integrates heat and power.

The situation in the transport sector is different. A large proportion of greenhouse gas emissions comes from transport. Fossil fuels comprised a total of 55 TWh in 2012. More than 95% of all transport activity is driven by fossil fuels, and although hydrogen and electrification of the transport sector are good alternatives for the long term, there will be significant transport work that must be carried out using liquid fuel. Here, liquid biofuels or biogas will be the only alternatives until other solutions are in place. Currently there is no clear alternative for aviation fuel other than biofuel, and some major stakeholders in Norway are working on developing bio-based aviation fuel.

The use of biochar for producing higher-grade products will be even more attractive. Future utilisation of biochar will concentrate on maximising its utilisation, where price, sustainability and the availability of alternatives will be pivotal factors. Use of biochar thereby involves a wide range of industries, competency and authorities, so opportunities and challenges must be approached within a correspondingly broad perspective. It is important to ensure that good ideas and solutions that bridge multiple disciplines and industrial sectors receive attention and do not fall by the wayside. Sustainable bioresource management should be given high priority in the years ahead. Efforts being carried out under the Skog22 strategy for the forestry-related sector will play a large role in ensuring this kind of integrative thinking.

Norwegian stakeholders

Norway currently utilises roughly 18 TWh of biomass annually for energy purposes. There is fragmentation among the Norwegian stakeholders, with a few large and many small companies across the various segments of the value chain, including producing and utilising biogas, managing wet organic waste, manufacturing pellets, and developing wood-burning stoves and fireplaces as well as incinerators of various scales for district and local heating. Norwegian forest owners and farmers play important roles as producers and users of land-based biomass. Changes in demand for cellulose fibre for paper production mean that new thinking will be needed relating to value chains and utilisation of biomass in order to maintain value creation in forestry and agricultural activities.

UTILISATION OF BIORESOURCES	Objective 1	Increased value creation on the basis of national energy resources and utilisation of energy
UTILISATION OF BIORESOURCES	Objective 2	Energy restructuring through efficient use of energy and increased flexibility in energy systems
	Objective 3	Development of internationally competitive industry and expertise in the energy sector

AMBITIONS

- Help to achieve a broad-based understanding of climate-friendly management of Norway's biological biomass.
- Increase value creation through the sustainable use of bioenergy from land-based and marine biomass.

STRATEGIC RESEARCH TOPICS

- Integrating bioenergy in future energy systems as part of a bioeconomy.
- Bioenergy as an integrated part of future biorefineries.
- Obstacles to increasing the use of bioenergy in the Norwegian system, including the use of forest residues and low-value biomass.
- Knowledge about carbon cycles and ecosystem impacts involving standing forest-based biomass.
- Sustainable biofuels for the transport sector with special emphasis on heavier vehicles, airplanes and boats.
- Enhancing utilisation of waste for heat, power and fuels.
- New types of sustainable Norwegian marine biomass.

SPECIFIC ACTIONS TO BE TAKEN

- Provide funding for development of technology and value chains for new bioenergy raw materials from forests, waste and marine sources.
- Help to follow up the Skog22 strategy with sound, sustainable energy solutions. Main focuses: heat and fuels.
- Provide funding for initiatives from industry which may have potential for value creation.
- Launch knowledge-building projects and researcher projects within the identified strategic research areas.

This trend towards a new bioeconomy is global, and important research is underway to increase production of materials, chemicals, biofuels and energy from biomass. Norwegian researchers and industry are taking part in these activities.

Norwegian challenges, advantages and opportunities

Annual increment in Norway's forests is 28 million solid cubic metres, based on 2012 figures. Of this, 17 million is forest balance, i.e. the maximum timber volume that can be removed annually to maintain a national balance without needing to reduce this volume at a later point in time. Total felling in Norway is currently some 11 million solid cubic metres annually, which means in theory that it is possible to harvest another 6 million solid cubic metres per year without exceeding the forest balance.

In anticipation of future competition for biomass, both within and outside Norway, it is critical to promote development towards utilising biomass for purposes where no good alternatives exist and in ways that use the raw materials efficiently. In the future, extraction of forest-based biomass for second-generation biofuels will compete for the supply of virgin timber (pulpwood). Biomass from forest residues and the like will still be able to be utilised for bioheat, and together with waste heat from biorefinery processes will continue to play a major part in the energy system.

In the longer run, moreover, there is additional potential related to increasing the production of biomass. A changing climate and more active forest management may expand the forest resource base. Norway also has opportunities in the area of marine biomass, where technology development and demonstration are still needed. Several companies now speak of "future blue-green fields" in reference to the possibilities for cultivating and utilising both marine and land-based biomass. Cultivation of marine biomass is highlighted in the HAV21 strategy.

[17] Statistics Norway–- Energy account and energy balance, 2012.
[18] Norwegian Water Resources and Energy Directorate (NVE) – Bioenergy in Norway (2014).
[19] SINTEF Energy Research, Avinor project.
[20] HAV21 is Norway's R&D strategy for promoting business development and effective management of the marine environment.

3.2.6
NATURAL GAS POWER WITH CCS

CARBON CAPTURE AND STORAGE

- For many years Norway has defined carbon capture and storage (CCS) as a priority focus area, and Norwegian research groups and companies are among the foremost in the world.
- The IEA states in its 2°C scenario that in 2050, 40% of the global energy supply will still come from fossil fuels. The agency stresses that CCS will need to play a significant role, contributing 14% of total cuts in greenhouse gas emissions in 2050. In its ETP 2014 the IEA also reports that technological progress is lagging behind targets and that efforts must be escalated.
- In its Energy Roadmap 2050, the EU emphasises that gas-fired power generation with CCS is a vital element in its future energy system.
- There is large potential for carbon storage on the Norwegian continental shelf, an area where Norway has a competitive advantage. In addition, the Norwegian maritime cluster holds a strong position in the field of transporting liquefied natural gas (LNG), with expertise relevant to ship transport of CO_2 and, in the longer term, hydrogen.
- Future carbon taxes levied may reduce the value of Norwegian natural gas reserves. Efforts to develop technology for decarbonising the utilisation of Norwegian natural gas may help to preserve its value under future tax regimes.
- The justification for public funding for research, development and demonstration lies:
  – ***to a large degree*** in increased value creation based on national energy resources and utilisation of energy;
  – ***to some degree*** in development of internationally competitive industry and expertise in the energy sector.

Market development and anticipated significance internationally and in Norway – relevance and potential

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 gas-fired power generation with CCS may help to ensure the competitiveness of the remaining gas reserves, which would safeguard their value and thus be of great significance in a socio-economic context. Gas-fired power generation 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.

In the longer term, producing hydrogen by decarbonising Norwegian natural gas may give hydrogen a larger role as a future energy source.

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 oil and natural gas reserves.

CCS could also be a substantial cost factor in other types of industries whose production processes emit large amounts of CO_2. Unlike the energy industry, such industries (e.g. cement, steel, petrochemicals) will have to rely on CCS to curtail their carbon emissions dramatically, 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.

According to the IEA, the world needs to be storing roughly 8 billion tonnes of CO_2 annually by 2050 to help to limit global temperature rise to 2°C. Europe's share of this should be at least 1,5 billion tonnes annually. Studies of potential CO_2 storage sites in Europe have calculated that roughly 25% of total European CO_2 storage capacity is located beneath the seabed on the Norwegian continental shelf in formations that have yielded oil and gas for nearly 50 years. Thus Norway possesses large-scale storage capacity, but few suitable sources for capturing CO_2. The rest of Europe, on the other hand, has major point sources of CO_2 that emit 10–20 million tonnes of CO_2 annually but few places to store CO_2 on land. By storing European CO_2 under the seabed in the North Sea, Europe could reduce its direct CO_2 emissions and Norway could compensate for its indirect emissions. No other CO_2 measure can offer the same climate benefit.

Norwegian stakeholders

Norwegian efforts in the field of CCS have generated significant expertise within a number of companies and several research institutes. The commercial stakeholders comprise suppliers of technology and systems as well as large technology users, such as Statoil, that will need this kind of technology for their commercial activities.

Norwegian challenges, advantages and opportunities

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 from CO_2 capture to transport and storage.

The country's most prominent competitive advantage is likely in the area of CO_2 storage, thanks to many years of experience from petroleum activities and CO_2 injection at the Sleipner and Snøhvit fields. The Norwegian continental shelf has the capacity to store all of Northern Europe's CO_2 emissions. This storage potential, together with the possibilities for using CO_2 for enhanced oil recovery, will represent a significant market opportunity for the Norwegian business sector.

CCS focus	Objective	Description
CARBON CAPTURE AND STORAGE	Objective 1	Increased value creation on the basis of national energy resources and utilisation of energy
	Objective 2	Energy restructuring through efficient use of energy and increased flexibility in energy systems
CARBON CAPTURE AND STORAGE	Objective 3	Development of internationally competitive industry and expertise in the energy sector

Hywind, Statoil's floating offshore wind turbine off Norway's southwest coast. *Photo: Statoil*

AMBITIONS

- Reduce greenhouse gas emissions, thereby increasing the value of Norwegian oil and gas reserves and other core industries by:
  – achieving large-scale CCS in industrial or gas-fired power plants in Norway;
  – establishing a central carbon storage site, preferably with potential for enhanced oil recovery (EOR);
  – establishing infrastructure for CO_2 transport;
  – reviewing the possibility of importing CO_2 to said central storage site;
- Ensure competence-building throughout the entire CCS chain.

STRATEGIC RESEARCH TOPICS

- Low-cost technical solutions and systems for CCS on Norwegian industry and power production.
- Technical solutions and systems for condensation, storage and ship transport of LNG, liquid CO_2 and in future liquid hydrogen.
- Cost-effective and safe geological storage (sequestration) of CO_2 and possibly temporary storage for use in EOR.
- Monitoring technology and models for long-term storage.
- Systems and solutions for minimising emissions and footprint of the carbon-management value chain, including carbon-neutral/carbon-negative solutions.
- Systems and technology (competency) based on large-scale application in Norway.

SPECIFIC ACTIONS TO BE TAKEN

- Start up testing and demonstration projects.
- Provide funding for initiatives from industry to develop competitive CCS technology and services.
- Examine and support development of measures and framework conditions that will contribute to removing legal obstacles to implementing CCS. Of particular relevance in this context are legal issues relating to transport and storage offshore.
- Facilitate and provide funding for active Norwegian participation in international CCS networks such as Horizon 2020, the ERA-NET scheme, EERA and ECCSEL.
- Provide funding for initiatives from industry which may have potential for value creation.
- Launch knowledge-building projects and researcher projects within the identified strategic research areas.

[21] *Nordic CCS Roadmap; see http://fagtrykk.no/sintefenergi/nordiccs/*

Through diligent R&D efforts, the Norwegian business sector has developed technology and expertise to position itself to supply capture technology for both power production and industrial processes to companies around the world.

Analyses carried out at the Nordic CCS Competence Centre (NORDICCS) and published in the Nordic CCS roadmap indicate that in eight of ten Nordic CCS projects, ship transport of CO_2 will cost less than pipeline transport. This opens up opportunities for new business activities in a Norwegian maritime sector that is well equipped to gain a foothold in the transport of liquid CO_2.

