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A collective R&D strategy for the energy sector

Final report

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Preface

This report is the culmination of a process initiated by the Ministry of Petroleum and Energy in the winter of 2007. The aim of Energi21 is to design a broad-based, collective R&D strategy for the energy sector.

The initiative was headed by a strategic committee consisting of committee chair Sverre Gotaas (Statkraft), Morten Røsæg (Hydro), Alexandra Beck Gjørv (StatoilHydro), Wenche Teigland (BKK), Steinar Bysveen (Norwegian Electricity Industry Association (EBL)), Arne Sveen (ABB), Anne-Lise Aukner (Nexans Norway), Monica Havskjold (Xrgia), Petter Støa (SINTEF Energy Research), Bjørg Andresen (Institute for Energy Technology (IFE)), Arne Bredesen (Norwegian University of Science and Technology (NTNU)), Anne Kjersti Fahlvik (Research Council of Norway), Kjell Olav Skjølsvik (Enova) and Halvor Kristian Halvorsen (Norwegian Water Resources and Energy Directorate (NVE)). The Research Council of Norway, represented by Hans Otto Haaland, served as the committee secretariat.

An important principle underlying the Energi21 proposal has been to ensure that all stakeholders in the industry have had the opportunity to participate, and activities were organised with this in mind. In its introductory phase, when the strategic committee was soliciting suggestions as to relevant priority areas, a number of dialogue meetings were held. Input was also encouraged via the Energi21 website. These contributions led to the formation of six targeted sub-committees, each of which prepared a strategy for its specific area. These sub-committees completed a major task in a very short time, and the strategic committee would like to extend special thanks to all those who participated in that part of the process.

Based on the sub-committees' conclusions, a draft report was circulated for review. Roughly 60 responses were received, representing widespread feedback. Based on this other input, the strategic committee prepared its final proposal for an R&D strategy for the energy sector.

The strategic committee would like to thank everyone who, in one way or another, has contributed to this effort and facilitated the realisation of the energy industry's first-ever collective R&D strategy. What remains now is to implement the strategy constructively, in a process that we hope will be just as inclusive and unifying as the process of devising this strategy.

Sverre Gotaas, Statkraft
Chair of the Strategic Committee

1. Core message

The Energi21 initiative was launched by Minister of Petroleum and Energy Odd Roger Enoksen in the winter of 2007 with the aim of designing a broad-based, collective R&D strategy for the energy sector. The mandate for the initiative identified value creation potential, environmental considerations, supply security, and efficient utilisation of energy resources as essential criteria for such a strategy. In addition, importance was to be attached to further developing existing research and industrial expertise.

Energi21 unifies energy stakeholders, for the first time, behind a shared vision and R&D strategy that forms the basis for a collective boost. Although the strategy is built on industry priorities, it also stresses closer collaboration between the authorities, trade and industry and other players in the research arena.

The strategic committee is convinced that this is an ideal time to introduce such a strategy; however, it should be noted that there are three essential elements that must be in place if a collective effort of this nature is to succeed:

- The industry's investments in R&D are based on the belief that they will lead to future profits. Stable, competitive framework conditions are therefore critical.
- Public R&D allocations as well as financial incentives directly aimed at the industry are necessary to increase the pace of R&D activity. The SkatteFUNN tax deduction scheme is one example, and others must be considered.
- Activities must be given priority under a cohesive strategy – which is the core message of this report.

Initiatives in other sectors have shown that a correlation exists between public funding of R&D and investment in R&D by industry. Ratios vary from industry to industry, but for the energy sector the ratio appears to be approximately 1 to 5 (a highly uncertain figure). There is a pronounced time delay after the public funding is allocated until the industry players fully follow suit and can capitalise on the efforts. A key point of the Energi21 collective strategy is to reduce this hold-up and to increase contributions by the industry.

It is difficult to quantify the need for investment in research and development in the energy sector. Given the attention being focused on renewable and environmentally friendly energy, the strategic committee feels that ambitions should seek to be both high and realistic. Reality dictates that allocations must be increased in increments and in concert with enhanced researcher recruitment and improved infrastructure for research and demonstration in the sector.

- The strategic committee suggests doubling the Ministry's R&D contributions in 2009, while the needs from 2010 onward will be much higher. These include public allocations of NOK 400 million per year (excluding funding for CO_2 management and nuclear power), which over time is expected to attract private investment of at least NOK 2.4 billion annually.
- It is not easy to estimate the need for funding for demonstration and commercialisation projects. Experience shows that these types of projects require substantial amounts of funding. An increase in the budgetary framework for R&D therefore carries with it a need for more funding for demonstration projects to ensure the commercialisation of R&D results.
- If Norway is to be considered an attractive country in which to conduct R&D activities, investment must be made in project support, in establishing highly qualified specialised research groups that bring stakeholders together on larger projects, and in infrastructure for research and demonstration. By way of example, there is currently no infrastructure for demonstration and commercialisation projects within ocean energy.

Based on the efforts carried out, the strategic committee has established the following vision for Energi21:

Norway: Europe's energy and environment-conscious nation – from a national energy balance to green energy exports
Norway has the natural resources, community of experts and social framework to become Europe's leading energy and environment-conscious nation, which will in turn make Norway:

- A society with low greenhouse emissions and high energy efficiency;
- A major supplier of environmentally friendly power to Europe;
- A nation whose R&D strategy and industrial policy will attract the world's foremost energy and technology companies.

To achieve this vision, the strategic committee recommends that:

- An **R&D initiative** to be established that focuses on five priority areas, as well as investment across the board in education and basic and applied research.
- Energy research to be strengthened through a **plan of escalating funding** that includes doubling today's allocations over a two-year period.

- Energi21 to **be organised** as a permanent activity with its own board, to ensure that the stakeholders remain involved and committed to realising the Energi21 vision. The industry and the authorities must cooperate closely on the objectives for and organisation of energy research.