A public station for charging electric vehicles. *Photo: Transnova/Gaute* Larsen

3.2.7
RAISING ENERGY EFFICIENCY IN BUILDINGS

RAISING ENERGY EFFICIENCY IN BUILDINGS

- The construction sector is a major energy consumer, accounting for 31% of energy use worldwide. Efficient utilisation of energy is an overall objective, and advances in the construction sector are essential for achieving this.
- New requirements and new technology will ensure that the buildings of tomorrow are built to low-energy and zero-energy standards, and in the long run will become net producers of energy in certain periods. The slow rate of turnover in buildings makes it essential to exploit the potential for energy efficiency in existing buildings, which calls for new technology for simple, effective measures. There is great potential here as well.
- Buildings of the future will be an important component of the flexible energy system. The trend in the construction sector is towards "smart building" concepts and ultimately "Smart Cities and Communities", and the sector's development must be increasingly viewed as part of the energy system's restructuring.
- The justification for public funding for research, development and demonstration lies **– *to a large degree*** in energy restructuring through the development of new technology and production of environment-friendly energy.

Market development and anticipated significance internationally and in Norway – relevance and potential

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. 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.

Energy efficiency has been steadily improving for many decades, aided in Norway by among other things increasingly stricter regulations on technical requirements for buildings. One stated ambition of the Storting's Agreement on Climate Policy is for the technical requirements to be issued in 2015 to employ passive-house standards, and subsequent regulations for 2020 can be expected to approach zero-energy standards. It is still unclear how these regulations will be formulated, but to achieve these aims, heating needs must be reduced and be met by local energy production. Buildings may be required to have the capacity to produce electricity, which will decrease need for an external supply of energy to all new and completely renovated buildings. These buildings will be transformed from energy consumers into net producers of energy in certain periods, which will necessitate new technology for buildings and in their interfaces with the energy system for both controlling and exchanging energy. These factors will form the framework for market development and research challenges in the area of energy for buildings. In addition there is great unrealised potential for reducing energy consumption in existing buildings by implementing specific measures using existing technology. The STREK-2020 report commissioned by the City of Oslo estimates savings potential from cutting energy consumption in existing buildings within the city limits at some 3 TWh, or roughly 30%. Good system models that can effectively simulate a building using various energy efficiency measures are needed in order to compare different energy efficiency measures and to maximise their respective potentials.

There are currently a number of mature, existing technologies that remain to be implemented in the market. The obstacles in these cases are mainly related to costs and the attitudes of the technology user. Moreover, there is still a need to develop new technology and solutions for raising energy efficiency, particularly in materials technology and systems/engineering solutions.

Norwegian stakeholders

This field encompasses many companies with widely varying competencies, approaches and levels of ambition. Architects, consulting engineers, property developers, installers of heating/ventilation/air-conditioning/sanitation, electrical installers, and a variety of producers and suppliers of technology and equipment are all represented. These generally fall into

RAISING ENERGY EFFICIENCY IN BUILDINGS

Objective 1	Increased value creation on the basis of national energy resources and utilisation of energy
Objective 2	Energy restructuring through efficient use of energy and increased flexibility in energy systems
Objective 3	Development of internationally competitive industry and expertise in the energy sector

one of three groups: 1) building structure (insulation, windows, etc.), 2) technical control systems (temperature control, ventilation, etc.), and 3) utilities (electricity, tap water, heating, cooling).

Norwegian challenges, advantages and opportunities

Opportunities in this area primarily involve either: 1) the value of reducing energy consumption along with associated environmental and climate benefits and economic gains, or 2) value creation related to businesses supplying technology, systems and expertise/consulting for the Norwegian and/or international construction sectors. Opportunities are related to the high potential for efficient energy use, not only in the buildings to be erected according to new construction regulations but also in existing buildings. Innovation activity in this sector has been low.

Increasingly strict building regulations approaching zero-energy standards target the energy-saving potential to be unlocked by new technology and new solutions. This potential applies to new buildings and major renovation projects, which must comply with applicable building regulations. Efficient heat pumps will be able to play an even greater role in meeting stricter requirements. Solar power is expected to contribute more and more, as rapidly dropping prices for solar panels are allowing for greater inclusion of building-adapted photovoltaics, in Norway as well. The designation of building regulations and definition of system borders will affect the scope and solutions. Future building regulations will also incorporate more extensive use of solar heating. Norway also has some of Europe's largest geothermal well fields for heating and cooling solutions. Combined needs for heating and cooling in buildings entails great potential for these systems.

Given the slow turnover rate of buildings, estimated at 2% annually, the effects of zero-energy and plus-energy standards have a long time perspective, yet they set an ambitious course that was unthinkable a few decades ago.

Additionally, more products and solutions need to be developed to facilitate energy savings in existing buildings. Many buildings (50–80%) that will be in use in 2050 have already been constructed. Much of the latitude for finding solutions in the context of renovation is determined by the existing building. Practical solutions will therefore involve an understanding of more than the purely technical aspects of energy efficiency, and good solutions may be different from those that apply for new structures.

[22] *Source: Ministry of Local Government and Regional Development working group on improving energy efficiency in buildings.*
[23] *Passive house: Reduced energy consumption through passive measures in buildings. Heating needs of less than 15 kWh/year for large parts of Norway, somewhat higher for colder areas.*
[24] *STREK-2020: A report commissioned by the City of Oslo in 2012 on how to increase energy efficiency in buildings and reduce the use of fossil fuels for heating in private homes. Part 3a, by Energidata Consulting and Xrgia.*

AMBITIONS

- Raise energy efficiency in Norwegian buildings.
- Encourage local and building-integrated renewable energy production.
- Achieve flexible integration of energy-efficient buildings into the energy system (electricity, heating, cooling).

STRATEGIC RESEARCH TOPICS

- Effective incentives for promoting development and implementation of new integrated energy solutions.
- Technical and economic optimisation of local and building-integrated renewable energy production and consumption profiles in low-energy, zero-energy and plus-energy buildings.
- Methods and incentives for realising planned, calculated and simulated energy use and monitoring of system performance.
- Materials and solutions for raising efficiency in existing buildings.

SPECIFIC ACTIONS TO BE TAKEN

- Help to follow up the Bygg21 strategy process for the construction industry and ensure that energy use is included on the agenda.
- Support initiatives from industry for projects with potential for value creation.
- Launch knowledge-building projects and researcher projects within the identified strategic research areas.

3.2.8
ENERGY-EFFICIENT INDUSTRIAL PROCESSES

ENERGY-EFFICIENT INDUSTRIAL PROCESSES

- Efficient utilisation of energy in energy-intensive industries is a critical competitive factor.
- Future access to energy with a minimal negative environmental impact will be increasingly important.
- Economic assessments play a key role in raising energy efficiency in industry; energy costs versus the cost of measures/technology often determine the extent to which efficiency measures are implemented.
- Waste heat from industry is a substantial resource that is underutilised, often because industrial facilities are located far from potential heat consumers and district heating infrastructure. Thus there is potential for new solutions that make use of waste heat, particularly where low-grade heat can be utilised.
- There is potential for other efficiency measures as well, and technological content will vary from industry to industry.
- The justification for public funding for research, development and demonstration lies:
  – ***to some degree*** in energy restructuring through the development of new technology and efficient production of environment-friendly energy;
  – ***to a large degree*** in development of internationally competitive industry and expertise in the energy sector.

Market development and anticipated significance internationally and in Norway – relevance and potential

There is significant potential to raise energy efficiency in industry, both internationally and in Norway. 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. As a result, the development of technology to lower the cost of energy-saving measures and the knowledge needed to create favourable framework conditions will play a key role in the ability to realise this potential.

According to ETP 2014 estimates, 19% of the greenhouse gas reductions needed to fulfil the 2°C target must come from improved energy efficiency in industry. This means that equipment suppliers developing new energy-efficiency technology for industry can expect a sizable market. For larger companies in energy-intensive industries, it will be a competitive advantage to develop their own energy-efficiency processes in-house.

Norwegian stakeholders

Companies playing an important role in this development can be broadly classified into two categories, those in the energy-intensive sector and suppliers of technology and equipment for the sector. In large-scale projects, both categories of companies often play an integral role in development, which is necessary to achieve the best results. The solutions are often customised. Norway has built up a substantial, world-class energy-intensive sector that is also involved in developing technology environments and a community of experts. In the production of both aluminium and ferrosilicon alloy, for example, there have been steady advances in energy efficiency over many years. Competitiveness in this industry is closely tied to specific energy consumption. With leading technology and an abundant supply of renewable energy, there is good potential for increased value creation in Norway within this industry.

In addition to the energy-intensive actors, there are a number of Norwegian companies that supply equipment to this sector in Norway, and some do so internationally as well. There is potential for companies that can develop new and more-efficient technology for this sector.

ENERGY-EFFICIENT INDUSTRIAL PROCESSES	Objective 1	Increased value creation on the basis of national energy resources and utilisation of energy
ENERGY-EFFICIENT INDUSTRIAL PROCESSES	Objective 2	Energy restructuring through efficient use of energy and increased flexibility in energy systems
ENERGY-EFFICIENT INDUSTRIAL PROCESSES	Objective 3	Development of internationally competitive industry and expertise in the energy sector

Norwegian challenges, advantages and opportunities

Norway exports roughly one-fourth of its hydropower in the form of energy-intensive products such as ferrous alloys, aluminium and more. Given the high potential of Norway's renewable energy resources combined with a skilled energy-intensive sector, there will be significant opportunity for further value creation in the years ahead. International carbon prices and the ability to develop energy-efficient processes will be critical to the competitiveness of Norwegian companies.

In its 2010 report the Energi21 working group for raising energy efficiency in industry described opportunities and ambitions leading up to 2020 and drew up a plan targeting a 20% reduction in specific energy consumption. A large proportion of the potential for reductions involved recovering waste heat or waste gases and utilising existing technology through enhanced coordination between and co-location of heat-producing and heat-demanding industrial activities. Electricity production from recovered heat is costly, but with good framework conditions for the industrial production itself, such investments can yield many kWh for the money. The largest reductions will occur in connection with investments in new production facilities and the development and introduction of new technology.

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-grade 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

- Expand the scope of energy-refining industries in Norway.
- Reduce specific energy consumption and greenhouse gas emissions.
- Increase the utilisation of surplus heat in all land-based industries, including better use of low-grade heat for heating and electricity production.

STRATEGIC RESEARCH TOPICS

- Improvement of processes, both incremental and ground-breaking.
- New, cost-effective technological solutions and methods for converting and upgrading surplus heat.
- New technology for accumulating heat for optimal integration with intermittent power production from renewable energy sources.
- Using waste heat to capture CO_2 from carbon-heavy processes (partial CO_2 capture).

SPECIFIC ACTIONS TO BE TAKEN

- Create arenas of cooperation and encourage projects partnering industry actors, supplier companies and research groups to facilitate the development of energy-saving technology and solutions.
- Support initiatives from industry for projects with potential for value creation relating to utilising surplus heat or other areas that may benefit industry in the form of higher energy efficiency.
- Provide funding for initiatives from industry which may have potential for value creation.
- Launch knowledge-building projects and researcher projects within the identified strategic research areas.

[25] *"Norway as an energy nation" (2012), an energy-policy platform for Norwegian industry, by the Confederation of Norwegian Enterprise (NHO).*

3.2.9
FLEXIBLE ENERGY SYSTEMS

FLEXIBLE ENERGY SYSTEMS

- A flexible energy system encompasses all energy-related infrastructures and their coordination. The system must accommodate both centralised and decentralised production with varying degrees of predictability as well as the storage of energy and changing energy consumption patterns, including restructuring of the transport sector.
- A flexible energy system is a critical factor for achieving Norway's energy and climate-policy targets while safeguarding security of energy supply.
- Coordination of subsystems will be optimised through the extensive use of automation, monitoring, control, information systems and new market mechanisms that also incorporate consumer behaviour.
- The justification for public funding for research, development and demonstration to a large degree lies in:
  – energy restructuring through the development of new technology and production of environment-friendly energy;
  – development of internationally competitive industry and expertise in the energy sector.