The strategic committee proposes to concentrate on five priority areas:

- Research on **efficient use of energy** in buildings, households and industry will be a key component of Energi21. Research in this area will comprise not only technological research and development, but also social science research in areas such as consumer behaviour.
- Given the natural advantages of Norway and the technological and industrial areas in which it excels, initiatives targeting more **climate-friendly power** from hydropower, wind power and solar energy are recommended. Investment in further strengthening the communities involved in solar cell technology is also recommended.
- R&D initiatives relating to **CO_2-neutral heating**, including bioresources, utilisation of heat from surroundings and waste heat. Within bioenergy, initiatives should encompass access to resources, production processes, distribution, and market systems.
- **An energy system to meet the needs of the future**. There are critical challenges in adapting local and regional energy systems to the international power system. Technology, market design and political framework conditions will be important here.
- If the Energi21 objectives are to be achieved, there is a need to enhance knowledge about the impact of **framework conditions** on the industry's investments in R&D and commercialisation of new technology. Knowledge about development trends in Europe and the impact of these on the organisation of R&D initiatives in Norway will be of great value.

This strategy is an instrument that can be applied in Norway's efforts to find solutions to the challenges being posed by global climate change.

The Energi21 process has found that there is great willingness on the part of the stakeholders to commit and contribute to a collective strategy. They are prepared to carry on with this commitment to create a common, binding initiative.

The vision of Energi21

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

Norway has the natural resources, community of experts, and social framework to become Europe's leading energy and environment-conscious nation.

To realise this vision, the strategic committee proposes:

Five priority areas for R&D:

- efficient use of energy
- climate-friendly power
- CO_2-neutral heating
- an energy system to meet the needs of the future
- desirable framework conditions for R&D

Investment across the board in education and basic and applied research

2. Background, mandate and work process

The Energi21 initiative was launched by Minister of Petroleum and Energy Odd Roger Enoksen in the winter of 2007 with the aim of designing a broad-based, collective R&D strategy for the energy sector. The strategic committee has prioritised areas in which R&D investments are essential to achieving results. This means that many important energy technologies and solutions will not be given priority here because research and technological development, in the committee's view, are not the most important factors for achieving desired results.

In devising the strategy, the primary emphasis has been on the potential for value creation. Environmental considerations, supply security, and efficient utilisation of energy resources also represent important guiding principles. Energi21 focuses on the capacity to further refine existing expertise in research and industry, as well as the likelihood that a new initiative will generate the desired earnings – and that R&D is necessary to trigger this.

The Norwegian R&D strategy will not be implemented in a vacuum. Input from other countries, especially the EU, regarding relevant areas of priority has been given due consideration. The strategic committee believes that Norwegian expertise, technology and products will be a valuable contribution in enabling the EU to reaching its ambitious goals.

The strategic committee, consisting of 16 members from industry, the research community and the authorities, was led by Sverre Gotaas, Senior VP of Innovation at Statkraft. During its efforts, the committee emphasised involvement, commitment and transparency. The strategic committee received input from six targeted sub-committees, each of which dealt with specific topics and then presented a report containing its recommendations. A number of dialogue meetings were held with industry and research groups during the process. A draft of the strategy was circulated for review in November, and this report incorporates the key input from that process.

The present report contains the strategic committee's proposal for how Norway can enhance research, technological development and commercialisation of environmentally friendly energy solutions.

3. The vision of Energi21

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

Norway has the natural resources, community of experts and social framework to become Europe's leading energy and environment-conscious nation, which will in turn make Norway:

- A society with low greenhouse emissions and high energy efficiency;
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- A nation whose R&D strategy and industrial policy will attract the world's foremost energy and technology companies.

Realising this vision will require systematic societal and industrial investment in:

- The Norwegian supplier industry and service providers;
- Strong, internationally oriented research institutions;
- Efficient use of energy, and a transition from fossil to environmentally friendly energy;
- Education in basic subjects such as natural science and technology.

Objectives for Energi21

Energi21 is intended to support national objectives in energy policy, environmental policy and industrial policy – and make these cohesive. Commercial forces will be essential in achieving these national objectives.

No specific objectives for the Energi21 strategy as such have yet been proposed, as great effort has been focused on formulating a strategy that industry, researchers and the authorities can all endorse. The coming board (see Chapter 7) is expected to launch efforts to set such objectives.

National objectives

Energi21 will support national objectives by:

- Generating solutions for and knowledge about raising energy efficiency and producing renewable energy that can contribute to reducing emissions of greenhouse gases.
- Generating solutions that make Norwegian companies internationally competitive in climate-friendly power and improved energy efficiency.
- Contributing new knowledge and new technological solutions that enhance supply security through greater variation in energy sources and flexibility in infrastructure.
- Building and further developing expert communities of high international calibre in research and industry.
- Ensuring the recruitment of high-quality specialists by making the sector attractive to students and researchers.

4. National starting point

This section of the report describes key elements in the national basis for the energy sphere. With this as a point of departure, Energi21 seeks to enhance national strengths and deal with challenges.

Exploit Norway's natural advantages

Norway is blessed with unique natural advantages with regard to renewable energy:

- **Water resources** can be utilised through both new constructions and by drawing on the full potential of existing facilities through modernisation and expansion. One challenge here is to use hydropower in concert with other renewable power and with Europe's thermal power.
- Europe's best **wind conditions**. The potential is enormous but somewhat demanding technologically and financially.
- **Ocean energy** also has vast potential. The technology is not yet well developed and its costs can be high.
- **CO_2 storage**. There is a potential for storing large amounts of CO_2 in geologic formations in the North Sea.
- Norway is seeing good growth in **usable biomass**. One challenge is to utilise this in an environmentally friendly way.

Exploit Norway's industrial advantages

- Norway has long experience with and major expertise in hydropower. Today this expertise is primarily operational, which is a strength internationally. One challenge to overcome is that **expertise in constructing hydropower plants** has somewhat atrophied owing to a dearth of national projects in the past 20 years.
- **A functioning power market** that has transparent price determination, well developed and competent institutions, and where price signals reach all consumers.
- Top expertise in **maritime activities and the offshore and process industries**. It is essential to use this competence in efforts to develop climate-friendly energy.
- Norwegian expertise in materials technology has laid the foundation for the country's current position at the forefront of the world's **solar cell** industry.
- Another important Norwegian industrial advantage is technological know-how regarding **power cables**.

Industrial policy challenges

- Compared to the oil and gas sector, the energy sector is perceived as **far less innovative** and as contributing less to value creation through technology development and internationalisation.
- Norway's **industrial policy** framework is not perceived as competitive.
- **Industrial structure** is another challenging point. The major engines are lacking, and most companies'
- shareholders are not primarily concerned with technology development. Some of the heavyweights, such as Statkraft, StatoilHydro and Statnett, and a variety of offshore companies and petroleum companies, are showing interest in new development of climate-friendly energy. Industrial structure also poses a challenge in the context of improving energy efficiency, where results depend on good teamwork between multiple small players from many sectors.
- **Suppliers** are important for innovation and value creation. In the area of electrical power and heating, suppliers are relatively small with scarce resources or are owned by international corporations. In the latter case, it is critical that the business segment located in Norway has corporate responsibility for technology development in its area.

Exploit Norway's advantages in research and education

- Norway has dynamic **research and education communities** within the areas of energy systems, energy production, energy transmission and energy use.
- There are several communities with **high-level expertise** in energy in general, in materials, and in storage of hydrogen.
- In general there is **healthy collaboration** between R&D communities and industry.

Framework conditions

Norwegian framework conditions must be competitive:

- There is a need for correctives to make up for insufficient demand in a national market.
- The framework conditions in other countries may be seen as more desirable.
- Incentives must be devised to promote use of the best technology and knowledge.
- Barriers outside the purely technical obstacles can often play a critical role in hindering success. In the energy use field, for example, such barriers are posed by economic and structural conditions.

5. The strategic committee's recommendations

5.1 A broad-based initiative with clearly identified priorities

Norway is a small nation in a dynamic world. The country must therefore seek initiatives that have a broad reach, to ensure that the strategy will have a firm basis, as well as identify targeted priority areas in order to obtain better results. Implicit in the vision of Norway as Europe's energy and environment-conscious nation entails proposals for:

- An increased, wide-scale commitment to R&D through basic and applied R&D, demonstration of solutions and training of specialists.
- Focus on the following five priority areas: raising energy efficiency, climate-friendly power, CO_2-neutral heating, flexible energy systems, and an energy and industrial policy that is conducive to good framework conditions.
- A doubling of the R&D allocations by the Ministry of Petroleum and Energy for 2009. This entails public investments of NOK 400 million annually [1] (excluding CO_2 management and nuclear power), which over time is expected to attract private investments of at least NOK 2.4 billion annually.
- A strengthening of the national system for demonstration and commercialisation of research findings and spread of new technology (Chapter 6, Recommendations to the stakeholders).
- Establishment of a permanent strategic body for the Energi21 initiative with a board and an organisation for implementing measures with updated strategy plans, as well as ensure involvement and commitments on the part of the stakeholders (Chapter 7, Organising the research).

The objective of the R&D strategy is to increase the focus on – and thereby increase funding for – the priority areas. Certain areas that share an interface with Energi21 are already the object of strong national focus, such as CO_2 management. The recommendations in this report do not include allocat-ions to these areas, since they are expected to be dealt with through other programmes and initiatives.

5.2 Greater, wide-scale focus on R&D

The cornerstone of a Norwegian R&D strategy is wide-scale investment in technological, scientific and social science research. Adequate breadth is essential to achieve sufficient focus on the priority areas. A comprehensive initiative involves giving priority to:

- Educating competent specialists – Norway's most important resource.
- Basic energy research, both technological and societal – Norway's foundation.
- Applied R&D with an eye to bringing the largest possible number of ideas forward to potential concept demonstration – Norway's candidates for success.
- Demonstration of solutions – Norway's winning technologies.

A wide-scale initiative will include fundamental fields such as mathematics, biology, physics, materials technology, chemistry, thermodynamics and more. These are fields of great significance to all energy technologies and will therefore be critical in achieving the objectives of Energi21. An initiative of this type must also encompass energy technologies that may be highly significant in the future but are not yet the subject of great interest in the industry. This applies to hydrogen, geothermal energy, nuclear power safety, and wave and tidal energy, among others.

5.3 Five priority R&D areas

Based on the priorities determined by the contributing sub-committees, the strategic committee has defined five areas of focus for R&D. The individual sub-committee reports are available separately and as a compilation (see appendices).

5.3.1 Improving energy efficiency; towards a low-emissions society

In every international analysis of what it will take to make the transition to a sustainable energy system, the list of measures starts with changing and reducing the use of energy. There is huge potential for reducing consumption by energy users. Experience indicates that measures aimed at the production and infrastructure segments of the value chain probably cannot compete cost-wise with saving kWh among end-users. Energy consumption is a complex area where it is imperative that the authorities employ cohesive instruments. More efficient energy use in accordance with the Energi21 strategy would help to free up valuable electrical energy.

An initiative relating to more efficient energy use may include the following elements:

Efficiency-optimised energy use in buildings and households

It will be necessary to use a broad-based approach that spans from building technology and building processes to control

[1] *This corresponds closely to the Research Council's budget input and the broad-based political agreement on energy reached in the Norwegian Storting. The needs from 2010 and beyond are much higher.*

systems and efficient energy use in buildings. It is especially important to strengthen user-driven research. Activities will need to cover the entire spectrum from short-term to long-term research and commercialisation, including projects related to solutions for energy-plus houses.