Market development and anticipated significance internationally and in Norway – relevance and potential

Market development must cover the entire climate-friendly, flexible energy system. A flexible energy system encompasses all energy-related infrastructures and their coordination. The system must accommodate both centralised and decentralised production with varying degrees of predictability as well as the storage of energy and changing energy consumption patterns. Consumption will increasingly be shifted to incorporate "prosumers" – end users that can alternately consume output from the grid and feed electricity back into it – as well as new energy demands adapted to environment-friendly transport. Coordination of subsystems will be optimised through the extensive use of automation, monitoring, control, information systems and new market mechanisms that also incorporate consumer behaviour. More and more, these concepts are being grouped under the concept of smart grids, which draw upon and coordinate parallel infrastructures such as the electricity grid, heating and cooling and even natural gas, and solutions for CCS will also be integrated. Ensuring personal safety, security of supply and quality of supply are key challenges to be faced as the flexible energy system develops and expands.

Flexible energy systems are being developed all around the world, driven primarily by the major reforms that must be undertaken with regard to the global energy supply and consumption. Flexibility in the energy system is imperative for implementing needed restructuring such as the phasing in of renewable energy with intermittent production profiles, compatibility between various energy carriers, rapid fluctuations in consumption, the need for energy storage, and large-scale changes in the transport sector. Development towards more flexible energy systems also entails integration and coordination of parallel infrastructures for electricity, district and local heating and cooling, and in time natural gas.

International investment in energy restructuring will create opportunities for providing technology and services. The European Commission has estimated that EUR 400 billion will

FLEXIBLE ENERGY SYSTEMS	Objective 1	Increased value creation on the basis of national energy resources and utilisation of energy
	Objective 2	Energy restructuring through efficient use of energy and increased flexibility in energy systems
FLEXIBLE ENERGY SYSTEMS	Objective 3	Development of internationally competitive industry and expertise in the energy sector

be invested in electricity distribution networks and another EUR 200 billion in transmission networks leading up to 2020. The Joint Research Centre, the European Commission's in-house science service, estimates that by 2020 some EUR 56 billion of this, or roughly 10% of total investment, will go towards making Smart Grids.

The authorities in a number of countries, including Norway, have decided to require implementation of advanced monitoring and control systems and DataHub for household/business electricity meter data. The new documents from the European Commission discussing the 2030 climate and energy policy targets point to the infrastructure as essential to success.

This discussion indicates that a closer focus on a more reliable, smarter grid is emerging in the EU from an investment perspective as well. The investment volume includes both reinvestment in existing facilities and new investments needed to satisfy new requirements and adapt to a flexible energy system. Future investment needs will create a window of opportunity for suppliers of technology and services, testing and verification, and integration of new technologies and solutions.

Climate change, too, has an impact on the energy system, as more extreme weather events are placing completely new strains and challenges on the grid in terms of safety, vulnerability and reliability, and on the security of energy supply in general. This in turn increases the need for risk assessment, planning, enhanced preparedness and automated management and control solutions. In addition to the challenges purely related to engineering, balancing production with consumption is more difficult due to higher unpredictability of energy supply and demand.

Norwegian stakeholders

In practice the entire Norwegian energy industry is more or less involved in or affected by the transition towards flexible energy systems. Companies developing technology, solutions and systems are mainly in the supplier industry or consultants collaborating with research and educational institutions. Norway has many strong companies focused on this field, with experience from cable technology to power electronics to ICT and systems supply. Many of these companies also target automated and flexible solutions offshore. The energy industry and grid companies in particular will be important users of technology and solutions and thus play a key role in their development. Some grid companies are also actively involved in research projects to develop competency and new solutions, but such grid-company participation needs to be further strengthened.

Challenges and opportunities

Energy restructuring is placing new demands on the energy system, related both to feed-in of new renewable energy 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.

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 section 3.2.1 Hydropower. 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.

The increasing complexity of future energy production and consumption requires significant development in the field of automation, monitoring and control, mostly in the distribution network but also in the transmission network. This development may open up market opportunities. Norwegian companies are also good at system technology operation and control, and have skilled groups for dynamic power system analysis.

The introduction of monitoring and control systems is an important component for realising the flexible energy system. It is essential that the meters to be installed possess the advanced functionality needed to carry out this wide-ranging improvement.

The Norwegian energy system is virtually all-electric. Several countries' energy plans are setting a course towards more electrification. Norway is far ahead in this respect and could help with its knowledge and experience. The conditions are also in place for Norway to function as a laboratory for testing and verification of technology and solutions in an all-electric society.

[26] *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.*
[27] *The EU strategy "Energy infrastructure priorities for 2020 and beyond".*

AMBITIONS

- Develop an energy system with cost-effective, operationally efficient integration of renewable energy in order to achieve targets for new production from renewable sources, distributed production and energy storage.
- Establish a dynamic, efficient energy system with greater flexibility for interaction between production and consumption at every transmission level, particularly with regard to distribution-related flexibility.
- Innovate new energy services in keeping with developing flexibility and new business models.
- Modernise the energy system to maintain security of energy supply during demanding weather conditions (e.g. extreme weather events).
- Take advantage of future renovation/upgrade projects and grid investments in Norway as well as within and outside Europe as opportunities to promote a Norwegian supplier industry for smart-grid components and systems.
- Enhance knowledge about increasing the proportion of renewables in the energy system, including outside Europe.
- Substantially accelerate innovation within electricity supply based on a national strategy for smart grids.
- Improve the funding instruments for RD&D in the industry.

STRATEGIC RESEARCH TOPICS

- Macro-economic research to enhance competencies as a basis for effectively targeting policy and funding instruments.
- Next-generation cable technology and electrotechnical components.
- Technology for closer monitoring, control and management.
- Architecture for future smart distribution networks.
- Models and tools for market modelling and for comprehensive assessments of infrastructure for electricity, heat and other energy carriers, internationally and in Norway.
- Knowledge and solutions for active end users, which by being closely tied to markets become more energy-efficient with the help of advanced monitoring and control systems, dataHub1 and new tariff and market structures.
- Implications of new types of consumption (e.g. electric vehicles, new household appliances) on system technology and operation.
- Output issues and their impacts on security of supply.
- Technology and solutions for decentralised energy storage.
- System technology and operation solutions for enhanced integration of local production and future low-energy/plus-energy buildings.
- Developing frameworks and business solutions in three areas:
  – Participation in reserve markets for Frequency Restoration Reserves (FRR) and Replacement Reserves (RR);
  – Energy deliveries at net peak demand;
  – Participation in upcoming power markets, primarily in Germany and the UK but also elsewhere internationally.

SPECIFIC ACTIONS TO BE TAKEN

- Enhance incentives and framework conditions that substantially accelerate the pace of innovation of power distribution companies.
- Facilitate and provide funding for large-scale testing and demonstration facilities for developing flexible grid solutions.
- Provide funding for initiatives from industry which may have potential for value creation.
- Launch knowledge-building projects and researcher projects within the identified strategic research areas.

3.2.10
DEVELOPMENT OF INCENTIVES AND FRAMEWORKS – MARKET DEVELOPMENT

DEVELOPMENT OF INCENTIVES AND FRAMEWORKS – MARKET DEVELOPMENT

- The development of energy policy is based on an underlying framework of environmental, climate and industrial policy guidelines. Together with the need to ensure the security of energy supply, this comprises much of what drives research activity and the phasing in of new energy technology and new solutions.
- This entails some difficult challenges, and fresh knowledge for policy development will be needed on an ongoing basis to ensure optimal framework conditions, incentives and instruments for achieving national and international targets. Politicians and the authorities will need access to continually updated knowledge.
- The justification for public funding for research, development and demonstration is therefore critical to development in the entire energy sector and is thus closely linked to the realisation of all of the objectives of the Energi21 strategy. Funding should therefore be directed towards:
  – developing internationally competitive industry and expertise in the energy sector;
  – increasing value creation on the basis of national energy resources and utilisation of energy in the long term;
  – energy restructuring through the development of new technology and production of environment-friendly energy.

Market development and anticipated significance internationally and in Norway – relevance and potential

Ensuring an economically and environmentally sustainable energy supply is a major international challenge. Economic growth coupled with stipulations to reduce greenhouse gas emissions constitutes a difficult framework, which is why research and development on new energy technology is high on political agendas throughout the world. Research activities must be conducted on a large scale, and there must be a strong willingness to invest resources. Just as important as developing new technologies is ensuring the application of new, effective solutions and paving the way for market forces to steer development in the right direction rapidly enough. A flexible energy system as described in Chapter 3.2.9 is critical to achieving these aims. Such a system must have the capacity to handle dynamics and variation in both production and demand, and the transport sector must also be integrated into end-user consumption. Policy structures, framework conditions and the power market will be key to advancing development. The necessary knowledge base can be built through strategic, targeted research in this area.

Norwegian stakeholders

Maintaining energy supply is a key task of the Norwegian business sector, and energy producers, grid companies and the supplier industry are all important stakeholders in the further development of the Norwegian energy system. Politicians and sectoral authorities, too, exert a strong influence on how this development takes place. These actors, together with research groups, comprise the broad range of stakeholders that will all play a decisive role in shaping the future energy system in Norway and internationally.

Norwegian advantages and opportunities

The knowledge platform in this area will be developed in various ways, including through national and international research projects where leading Norwegian research groups in energy-related, social science approaches represent a strength – and an advantage. Public funding of research in this area has been given a substantial boost in the past five years, due in part to the Agreements on Climate Policy and recommendations in the previous Energi21 strategy reports, and this has resulted in the establishment of three FME Centres for Social Science-related Energy Research (FME Samfunn). Including funding for the FME Samfunn centres and programme activities, Research Council funding in this area has increased by 230% from 2008 to 2013. This provides an excellent foundation for further development as well as opportunities for preparing qualified, knowledge-based analyses as a basis for decision-making.

Other aspects – there are macro-economic aspects in many areas, such as:

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 overall integral structure of the energy system and the impacts of various framework conditions and incentives, so this is an important area for continued research and developing new knowledge.

Balancing power based on Norwegian resources will require development of a market for power and system 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.

AMBISJONER

- Develop an energy system with cost-effective, operationally efficient integration of renewable energy in order to achieve targets for new production from renewable sources, distributed production and energy storage.
- Enhance knowledge about increasing the proportion of renewables in the energy system, including outside Europe.
- Establish a dynamic, efficient energy system with greater flexibility for interaction between production and consumption at every transmission level, particularly with regard to distribution-related flexibility.
- Innovate new energy services in keeping with developing flexibility and new business models.
- Modernise the energy system to maintain security of energy supply during demanding weather conditions (e.g. extreme weather events).
- Take advantage of future renovation/upgrade projects and grid investments in Norway as well as within and outside Europe as opportunities to promote a Norwegian supplier industry for smart-grid components and systems.
- Substantially accelerate innovation within electricity supply based on a national strategy for smart grids.
- Improve the funding instruments for RD&D in the industry.