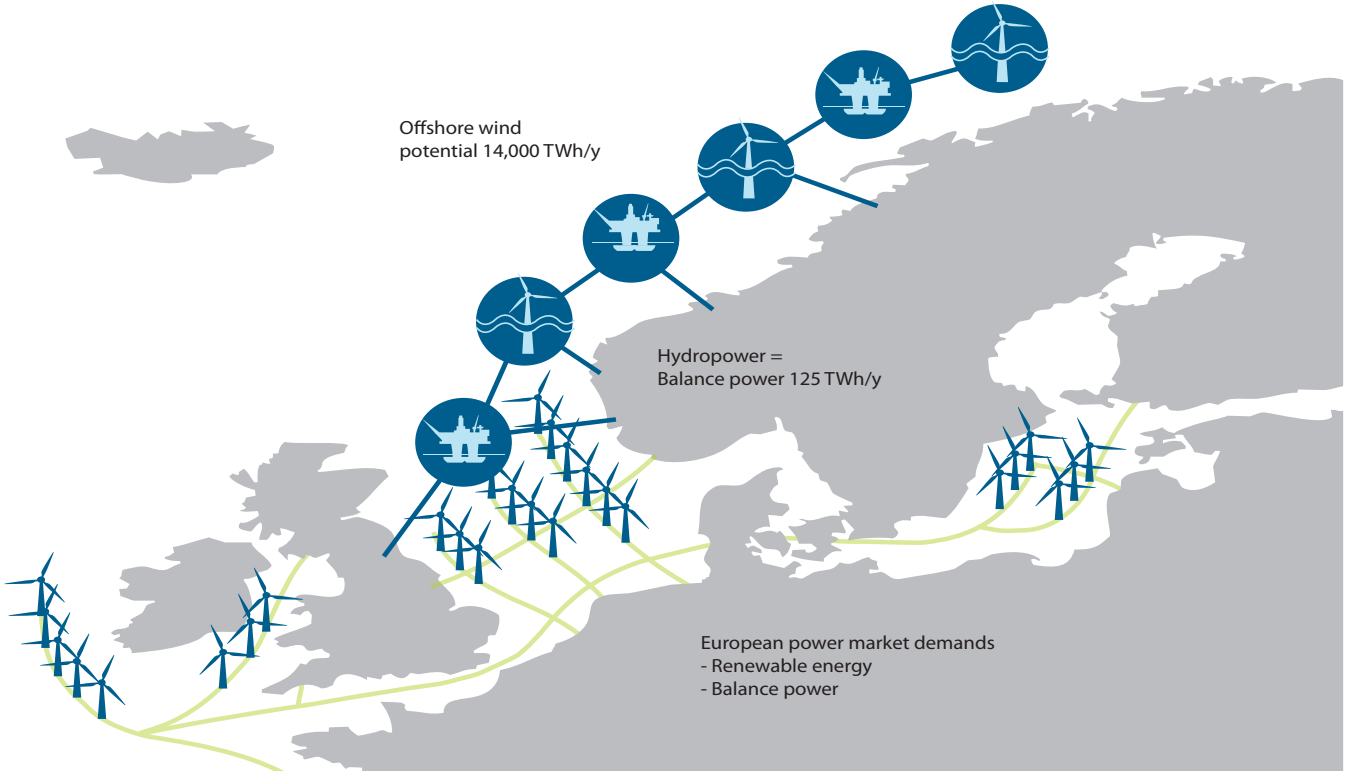
Optimising energy efficiency in the industry
When it comes to the energy industry itself, a wide-ranging approach will also be important. Large potential may be realised through existing technology, while other areas, such as utilisation of process heat for power production, will require substantial R&D efforts.

Knowledge about energy use
There is a need to enhance the pool of knowledge regarding consumer behaviour and energy use as a basis for implementing measures that facilitate consumers' efforts to make use of existing solutions. Included here is knowledge about organisational barriers and life cycle analyses for energy use in buildings and industry. A better statistical base and comprehensive studies of potential are also essential.

5.3.2 More climate-friendly power – from water, wind and sun

In addition to realising the most profitable projects within energy use, it is also vital to exploit new sources of climate-friendly energy. Hydropower and wind power on land are both areas where it is possible to capitalise on existing expertise, and results may thus be anticipated within a relatively short time-frame. Offshore wind power and CO_2 management are areas with a longer-term time perspective. Based on natural advantages and areas in which Norway excels technologically and industrially, the strategic committee recommends the following priorities within climate-friendly power production:

Hydropower
Hydropower will assume a central role in the output of power in the power market of the future, in which climate considerations will necessitate more non-regulatable power production and in which Norway will increasingly interact with the European power market.



Potential is great in Norway for further renewable power production and increased interaction with the European power market. Illustration: Endre Barstad

Norway's hydropower expertise will be of great value internationally – to universities, research institutions, consultants and suppliers, as well as to energy companies that are planning to establish operations abroad. Knowledge needs will include:

- operational and environmental consequences of alternative regulation of production
- market-related and technically optimal solutions for coordination of regulatable and non-regulatable production
- optimal use of water resources and increase in operational efficiency gained by renovating power facilities

Wind power on land

Land-based wind power is a well established, mature market. For Norwegian players, experience from operations on land and in shallow waters is vital for developing wind power production at sea. Key research and development needs in this area are:

- reducing investment and operational costs
- environmental impact of land-based wind power production
- social science research related to energy production as part of regional development

Large-scale offshore wind power

There is enormous potential associated with offshore wind power in Norway. An established competence platform already exists in the scientific disciplines with high basic expertise in industries related to oil, gas, maritime activities and power production. Offshore wind power production, both in deep and shallow waters, has already been identified as an important area of focus for several of Norway's major industrial companies. As is the case with Norwegian offshore technology, there should be significant potential for Norwegian-developed technology and supplier services on the international market. The development of cost-effective solutions for offshore wind power will pose significant challenges, such as:

- regularity, operational costs and access
- establishing the infrastructure for power transmission and hooking up to mainland grids

Solar cell technology

The Norwegian solar cell industry has already generated substantial value creation, and possesses considerable growth potential both in terms of activity in Norway and on the large international market. Expertise in this industry is high, and Norwegian researchers have bold ambitions in this area. Since this is a field in which Norwegian value creation is in high focus, the R&D strategy prioritises those areas considered by the industry to be of the greatest importance in the long term. At present, the procurement of sufficient quantities of pure materials poses the primary challenge. Other research challenges include:

- industry-driven competence-building for next-generation technologies
- new materials, e.g. nanomaterials
- development of products for integration into buildings

5.3.3 CO_2-neutral heating: increased utilisation of bioresources and heat from surroundings

In addition to realising the most profitable projects within energy use, it is also vital to exploit new sources of climate-friendly energy. Environmentally friendly heating solutions can be expected to be constructed in Norway within a relatively short time frame. One challenge lies in finding the most cost-effective solutions.

In the area of bioenergy, there will be a need for long-term activities, related for instance to advanced combustion, as well as for shorter-term activities involving concepts based on existing technology that can be brought to the pilot stage. The heating and refrigeration market is an interesting market in which there are already energy resources, technologies and system solutions that can be applied today. At the same time, there is a need for innovative solutions, in both the medium and long-term.

Bioenergy

There is a need for efforts throughout the entire bioenergy value chain, from collection and storage to heating and refrigeration solutions. The initiative must include:

- refinement of processes from raw materials to fuel, both for waste as well as for forestry and agricultural products
- developing better combustion processes aimed at efficient energy utilisation and environmentally friendly combustion
- developing various technologies that supply combinations of electricity, fuel, heat and refrigeration – from biomass and waste or a combination of these sources
- social scientific aspects of the development of markets for biomass and heating, including problems associated with environmental impact and ethical issues

Distributed heating and refrigeration solutions for buildings
In order to apply new solutions, it is essential to make them simple and cheap. Cost, design and user-friendliness must be a key focus, and system harmony must be given adequate consideration. Here there is a need for innovative thinking and system development.

R&D investments should contribute to assembling different elements into good solutions for meeting the heating and refrigeration needs of various types of buildings. Challenges here include:

- solutions for simple heat pumps and thermal storage systems, super-efficient wood-burning ovens, solar-based heating and refrigeration in conjunction with a heat pump, and cost-effective district heating
- heat for industry, based on utilising process heat, coordination of heat pumps and thermal storage, and bio-based solutions
- efficient energy utilisation from seawater, geothermal heat and other heat from the surrounding environment

5.3.4 An energy system to meet the needs of the future: capacity and flexibility

The vision of Norway as a genuinely low-emissions society and a major supplier of climate-friendly power to Europe is contingent on significant restructuring of both the local and the international energy systems. Better utilisation of local resources, increased international collaboration between national stakeholders, and a large proportion of unregulated renewable power will challenge the level of supply security that Europe enjoys and which is a fundamental condition for value creation and welfare development. It is important to create a framework for realising the enormous potential of wind power along the coastal areas as well as easily regulatable hydropower in such a way that Norway emerges as a strategic partner for Europe in its role as supplier of reliable and renewable energy. The situation today is one in which certain parts of Norway are subject to irregularities in the availability of power, while at the same time demands are rising for the development of solutions that have less environmental impact. Realising an energy system for the 21st century will require R&D in the following areas:

Infrastructure
Needs include: research to advance environmentally friendly technology as well as planning tools to ensure optimal coordination between end use, infrastructure for a greater number of energy carriers, and local energy production/storage. Research is also needed on a subsea transmission grid that facilitates the delivery of climate-friendly power to Europe on a large scale.

Market design
It is important to design a set of commercial rules for the market stakeholders that promote a sound economy. This applies both locally – for better utilisation of resources and teamwork between the producer, infrastructure and end user – as well as internationally, for better utilisation of global resources through greater interaction between nations.

Frameworks and incentives: an attractive R&D nation
Essential in this context are national and international laws, rules and support schemes for developing and monitoring the energy system, including knowledge about the balance between market price supports and regulation.

Research efforts on energy systems will provide the knowledge needed to ensure sound resource utilisation and to draw the benefits from R&D activities in the other areas.

One example of this is the realisation of a North Sea grid for transporting offshore wind energy to Europe that also facilitates the use of hydropower as regulating power, as well as electrification of petroleum activities. Another is the close interaction required between end users, infrastructure, and local suppliers of energy and services.

5.3.5 Frameworks and social analysis

An R&D strategy is a part of something larger. If the strategy is to succeed, it must operate in conjunction with other forces that motivate stakeholders. Players in the market must realise they are well served by investing in R&D and the authorities must provide the framework conditions, research infrastructure and innovation communities that can attract the world's foremost energy and technology companies.

If the objectives of Energi21 are to be reached, it will be necessary to enhance the knowledge base in relation to several key areas, including:

- Knowledge about trends in European energy policy and the impact of this on the targeting of Norway's energy policy and R&D initiatives.
- Knowledge about the framework conditions of various countries and the significance of these conditions in relation to the industry's investment in R&D and for the implementation of new technology and energy-efficient solutions.
- Knowledge about and development of models, instruments and tools that can effectively help to realise the stated energy policy objectives. This includes, among other things, better understanding of the future's supply and demand sides.

6. Recommendations to the stakeholders

The authorities

The success of this R&D strategy and its set of prioritisations will depend completely on productive interaction between public and industry R&D investments and national industrial policy.

In the world of research, international collaboration is essential. If the vision of Energi21 is to be realised, Norwegian researchers must seek knowledge abroad, and international researchers must be encouraged to come to Norway to work. The measures and bureaucracy associated with such activities are comprehensive and would benefit from simplification.

The Research Council of Norway, Innovation Norway and Enova comprise the government's most important tools for promoting research, development and commercialisation. It is essential that these institutions coordinate, streamline and reinforce their instruments for technology development, demonstration and commercialisation.

Regulation of the energy sector must complement the public agencies for innovation instruments if the Energi21 objectives are to be met.

The energy sector has no established infrastructure for testing and demonstration of technological solutions. This applies particularly in the case of ocean energy. It is incumbent on the authorities to ensure that this kind of infrastructure becomes available.

The strategy pinpoints specific priority areas. During the broad-based Energi21 work process, a number of other important areas were identified as being in need of further work. However, these are considered outside the primary scope of Energi21.

These areas include:

CO_2 management

No one doubts the assessment of coal power as the major growth market ahead. Carbon Capture and Storage (CCS) at coal-fired power plants is therefore being given priority internationally. Norway, on the other hand, is giving priority to CO_2 management for gas-fired power. The research aspect of this activity is dealt with by the Research Council while the demonstration aspect is dealt with by Gassnova. CO_2 management of coal power has much in common with corresponding management gas power, so expertise here will be shared. This includes everything to do with the transport and depositing of CO_2, as well as the actual separation of CO_2.