STRATEGISKE FORSKNINGSTEMAER

- Identification of incentives, market design and other instruments that can ensure socially optimal energy demand with different time horizons.
- Studies of instruments, regulations and decision-makers' commitment to energy restructuring and changing energy consumption patterns.
- Potential for and impacts of increased electrification of society.
- Scenario studies to learn more about the effects of Norwegian and European energy and climate policy.
- Knowledge about market design and market integration at the national and European levels to promote optimal integration of renewable power production into a market with conventional production.
- Differentiated instruments for promoting and introducing immature technologies into energy markets.
- Differentiated instruments for achieving the long-term objective of a sustainable energy system in the most effective manner.
- Research that focuses on efficiency of resource use and environmental impacts to weigh the balance between local and global measures and local and global effects.

HANDLINGER FOR IVERKSETTELSE

- Launch knowledge-building projects and researcher projects within the identified strategic research areas.
- Encourage increased cooperation between Norway and Europe on topics such as market design, market integration, framework conditions, innovation and entrepreneurship.
- Develop a shared database for researchers, containing information on technology and demand as well as other relevant data for studies of energy systems and markets.
- Provide funding for relevant initiatives from industry and other users in this area.

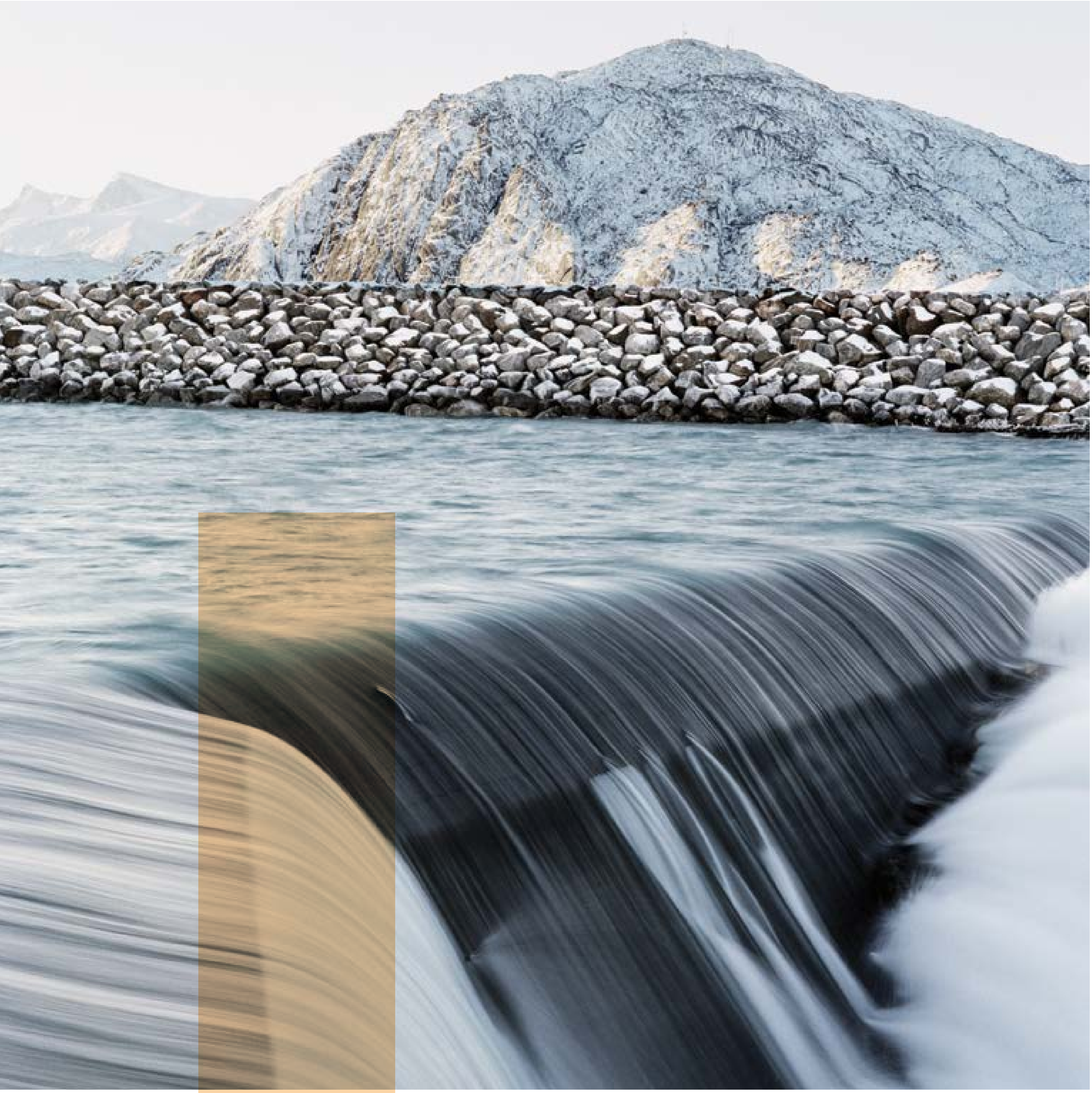
Realising the potential for reducing energy consumption in buildings requires insight into the decision-making mechanisms of residents, building owners and building contractors.

Technical solutions that allow desired functionality are a prerequisite for a well-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 market for green electricity certificates 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.

Holmvassdammen dam at Statkraft's Svartisen Hydropower Plant. *Photo: Christian Houge*



3.2.11
OTHER ENERGY TECHNOLOGIES AND ENERGY CARRIERS

3.2.11.1 Thorium-based nuclear power

Norway may have the world's largest reserves of thorium, with deposits estimated at 170 000 tonnes, corresponding to a potential energy content 100 times greater than all the recovered and discovered oil on the Norwegian continental shelf. Despite these U.S. Geological Survey estimates, no explicit mapping of actual deposits has been conducted at the main site in Ulefoss, Norway, although calculations by the regional geologist support the estimate. No mapping of the economic and technical feasibility of recovery has been done yet.

Thorium has entered Norway's energy debate periodically over the past decade, but so far Norwegian energy policy has rejected development of nuclear power. The Energi21 board is of the understanding that this is still the case today. From an international perspective, however, it is incumbent upon every country to inform the world of any resources and possibilities that may contribute to a more secure and sustainable energy supply.

The Norwegian Thorium Report Committee report submitted in 2008 states that it was demonstrated in the 1960s and 1970s that thorium could be used in practically any kind of existing reactor, but that this was never implemented because the thorium fuel cycle could not compete with the uranium fuel cycle.

There is still insufficient information about the possibility of utilising thorium and recovering this resource in Norway.

3.2.11.2 Deep geothermal energy

The potential associated with deep geothermal heat is tremendous. Geoscience Australia, for instance, has calculated that 1% of the geothermal energy existing at less than five kilometres deep in Australia could cover the entire country's energy needs for 26 000 years. Advances in the areas of geological characterisation, drilling technology, the understanding of reservoirs during production, and technology for constructing enhanced geothermal systems will all help to realise this potential, primarily in zones with naturally high temperature gradients. These factors together with the temperature gradient will determine the economic attractiveness of utilising geothermal energy in a given location. Research to reduce drilling costs may help to enhance the possibilities.

The potential for deep geothermal energy production on the Norwegian mainland has only been surveyed minimally but appears to be limited. It is known that high geothermal gradients exist offshore and in Svalbard. Thus far no projects have attempted to draw heat from great depths, and the Energi21 board considers the potential for this energy source to be no greater in Norway than in many other countries. Targeted surveys will be needed if identifying other areas on the mainland with potential for deep geothermal energy production is desired.

ETP 2014 estimates the potential for geothermal energy at 200–300 TWh, divided roughly evenly within and outside the OECD, but at the same time the report stresses that advances are needed to achieve this.

In its political platform, the Norwegian Government recommends establishing an FME centre for geothermal energy. The Research Council plans to issue a funding announcement for a new round of FME centres in January 2015, and it will be possible for actors in the field of geothermal energy to apply. The need for research efforts targeting geothermal energy should be assessed on an ongoing basis.

3.2.11.3 Wave, tidal and osmotic power

Marine energy and tidal power hold a certain potential in Norway, and different calculations yield differing estimates as to the magnitude. The opportunity to utilise wave power has intrigued research groups, inventors and serious industrial companies for many years, and many different technologies have been patented and tested to harness the energy of waves and currents. Many challenges remain, however, and no technology has emerged that can be considered nearly ready for commercialisation. The Energi21 board assesses the potential for wave power to be limited compared to other renewable energy sources and thus does not recommend targeted activity in this field. Marine energy is on the agenda of EU research programmes, so Norwegian companies looking to develop new concepts are recommended to do so through those programmes.

Some research activity has targeted osmotic power in Norway, and one large company had been working to develop the technology but has now ceased those activities. The Energi21 board assesses the potential for osmotic power to be limited compared to other renewable energy sources and thus does not recommend targeted activity on this technology.

3.2.11.4 Hydrogen

Significant development activity has been focused on hydrogen in Norway. In 2004 an Official Norwegian Report on hydrogen as an energy carrier addressed both stationary and transport applications. During this period, an assortment of large Norwegian companies had high ambitions and many good projects and initiatives were launched with support from the authorities, among them development of the "Hydrogen Highway". In connection with this, some infrastructure has been built up, and Norway can be regarded a leader compared to many other countries based on its efforts in this early stage. Several automobile producers have used Norway as a demonstration arena for their hydrogen vehicles.

Some of the Norwegian companies have withdrawn from hydrogen development and have taken a wait-and-see approach, while other companies have entered the competition. The hydrogen-related opportunities for Norwegian companies can be classified in simple terms as 1) development of technology and equipment, and 2) usage in transport within Norway. Akershus County and the City of Oslo have entered into an agreement with the company Ruter to test hydrogen-powered buses in Oslo's public transport network.

Currently at least eight of the world's leading automobile producers are working on hydrogen and fuel cells, with specific plans for market introduction. The development of hydrogen vehicles has benefitted from the proliferation of electric vehicles. A hydrogen fuel cell vehicle is basically an electric vehicle whose battery has been exchanged for a hydrogen tank and a fuel cell that converts a continuous input of the reactants hydrogen and oxygen into electricity.

In a longer-term perspective there is potential for large-scale production of hydrogen for export via pipeline or ship. The former holds opportunities for technology suppliers that are able to develop components and parts for either the automotive industry or supply-line infrastructure. There are currently only a handful of such companies, but these may develop further, and others may enter the market. Hydrogen for the transport sector represents an opportunity to reduce the sector's greenhouse gas emissions, and it is one of several technology tracks that must be pursued. Hydrogen vehicles are afforded the same incentives as electric vehicles.

Despite the relatively modest scale of commercial hydrogen activity in Norway, the country has a substantial project portfolio and competency base in the field. These are built partly on many years' national efforts and partly on extensive participation in the European Commission's Fuel Cells and Hydrogen Joint Undertaking (FCH JU). The need for activities related to research, development, demonstration and market introduction in the area of hydrogen must be assessed on an ongoing basis relative to emerging opportunities and commercial ambitions.

3.2.11.5 New/unknown technologies

It is always possible that completely new solutions will emerge or that a technological breakthrough in one area will open up opportunities in another area. The foundation for such breakthroughs is laid by facilitating research of high international calibre and supporting the best research groups and companies with a high level of competence. The authorities that fund research activities must sustain this foundation through their funding mechanisms while promoting interaction and cooperation with highly capable international partners.