Research challenges in this area include:

Power production featuring CO_2 capture

- Cost reduction of CO_2 capture
- Developing technologies that obviously raise the extraction factor and profitability of power production using CO2 capture

CO_2 storage

- Sound methods for storing CO_2. Gaining acceptance in society for these methods.

Recommendation: The strategic committee, in keeping with its mandate, has not prioritised CO2 management, but has chosen to define these efforts as being outside the sphere of Energi21. The committee asserts that the international market will be in coal power carbon capture and storage, so it is important to apply the Norwegian efforts in gas power to better equip Norwegian players to compete internationally for CO2 management of coal power.

A smoothly functioning European market

To achieve the objectives and vision of Energi21, the energy industry and supplier industry are dependent upon a smoothly functioning energy market in Europe, especially in Northern Europe. Further expansion of the transmission grid, good design of trade regulations, and market design are necessary for growth in the Norwegian energy industry and in keeping with the Energi21 vision.

Recommendation: The Ministry of Petroleum and Energy must work actively to develop and improve the Northern European power market. Stronger efforts should be directed toward the European Commission, Nordel (cooperation agency for Nordic central grid companies) and the Council of European Energy Regulators.

Energy in the transport sector

The strategic committee has not highlighted hydrogen as a prioritised area, due to its view that this technology will not have its greatest significance in the stationary sector. Hydrogen may have a role to play in the transport sector and is therefore dealt with there, in addition to being part of the wide-scale initiative.

Energi21 will primarily have a responsibility for the supply side of energy to the transport sector. Energy use in transport is increasing and mainly involves fossil fuels. This strategy takes into account that converting energy use in transport will require increased supplies of environmentally friendly alternatives such as electricity and biofuels.

This area is discussed in the Government's white paper on climate, among other places.

For hydrogen, a separate strategy and action plan have been implemented, cf. Strategic Hydrogen Council. The Energi21 process dealt with the following topics:
- developing zero-emissions ships
- construction of infrastructure for electric/hybrid and gas/hydrogen supply
- logistics in the areas of transport
- biofuels: problems relating to raw materials
- hydrogen as an energy carrier
- the future will see less distinction between energy sources used for production of power and heat and for transport

Recommendation: the Ministry of Petroleum and Energy should take the initiative vis-à-vis other relevant ministries to ensure that research and framework conditions in the transport sector are viewed in an overall perspective.

Energy use in buildings
Energy use in buildings depends on a number of circumstances, and the responsibility at the government level is shared by several ministries. The public authorities – both state and municipal – should take the lead and use life cycle costs as the basis for all new building in order to encourage the market to adopt energy-efficient solutions.

Recommendation: The Ministry of Petroleum and Energy should take the initiative to promote the utilisation of cohesive government instruments concerning research and framework conditions relating to energy use in buildings. This can be followed up in Energi21 through a dedicated sub-committee.

The strategic committee discussed the issue of thorium fuel and decided not to go into depth on this topic. The committee refers to the Norwegian Thorium Committee, which is to submit its report in February 2008. Any response to that committee's proposals would have to be dealt with by the board of Energi21.

Regardless of the outcome of the thorium fuel issue, the strategic committee emphasises the significance of further investment in groups associated with safety and conduct in nuclear power.

Industry

Reaching the objectives set for the Energi21 strategy – and realising the potential within climate-friendly energy and improved energy efficiency – will require more active participation from industry than has been the case thus far. If teamwork on Energi21 can be achieved as envisioned in this strategy, industry is expected to increase its investment in R&D. A permanent Energi21 should establish clear objectives for what is expected in the way of increased investment from industry and the authorities.

The industrial sector must become more aware of its two roles (below) and must have the courage to try out new solutions (demonstration projects):

- The technology user that can create markets through its demands on suppliers
- The technology supplier that can contribute to creating markets through its tenders

Industry organisations and the larger companies must take active part in Energi21 and make sure to encourage participation of all the players needed, energy companies as well as suppliers, to make it possible to reach the objectives. In energy use it is particularly vital to achieve interaction between the players in building and property management.

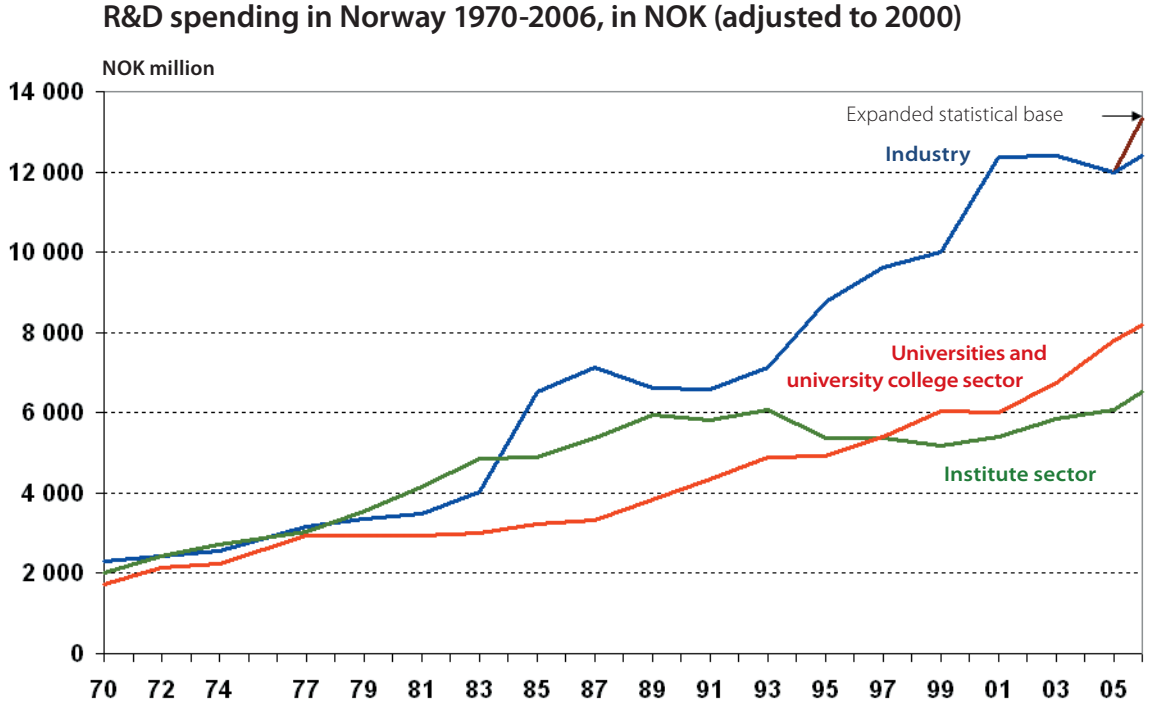
Long-term knowledge-building is necessary within the individual company and in research communities, particularly since technology related to renewable energy and higher energy efficiency will evolve greatly in the next 20 years. Companies and R&D groups will need a competent workforce to meet the challenges of tomorrow. The industry and its organisations are expected to employ direct involvement and financing to help to develop dynamic R&D communities and promote the recruitment of specialists.

Research communities

In this strategy, value creation potential is ranked above breakthroughs in research. The research communities must show commitment and take responsibility for the implementation aspect, e.g. by further developing their already good collaboration with industry.

It is critical to use a cohesive, multi-disciplinary approach when confronting challenges in the field of energy and the environment. It is essential to break down barriers between disciplines; for example, more knowledge about consumption and the way society acts is needed as a basis for work on technological development.

Competing for the top minds will hardly become less important in the future, and research communities and educational institutions must work to ensure that good researchers wish to work in the prioritised fields, and that they will have the opportunity to pursue a career in these areas.



Source: Statistics Norway and NIFU STEP

R&D spending by industry, universities and university colleges, and the institute sector

7. Organising the research

Need for investment in research, technology development, demonstration and commercialisation

The strategy submitted is and must be ambitious, given the great challenges we face. From the small-nation perspective of Norway, demand in the markets will be virtually unlimited; the capacity of the players will be the primary limiting factor for growth opportunities and thus the level of ambition.

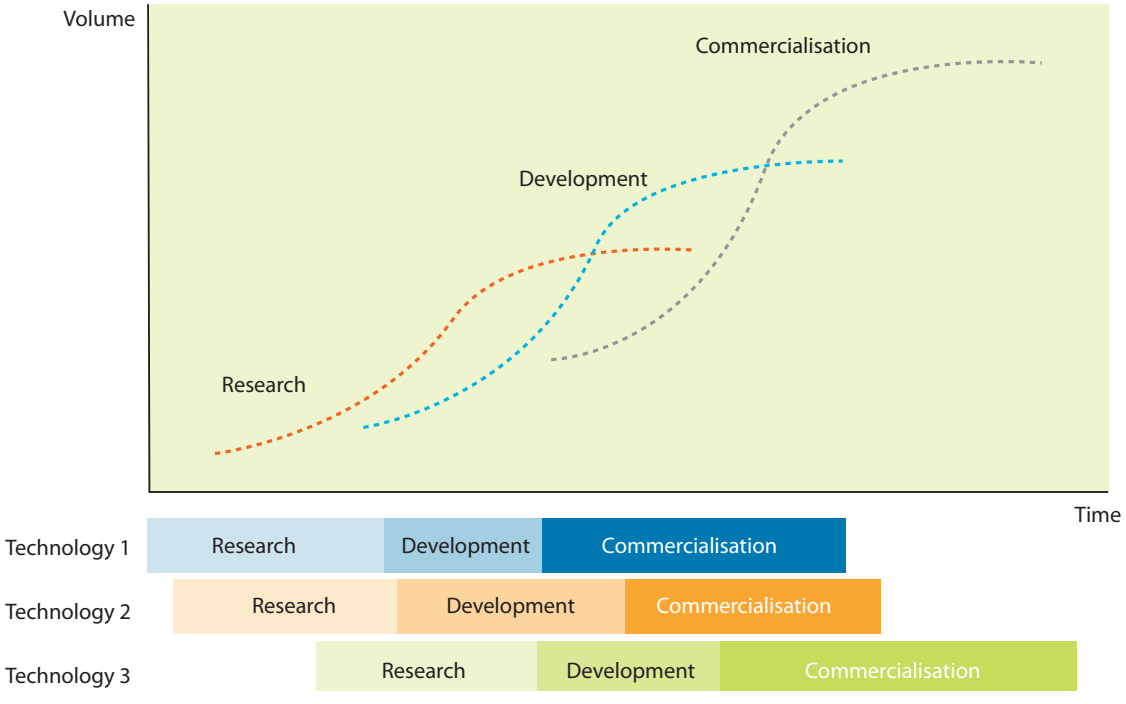
An important criterion for the success of Energi21 is that the collective investments in the industry are increased across the entire value chain, from research to demonstration and commercialisation. In return for contributing with its share of this increase, industry will expect that targeted, predictable support systems to be put in place in order to be able to build up technological communities over time.

Circumstances within the five prioritised areas and the wide-scale initiative are very different, in terms of both maturity of technologies and industrial structure. This makes it necessary to employ different instruments and asymmetrical distribution of funding between basic research, applied research, technology development and demonstration.

R&D investments in the area of environmentally friendly energy totalled roughly NOK 1.4 billion in 2006, of which NOK 1.2 billion was private. Given the attention being focused on renewable and environmentally friendly energy, the strategic committee feels that ambitions should seek to be both high and realistic. Reality dictates that investments must be increased in increments and in concert with enhanced researcher recruitment and improved infrastructure for research and demonstration in the sector. The strategic committee therefore suggests doubling the R&D allocations in 2009 from the Ministry of Petroleum and Energy, while the needs from 2010 onward will be much higher. *This includes public investments of NOK 400 million per year (excluding CO_2 management and nuclear power), which over time are expected to attract private investments of at least NOK 2.4 billion annually.*

Increasingly, successful R&D results are commercialised via technology verification, demonstration and application. The strategic committee, without quantifying, believes that the need for public support for market introduction will be significantly higher than support for pure R&D. Particularly within individual technologies, such as power production, demonstration of new technological solutions will necessarily involve very high costs and require considerable funding.