[28] *U.S. Geological Survey, 2007.*
[29] *Norwegian Thorium Report Committee, 2008.*
[30] *"Thorium in Fensfeltet – resource estimate", Report 1-2012 by Sven Dahlgren, regional geologist for Telemark, Vestfold and Buskerud counties.*
[31] *Transnova report on status of knowledge for phasing in hydrogen as a fuel in Norway.*

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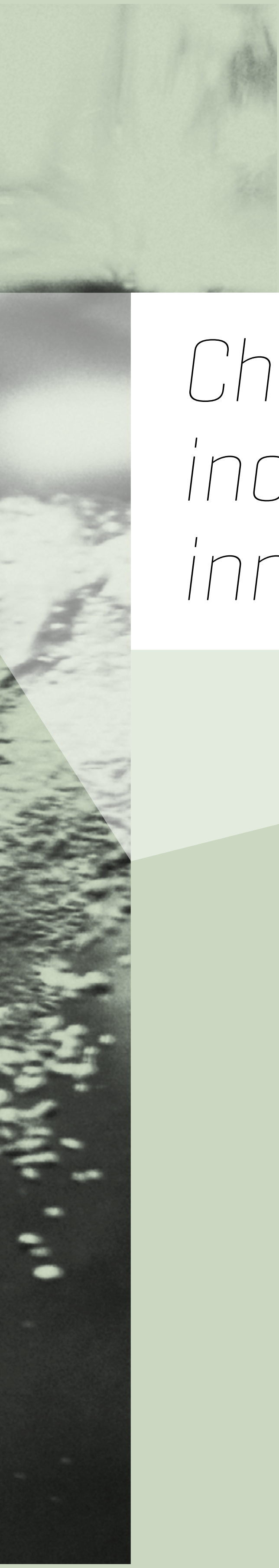


Challenges and incentives along the innovation chain

This chapter presents and discusses key elements of the framework underlying a number of the strategic recommendations and measures proposed in this strategy.

4.1

Targeted, long-term R&D activity

An essential prerequisite for achieving strategic objectives and successful implementation of measures is active involvement and efforts on the part of the authorities, the business sector and research communities in education and research, demonstration and commercialisation of new technologies and solutions.

Targeted, sound, long-term research, development and demonstration activities are crucial to knowledge and technology development, future value creation and adequate security of energy supply. Future value creation in the energy sector will require 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.

4.2

Various phases of innovation

The innovation cycle starts with basic research and ends with market introduction. Successful innovation is dependent on the contribution of a variety of stakeholders, including technology developers, technology users, the authorities and funders. Research infrastructure also plays a key role in testing, demonstration and verification of new technological solutions. Interaction and collaboration among the various stakeholders is essential to ensuring an effective innovation process and realisation of products and services. Energy technologies and knowledge are developed in an interplay with one another, and instruments will vary according to project type and technological maturity. Figure 8 illustrates the different phases of the innovation cycle, anticipated need for capital and the areas of function of the instruments. The need for equity intensifies as the progression moves further along the innovation chain, and the allowable share of state aid will depend on whether the activities are part of a commercial or non-commercial regime.

There are many different definitions, categories and terms for the phases of innovation. The Technology Readiness Level (TRL) system is employed by EU programmes, and has in recent years become more integrated into the description of a technology's position in relation to the degree of maturity and the distance to market introduction. The system is a more detailed categorisation than the one traditionally used in Norway. Figure 9 depicts the levels of the TRL system.

The process from testing and demonstration to commercialisation consists of several phases, and its success is highly dependent on private capital from and the commitment of the business sector.

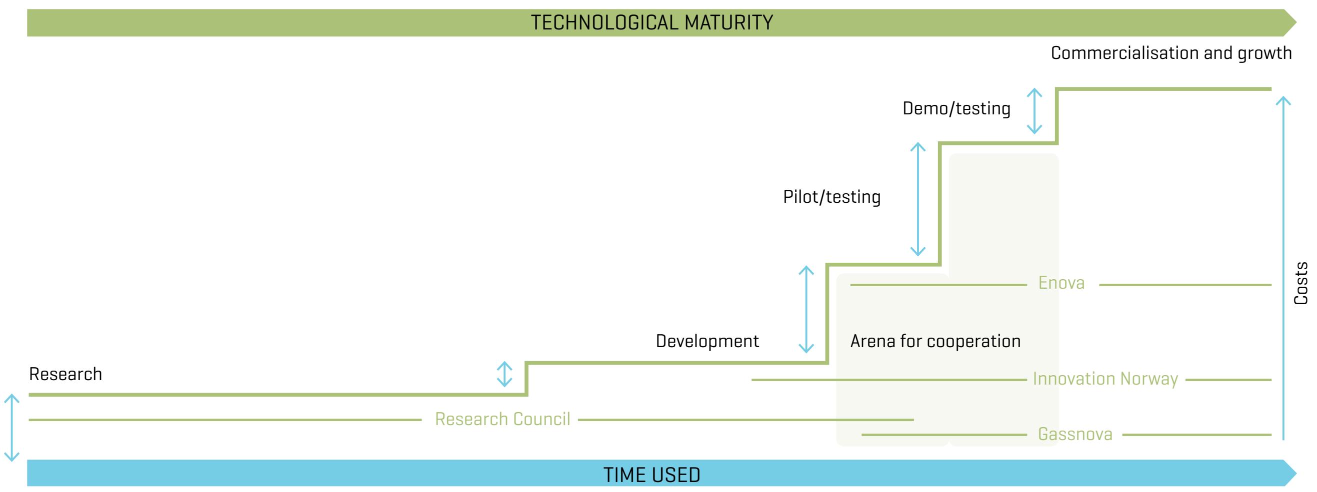


Figure 8 The various phases of the innovation cycle and the need for capital.

A good deal of innovation and renewal takes place in an existing framework, and as a rule it is easier to put new solutions into operation in existing industry. In some cases, however, it is more appropriate to establish new companies based on commercialisable research results from universities and research institutes.

There are currently a number of public funding instruments designed to reduce risk and be a catalyst for innovation. They target the following phases:

Pre-seed phase: Proof-of-concept of technology based on the R&D results of a research project. The results are typically in a small-scale lab version, and encompasses TRL 2 and TRL 3. Relevant Norwegian research and innovation system actors include the Research Council programme Commercialising R&D Results (FORNY2020), TTOs, Sinvent, and more.

Seed phase: Technology development via large-scale prototypes. Prototypes are put into a system and the technology is demonstrated. The encompasses TRL 4, TRL 5, TRL 6, TRL 7 and TRL 8.

Relevant actors in Norway include ProVenture Seed (a new fund with 50% state funding channelled via Innovation Norway), Alliance Venture (a new fund with 50% state funding channelled via Innovation Norway), Sarsia Seed, SINTEF Venture, and more.

Venture capital phase: The technology has been proven functional at the commercial level, and the first customer invoice has been submitted. This phase is equivalent to TRL 9. Relevant actors in Norway include Investinor (wholly owned by the Ministry of Trade, Industry and Fisheries), Viking Venture (private), Northzone (private), Verdane (private), and more.

Private equity phase: Mature companies in which growth is sought through restructuring. This phase is equivalent to business development after TRL 9. Relevant actors in Norway include Herkules (private), FSN Capital (private), Verdane (private), Reiten (private), and more.

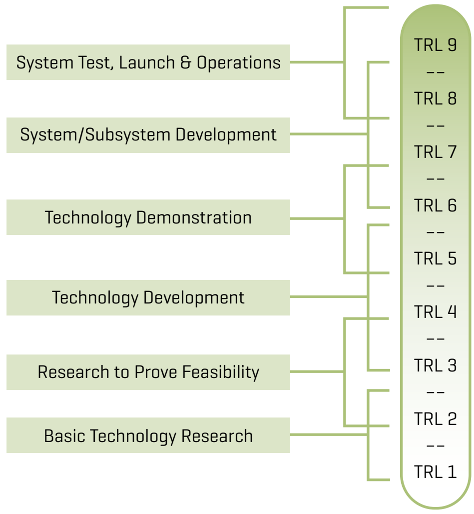


Figure 9 The TRL system measures technological maturity.

[32] *Technology Transfer Offices (TTOs) in Norway are affiliated with universities and some research institutes, and facilitate the commercialisation of research results through innovation.*

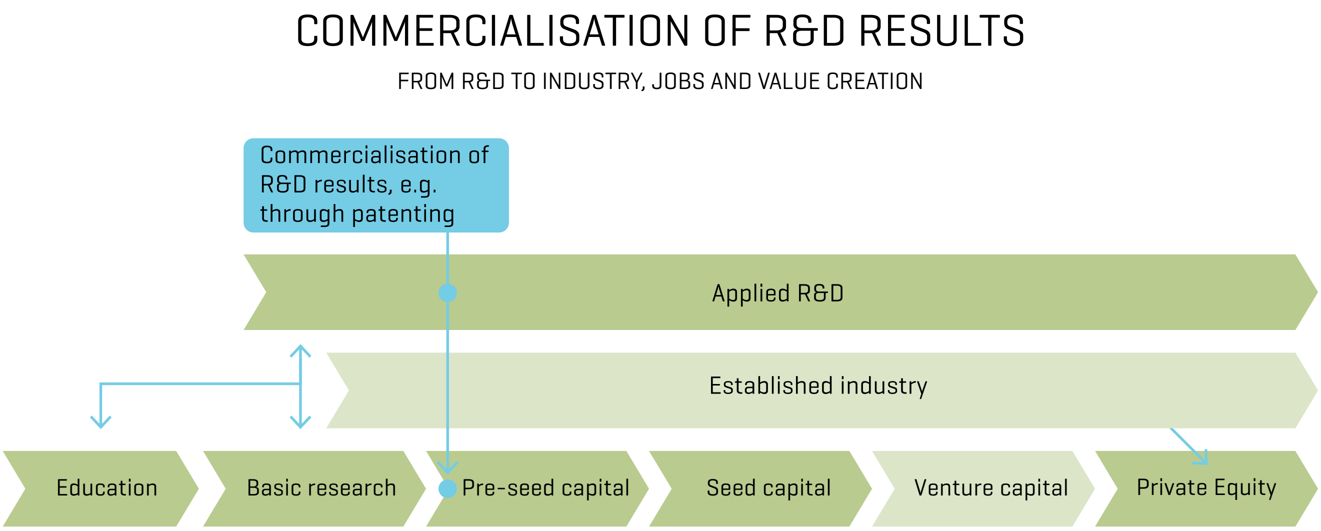


Figure 10 Commercialisation of R&D results – need for seed capital.

4.3

Interaction between mature and immature technologies

This strategy encompasses technologies in various phases along the innovation axis. The technologies vary in terms of maturity and type of industry. In the priority focus area on carbon capture and storage (CCS), for example, the technology is immature and there is no market as of yet. This is reflected in the small number of industry actors involved and the uncertainty surrounding future market volume. The situation is the complete opposite for hydropower technology. Hydropower is a mature technology area, with a highly experienced, well-established market and a sound industrial structure comprised of power producers, a supplier industry and a consultancy industry.

A large proportion of renewable energy technology and CCS technology is immature, the market prospects are uncertain and there is substantial risk related to future earnings. There is a need for risk mitigation instruments during the technology development and demonstration period in light of stakeholders' willingness to invest and take risks. This will require the use of a variety of instruments and allocation of funding to basic research, applied research, technology development and demonstration projects.

Innovation is not always a linear process, and technology development often shifts back and forth between the various phases along the innovation axis. Many technologies are composed of multiple individual components with varying degrees of maturity, and thus there is a need for development at various stages of the innovation cycle.

Offshore wind power is a technology area in which many individual technologies and solutions are found in different phases along the innovation axis. For example, many types of wind turbines must be considered mature, while floating concepts intended for floating offshore wind power are immature and still under development. Figure 11 shows examples of technology areas related to offshore wind power at various stages of maturity along the innovation axis.

When designing and administering funding instruments, it is vital to know and understand the typical development needs for the various technologies and appurtenant subcomponents in order to successfully innovate and improve technology.

Many renewable technologies have been successfully developed through an optimal interaction between funding instruments, technology developers and the market. Internationally, land-based wind power and solar power (photovoltaic facilities) are good examples of successful technological innovations.

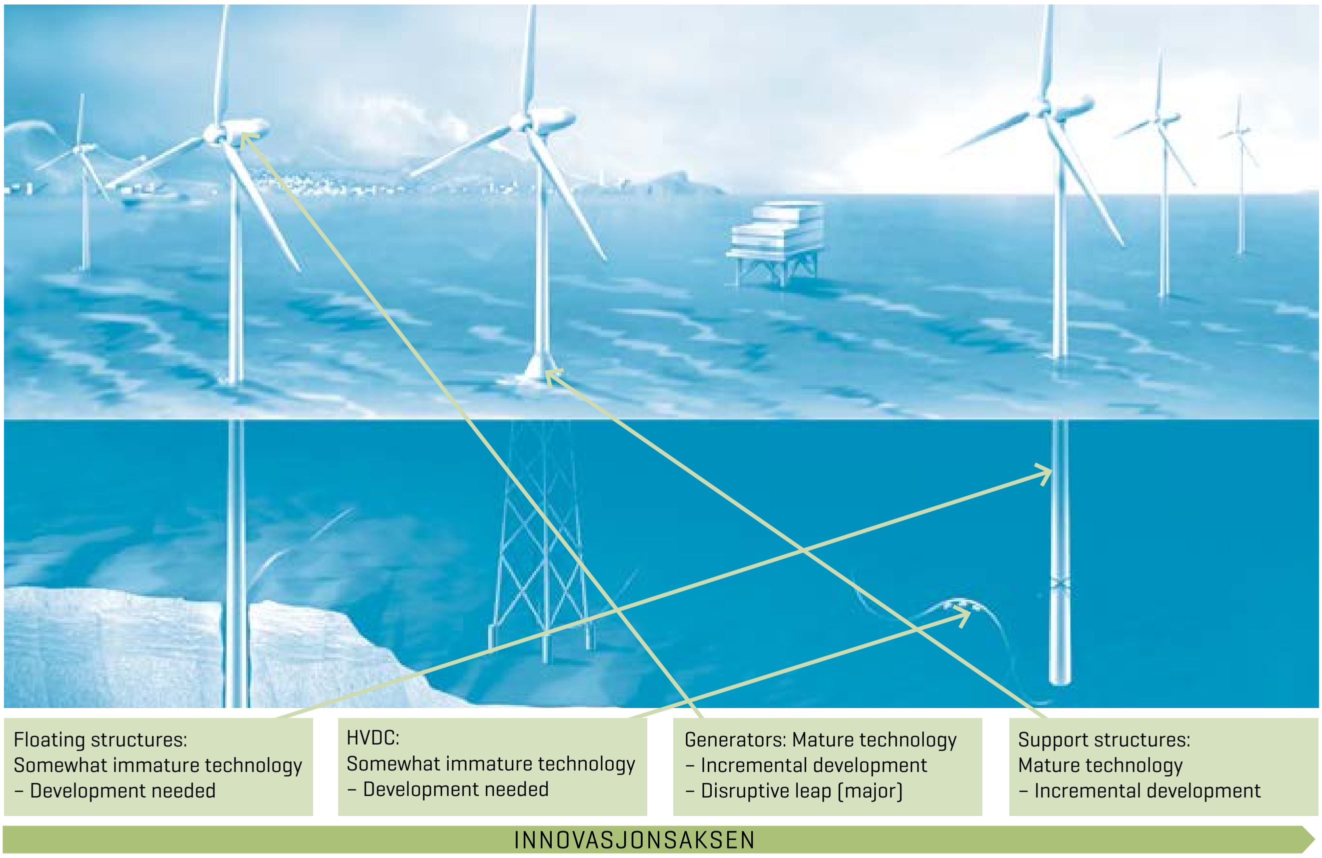


Figure 11 Technology areas related to offshore wind power: placement along the innovation axis. Illustration: Energi21/NOWITECH

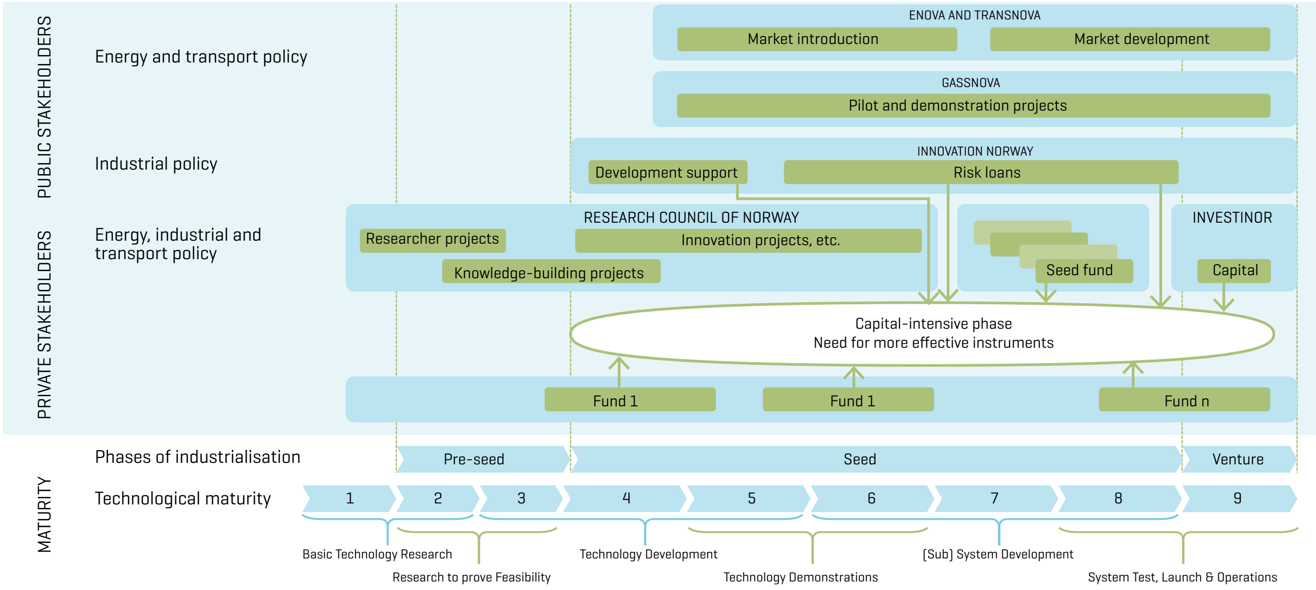


Figure 12 Instruments in relation to objectives, project relevance and stages of the innovation chain.

4.4

Instrument platform for technology and knowledge development

Norway has a well-developed research and innovation system that administers public funding for research and development in the areas of climate-friendly energy technology and CCS. Funding is channelled via dedicated research programmes (the Large-scale Programme for Energy Research (ENERGIX) and the Norwegian RD&D CCS programme (CLIMIT)), the public basic funding scheme for research institutes, and programme and project support administered directly by the stakeholders in the research and innovation system.

The Research Council, Enova, Gassnova, Innovation Norway and Transnova are the public sector stakeholders with the greatest influence on the realisation of the ambitions and objectives of the Energi21 strategy. Investinor also plays an important role vis-à-vis relatively newly established companies in the venture capital phase. Other stakeholders in the public sector also have influence, for example in the context of requirements, regulations and the statutory framework. A wide variety of instruments is available to promote the development of new knowledge, technology and industry. The schemes administered by the public sector stakeholders offer support along the entire innovation chain, from basic research to market introduction.

Figure 12 illustrates the public sector stakeholders' operative instruments, with a description of objectives, project relevance, the various stages of the innovation chain and technological maturity. The instruments administered by Transnova are also included here because segments of Transnova's portfolio address energy-related topics (electrification of road transport and renewable fuels).

Not only do the instruments have to cover the entire innovation chain, it is crucial that the objectives of the various instruments are coordinated. Effort should be made to avoid situations in which projects are given priority in an early stage of the innovation chain only to be stopped as they come close to fruition because the objectives of the various instruments have not been harmonised or the thematic priorities are different.

The Research Council, Enova and Innovation Norway collaborate on communicating, coordinating and enhancing the profile of their respective instruments for actors in the research sphere (the business sector and research communities). These activities are important to ensuring optimal utilisation of public funding and clarifying the interplay between the various instruments.

A mapping study conducted by the Energi21 forum in 2012 shows that roughly NOK 1.4 billion in public funding was awarded to 644 research, development and demonstration projects on climate-friendly stationary energy technology, CCS, low-carbon transport (electrification/biofuels) and stationary hydrogen. Support for Technology Centre Mongstad (TCM) is not included here. An overview of the distribution of funding among the thematic and technology areas is provided in Figure 13.

[33] *Energi21: Mapping of support for R&D and demonstration activities from the Research Council, Enova, Innovation Norway and Transnova in 2012 (Kartlegging støtte til FoU og demonstrasjon fra Forskningsrådet, Enova, Innovasjon Norge og Transnova i 2012, in Norwegian). www.energi21.no*

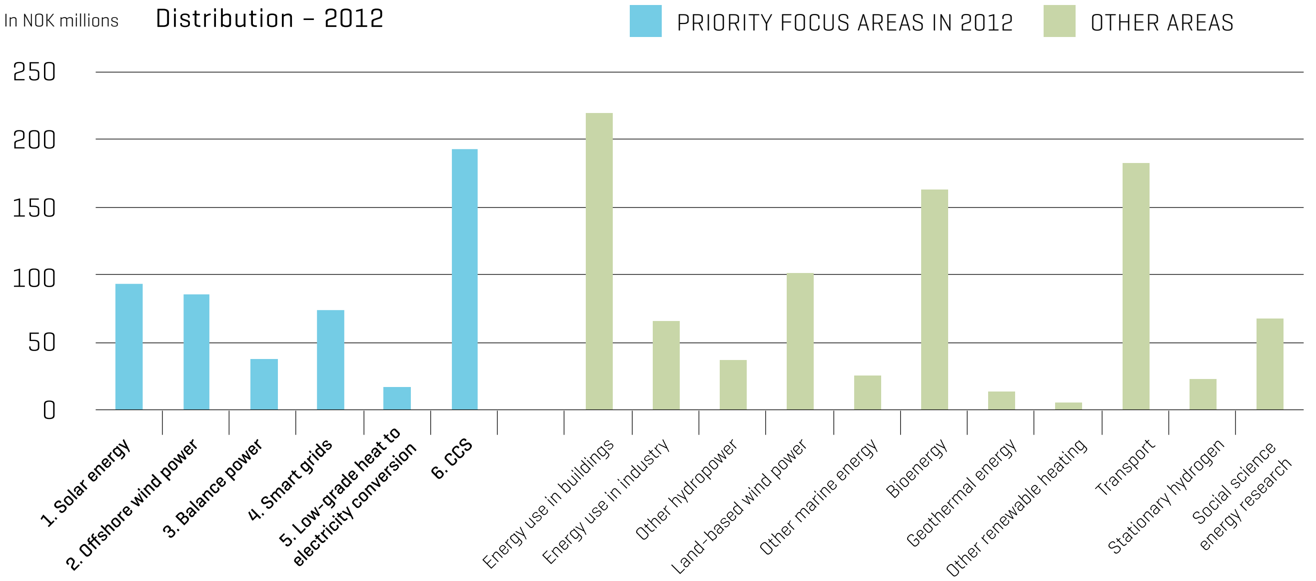


Figure 13 Public R&D funding in the energy sector in 2012, by thematic area. Energy use in buildings includes Enova's support for energy efficiency measures in private households. In 2012 support for renewable energy production via the Norwegian-Swedish electricity certificate market totalled NOK 25 million for small-scale hydropower (included in the column Other hydropower) plus another NOK 5 million (included in the column Land-based wind power). Support for TCM is not included here.

The six columns on the left-hand side of the figure show the total amount of funding allocated within the six priority focus areas of the 2011 Energi21 strategy. The overview encompasses all ongoing projects in 2012, including projects started up in previous years. The initiative to establish most of these projects was taken before the Energi21 strategy report was published in June 2011. The priority focus areas are listed below each column.

The group of columns on the right-hand side of the figure shows the funding allocated to the remaining thematic and technology areas within stationary energy, CCS, low-carbon transport and stationary hydrogen. Projects based on energy-related social science topics have also been included here. The data was compiled on the basis of the project portfolios of the Research Council, Enova, Innovation Norway, Gassnova and Transnova.

The most expedient distribution of funding will vary on the basis of several factors, including industrial structure, market development and potential, the ambitions of the industry itself, and the capacity to participate financially.

Distribution of R&D funding in 2012 along the innovation axis

Figure 14 illustrates the distribution of the same R&D funding in the energy sector in 2012 along the innovation axis. The projects are categorised according to the guidelines on state aid for research and development and innovation under the EEA Agreement. Most public funding in Norway is awarded to industrial research and experimental development. Support for industrial research is primarily allocated to relevance-driven knowledge development in the form of knowledge-building projects at the Research Council, and also includes the Council's Centres for Environment-friendly Energy Research (FME) scheme. Experimental development is encompassed under the Research Council's funding for innovation projects. Here, the business sector is in the driver's seat and public funding instruments are designed to reduce risk.

The mapping study of public R&D funding reveals that there are fewer projects with public funding in the testing and demonstration phase. This curve applies to most of the technology areas, with a few exceptions. The study shows a low level of activity regarding market introduction. There are several possible explanations for this:

- There may be lack of project initiatives. Enova points out that it has funding available for allocation, but there are not enough good projects.
- The business sector may experience too many obstacles to obtaining funding, for example that the percentage of state aid is lower than anticipated.
- There may be a lack of access to private capital among the industry actors. The figures above are composite figures for all of the technology areas. The need for risk-mitigating support from the authorities will vary from technology to technology and market to market.
- Not all research, development or demonstration projects involve the public research and innovation system. A number of projects are carried out without public funding.

The Energi21 board has not assessed what would constitute the proper balance for this curve profile. Such an analysis must be based on the curves for each individual technology, not a collective average.

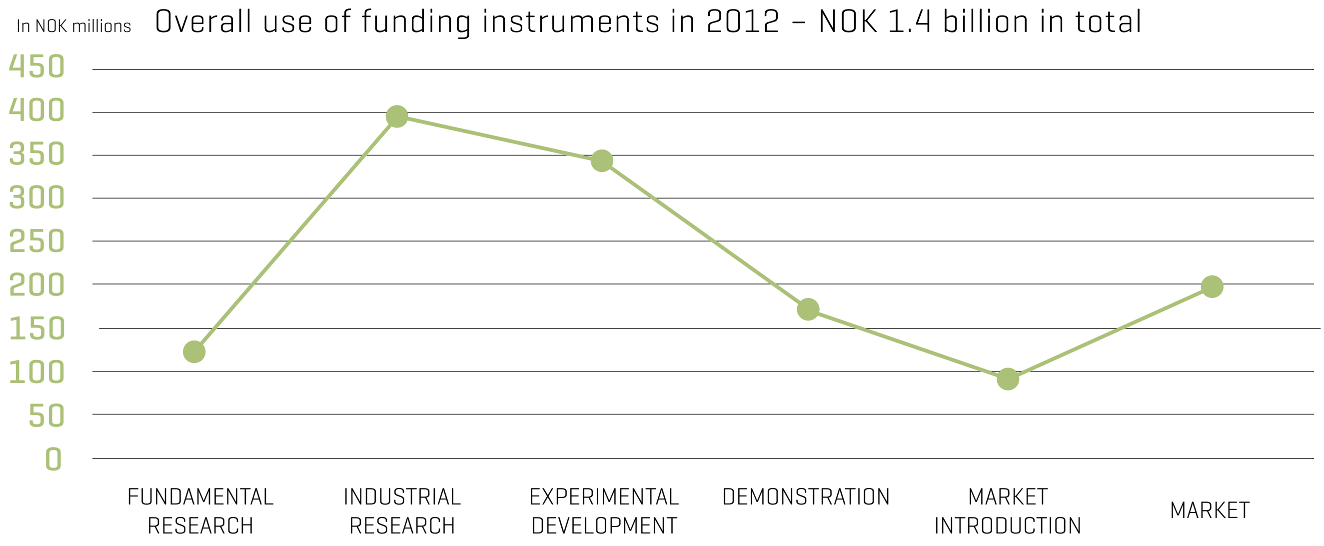


Figure 14 Distribution of overall public funding in 2012 along the innovation axis. Support for renewable energy production via the Norwegian-Swedish electricity certificate market is included here, with NOK 30.2 million for new capacity in Norway in 2012 (0.9% of the certificate payments) and the remaining NOK 3 231 million for new capacity in Sweden. Support for TCM is not included here.

4.5

Gap between research and the market

The need for instruments varies along the innovation axis, as does the need for private capital. Several of the priority focus areas set out in the Energi21 strategy encompass technologies in the testing and demonstration phase. This is a capital-intensive phase in which a long-term, venture capital investment policy is needed to put together sufficient financing. Ensuring adequate public and private funding for projects that have reached the testing and demonstration phase is currently a challenge. Testing and demonstration activities are often critical to qualifying technologies and services for a specific market.

For certain technologies, there is a need to close the gap between research and development on the one hand and instruments for market introduction on the other. Capital is needed – both via public funding instruments and in the form of private industry funding – to finance the step up to the next phase.

Seed capital is needed to establish new companies and value creation on the basis of research results. A certain amount of seed capital may be found in the private market, but in many cases it is inadequate or inaccessible. Achieving the ambitions of creating new green industrial growth and laying the foundation for a robust industrial structure in the long term will require seed capital to facilitate the further development of today's ideas and solutions

4.6

Testing and demonstration activities in the international arena

Many technology areas have an international market, where investment and construction of facilities are taking place outside Norway. This is where the markets and opportunities lie. This poses a challenge for a number of actors.

Offshore wind power is a technology area in which there is a demand for testing and demonstration facilities. Such facilities are essential tools for qualifying technology products for market access. The market for offshore wind power is an international one, and the major power plants are being installed on continental shelves other than Norway's. In the area of CCS, cooperation has been established between various pilot testing facilities around the world under the auspices of TCM. The European Carbon dioxide Capture and Storage Laboratory Infrastructure (ECCSEL) was established to make optimal use of infrastructure in the EU.

There is a need to clarify how the public research and innovation system can help Norwegian actors to access and take part in international testing and demonstration activities. It may seem paradoxical that the main reason for funding research and development is to cultivate a Norwegian business sector that can compete in the international arena. At the same time, there are talented actors that have successfully completed their research and are ready to take the next step, but cannot take full advantage of available opportunities due to limitations in the public research and innovation system. This may be a deficiency in the system, and fresh thinking and change may open up new opportunities. See also Part 1, Chapter 5.5.

4.7

Adequate access to relevant competency

Given the rapid pace of technology and market development, new knowledge and capital are crucial to gaining a market position and ensuring adequate recruitment. Companies must employ highly knowledgeable professionals to remain at the forefront of their field and successfully meet tomorrow's challenges. While the industrial sector itself is responsible for long-term competence-building and recruitment to industrial activities, the public sector is responsible for ensuring that there are excellent educational institutions that can train candidates and serve as relevant, expert research partners for the industrial sector. Recruitment is a genuine problem in certain segments of the energy industry, and competition for personnel with the proper competencies is tough.

In addition to theoretical knowledge, the industry is looking for practical operational knowledge and experience. For a number of companies, specialist knowledge is essential for efficient operation of their facilities. The average age of employees in the land-based segment of the energy industry is high, and these employees will have to be replaced by competent personnel. Norway has good universities and university colleges in the energy sector. It is important that these institutions help to equip their graduates with an extensive, up-to-date, industry-relevant knowledge portfolio upon entering working life. Cooperation between the business sector, research communities and educational institutions is essential to ensuring the training of professionals with high, relevant competence. Industry participation will promote the integration of practical and theoretical knowledge and the development of forward-looking, market-oriented expertise.

In addition to strong research and educational institutions, it is also important to market and generate interest in mathematics, natural science and technology at early educational levels. This will create a foundation for subsequent choice of profession and decision to study technology disciplines. The business sector can play a role here by establishing a presence in and collaborating with schools. There are currently a number of productive measures and initiatives of this type.

Energy companies stress that there will be a particular need for engineers and skilled workers in hydropower in the years ahead.

4.8

Innovation capacity and willingness to engage in research-based activities

Industry-led initiatives and industry participation in R&D and demonstration projects are critical to the implementation of the strategy's recommendations. All phases along the innovation axis 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 capacity of the commercial actors involved, but the industrial sector itself must generate concepts and identify relevant research topics as well as provide the largest proportion of funding.

Innovation capacity and willingness to engage in research-based activities is vital for success, and varies according to the industrial actors' technology and market areas. The attitudes of commercial actors 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 capacity is influenced by a number of factors, including financial resources, regulatory frameworks and other operational framework conditions. The realisation of 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 and the creation of innovation arenas and active industrial clusters.

4.9

Obstacles to R&D activity

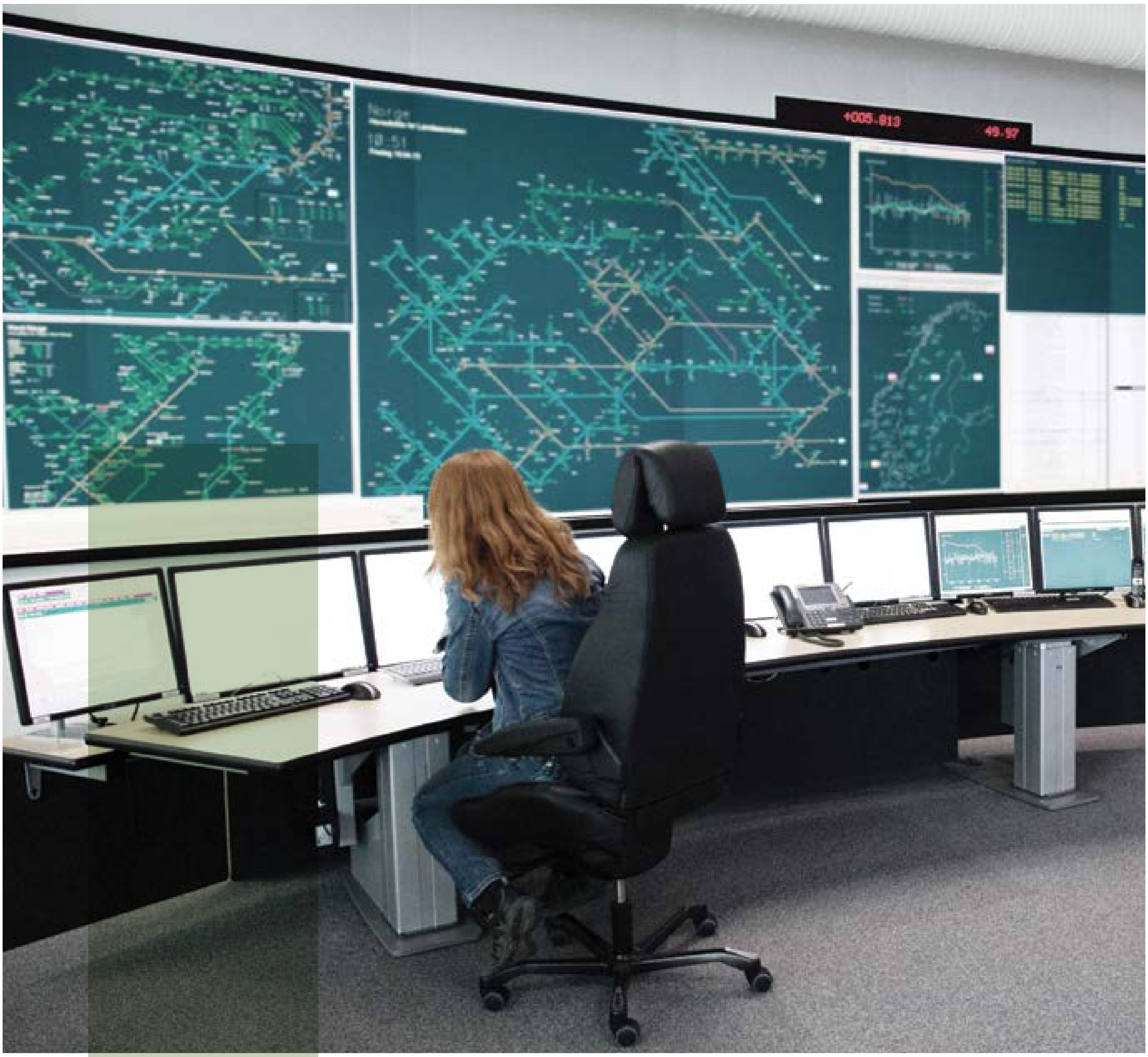
Despite the fact that technology and knowledge development is vital for industrial activities and value creation, there are obstacles that impede trade and industry's commitment to R&D and to establishing and carrying out R&D activity.

Based on dialogue with research and industry stakeholders, the Energi21 board has identified a number of obstacles to research activity in national and international arenas. A selection of these is presented below in no particular order, and represents only a sample of the input submitted by the stakeholders in connection with the Energi21 strategy:

- Unclear market prospects and unreliable framework conditions;
- High risk and difficult access to capital;
- Lack of innovation capacity and willingness on the part of technology users;
- Day-to-day operating activities take precedence over research activities because time, resources and access to personnel are genuine challenges;
- Investment strategies are dominated by short-term focus on risk and profitability;
- Demanding ownership and requirements regarding returns;
- Low energy prices and cost-intensive projects;
- Difficult situation with regard to time and resources and lack of personnel;
- Lack of motivation for change in an already smoothly functioning energy system;
- Lack of competent capital.

The industry itself is responsible for surmounting the obstacles to research activity and commercialising new energy technology. The authorities, however, should facilitate and encourage industry efforts by introducing and using instruments and maintaining favourable framework conditions.

Monitoring, control and steering of the power system. *Photo: Statnett*



Attachments

Attachment 1:

Mandate for and membership of the Energi21 board

MANDATE

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 energy research:

- 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 energy supply by improving coordination of and energy industry participation in research, development, demonstration and commercialisation of new energy technology.

The strategy will also focus on knowledge-building that can help Norway to become a major supplier of environment-friendly energy, system services, knowledge and technology to Europe.

The strategy is to 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 developed 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 assess on an ongoing basis whether the revised strategy should be made more concrete, targeted and action-oriented. The board is also to assess the need to establish working groups in the priority focus areas and follow up the work of any such groups.

The board must remain apprised 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 every two to three years.

THE ENERGI21 BOARD AND ADMINISTRATION

Board members:

Sverre Aam, SINTEF Energi, *Chair*
Anne Jorun Aas, SIGLA
Ragne Hildrum, Statkraft
Jan Ove Gjerde, Statnett
Anna Maria Aursund, Troms Kraft Produksjon
Sigrid Hjørnegård, Energy Norway
Arne Sveen, ABB
Arne Mathias Bredesen, NTNU
Eva Dugstad, IFE
Audhild Kvam, Enova
Svein Eggen, Gassnova
Rune Volla, Research Council of Norway

Observers:

William Christensen, Ministry of Petroleum and Energy
Tore Grunne, Ministry of Petroleum and Energy
Jun Elin Wiik Toutain, NVE

Secretariat/administration:

Lene Mostue, Energi21

Attachment 2:

Working group: Solar power technology

The working group was established by the Energi21 board with the following mandate:

Bidra med strategiske anbefalinger knyttet til:

- The Norwegian solar industry: make-up, technologies and market position;
- Market development for the solar industry and Norway's competitive advantages;
- Current research and education platform;
- The industry's ambitions and goals;
- Drivers of research in the industry and what are deemed to be obstacles to RD&D;
- Strategic technologies for RD&D;
- Necessary measures for goal achievement and realisation of essential RD&D activity.

In addition, a simple survey was conducted among industry stakeholders to establish a broader basis for the assessments of the working group and ensure that the assessments addressed stakeholder needs. The response was good, and the stakeholders have a relatively similar view of market developments.

Ekspertgruppens sammensetning:

Rolf Jarle Aaberg (leder)	EAM Solar
Espen Krogh	Prediktor
Alf Bjørseth	Scatec
Roar Haugland	Scatec Solar
Ragnar Tronstad	Elkem Solar
Ingeborg Kaus	SINTEF
Ole Jakob Sørdalen	Eltek
Timothy Lommasson	Teknova
Erik Stensrud Marstein	IFE/FME Solar United
Vebjørn Bakken	University of Oslo
Tore Helland	Mosaic Solutions
Jon Dugstad	IntPOW
Bjørn Thorud	Multiconsult
Øyvind Nielsen	NorSun
Gabriella Tranell	Norwegian University of Science and Technology (NTNU)

Sekretariat:

Trond Moengen	Energidata Consulting
Lene Mostue	Energi21

The report from the solar power working group (in Norwegian) is available at: www.energi21.no

Attachment 3:

Strategic expert group

In autumn 2013, the Energi21 board established a multidisciplinary expert group comprised of resource persons from the energy industry and research and educational institutions. The make-up of the expert group represents the diversity of industrial structures, and technology and competency areas. The group has made active use of the networks of the individual members in its work and in preparing the documentation.

The mandate for the expert group was primarily to provide fact-based input and a basis for the board's decision-making with regard to strategic priorities and choices for future national focus on RD&D activities.

Members of the strategic expert group:

ABB	Stian Reite
Aker Solutions	Oscar Graff
BKK	Hans Terje Ylvisåker
NTNU	Asgeir Thomasgaard
Goodtech Recovery	Håvard Arvesen
INTPOW	Line Amlund Hagen
Kragerø Energi	Geir Elsebutangen
Norwegian Smartgrid Centre	Grete Coldevin
NTNU	Ånund Killingtveit
SINTEF	Nils A. Røkke
Skanska	Tor Helge Dokka
Statkraft	Erik Høstmark
Statnett	Gerard Doorman
Statoil	Trine Ingebjørg Ulla
Statoil	Olav Kårstad
University of Oslo	Anders Elverhøi

The expert group's deliverables comprised individual memoranda submitted in connection with Energi21 board meetings and as input for the scientific assessments in the strategy document.

Attachment 4:

Glossary

R&D
Research and development (R&D) is any creative systematic activity undertaken in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new applications.
R&D can be divided into three activities:

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.

Applied research is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.

Experimental development is systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, products or devices; to installing new processes, systems and services; or to improving substantially those already produced or installed.

The basic criterion for distinguishing R&D from related activities is the presence in R&D of an appreciable element of novelty and the resolution of scientific and/or technological uncertainty. Source: OECD

Innovation
An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. Innovations are based on the results of new technological developments, new technology combinations, or the use of other knowledge, acquired by the enterprise. There are four types of innovation: product innovation, process innovation, marketing innovation and organisational innovation. Source: OECD

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.

Energy company
A company that delivers electricity, heating or other energy services.

Grid company
A company that owns and operates a power grid or grids for transmission of electrical power, such as a distribution grid and/or regional grid. Regulated monopoly.

Supplier company
A company that delivers equipment and/or services that are part of the value chain for energy production and consumption.

Technology supplier
A company that delivers technology and solutions that are part of the value chain for energy production and consumption.

Technology developer
An actor that develops new or improves existing technology. Actors may be supplier companies, R&D groups at universities and university colleges, or private individuals/entrepreneurs.

Technology user
An actor that procures and uses developed technology.

Horizon 2020
The EU Framework Programme for Research and Innovation for the 2014–20 period. Horizon 2020 is the world's largest research and innovation programme, with a budget of EUR 70 billion over seven years.

FP7
The EU Seventh Framework Programme for Research and Technological Development.

IEA
The International Energy Agency.

IPPC
The Intergovernmental Panel on Climate Change. Established in 1988.

Reservoir
A natural or artificial lake for storing water in periods of high watershed runoff and low consumption. Stored water is used in periods of high consumption.

Reservoir capacity
The total volume of water (m3) that can be stored in a regulating reservoir between the highest regulated water level (HRWL) and the lowest regulated water level (LRWL). Reservoir capacity is also often measured as the amount of electrical energy that can be produced with the stored water.

Balancing power
Balancing power has more than one meaning. From a purely commercial perspective, in today's Nordic power market it represents a specific amount of power in kWh at a specific price. The price varies from hour to hour.

In a more overall perspective, balancing power addresses the need to stabilise the increasingly greater fluctuations that will occur in the power supply with a rising proportion of intermittent renewable power, e.g. wind power.

Power system balancing services
Services that supply output to compensate for intermittent power production by utilising the regulating abilities of hydropower produced from reservoirs.

Energy storage
Also known as energy accumulation. The process of storing energy for later use with the help of mechanical, thermal, electrical or chemical methods.

Energy system
Infrastructure that links together components and systems for energy production, energy transmission and energy consumption.

Energy
Energy is the capacity to do work, and is the product of power and time. Electrical energy is often measured in kilowatt hours (kWh). 1 kWh = 1 000 watt-hours. Other energy is measured in joules (J).

Power balance
The calculation of the balance between power supply and power demand within a given time period. The power balance can also be used to show how power demand can be covered under various conceivable conditions in relation to access to water, exchange of intermittent power, electricity prices, etc.

TRL
Technology Readiness Level. A system for measuring the degree of maturity of a technology or concept. The TRL system consists of nine levels.

SME
Small and medium-sized enterprises. Often used about enterprises with fewer than 100 employees.
Carbon capture and storage
Encompasses the capture, transport and storage of CO_2 along the entire value chain.

Competitive advantage
A nation's advantage in a market in comparison to one or more other countries that can enhance potential to gaining a market position. An advantage may be linked to technology, expertise, resources, industrial experience, etc.

TCM
Technology Centre Mongstad. TCM is the world's largest facility for testing and improving CO_2 capture technologies.

Notes

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