The dynamics of development from research via development to commercialisation



Different phases require different use of resources, which must be reflected in both the public resources set aside and the industry's own prioritisations.

Stepping up R&D investments as proposed in this strategy will also make it necessary to increase public allocations for demonstration of technologies.

Commercialisation of R&D results, in the form of new technology and new services, requires a combination of industrial development and technological development. Both the investment picture and the use of innovation instruments in this area are complex, and the strategic committee's work did not conclude with clear recommendations for this area.

Instruments – specialised research groups, wide-scale initiatives, R&D infrastructure

The strategy presumes that innovations occur in networks that include research, development and demonstration more or less simultaneously. The iterative process between pilots, demonstration activities and R&D is important in many of the areas proposed by Energi21. This process must be "oiled" to achieve progress in development and ensure business activity along the way towards mature, or fully developed, solutions. For example, innovation instruments which promote "pre-commercial" or early markets are important.

Good infrastructure for research and demonstration will be important. Closer collaboration between private players and all the key public stakeholders will be called for, and the Energi21 strategy will lay the foundation for this through the organisation of centres. This work method involves coordinated, long-term collaboration between the most eminent national research and technology communities within a prioritised field.

Interaction between public stakeholders

The current collaboration between the Research Council (research and technology development), Innovation Norway (innovation and commercialisation), Enova (investment support, market change) and the Norwegian Water Resources and Energy Directorate (NVE) (market design, regulation and public administration) must be developed, particularly within the five prioritised fields. Demonstration projects, for example, require closer cooperation to coordinate research funding, innovation funding and investment resources from the established funding systems administered by the Research Council, Enova and Innovation Norway.

The EU's research programmes are vital for Norwegian stakeholders, both financially and strategically. One important task of Energi21 is to effectively coordinate Norway's prioritisations with those of the EU.

Organising Energi21 as a strategic process

This report describes the first phase of a national strategy. A deeper understanding and more detailed specification of the prioritised areas is needed. The strategy will also need to be updated regularly. An action plan extending over a four-year period will be prepared on the basis of this strategy. A long-term perspective should be laid out for the initiative, and evaluations should be conducted at regular intervals.

The strategic committee recommends the establishment of a strategic board for Energi21 to deal with these tasks. The board will establish working groups for the prioritised areas; the number and organisation of these areas will vary over time. The board will assist in maintaining contacts with other relevant processes such as the Energy Council established by the Minister of Petroleum and Energy.

In a separate submission to the Ministry of Petroleum and Energy, the strategic committee will submit more details pertaining to the organisation, individuals for appointment for a board and an accompanying mandate. The main elements of a proposal will be:

- The primary objective of the strategy is to lay a foundation for the overall coordination of technology development, demonstration and commercialisation so that the stakeholders can come together in a more effective and collaborative network with common goals.
- The establishment of a permanent structure, Energi21, with a board and secretariat responsible for ensuring that the energy sector has an overall strategy for research, development, demonstration and commercialisation.
- The board will consist of representatives of the energy companies, the supplier and services industry, organisations, research and education institutions, and the authorities. Reciprocal representation on the boards of stakeholder representatives will ensure close coordination between Energi21 and the boards that allocate public funding.
- The board, via a secretariat, will be responsible for adding depth to, developing and updating the strategy in a manner that serves to unify the Norwegian energy sector.
- The strategy will pinpoint prioritised technology areas, and the board will establish targeted sub-committees to identify the needs and initiatives within the specific fields. The number and organisation of the priority areas will vary over time.

Implementing the strategy

Energi21 will have no funding instrument of its own to translate the strategy into action. Its usefulness to the stakeholders and the Norwegian energy sector fully depends on its quality of processes and results. Energi21 is to contribute to the prioritisation process, thereby creating a cohesive basis for stakeholders. Implementation will take place as before through the stakeholders.

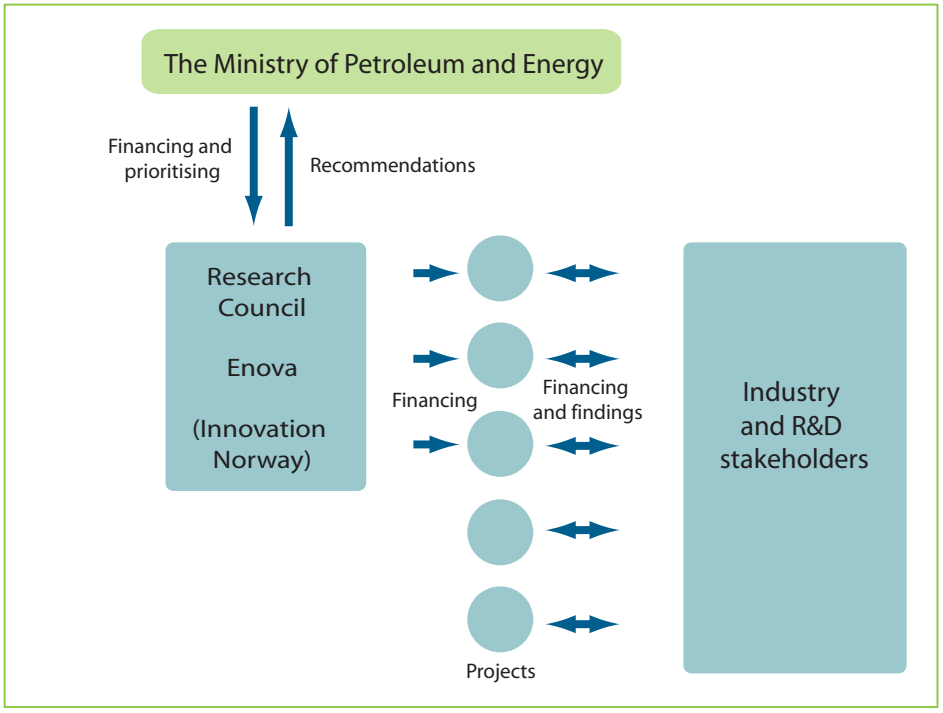


Figure 1: ***Current mode of operation***

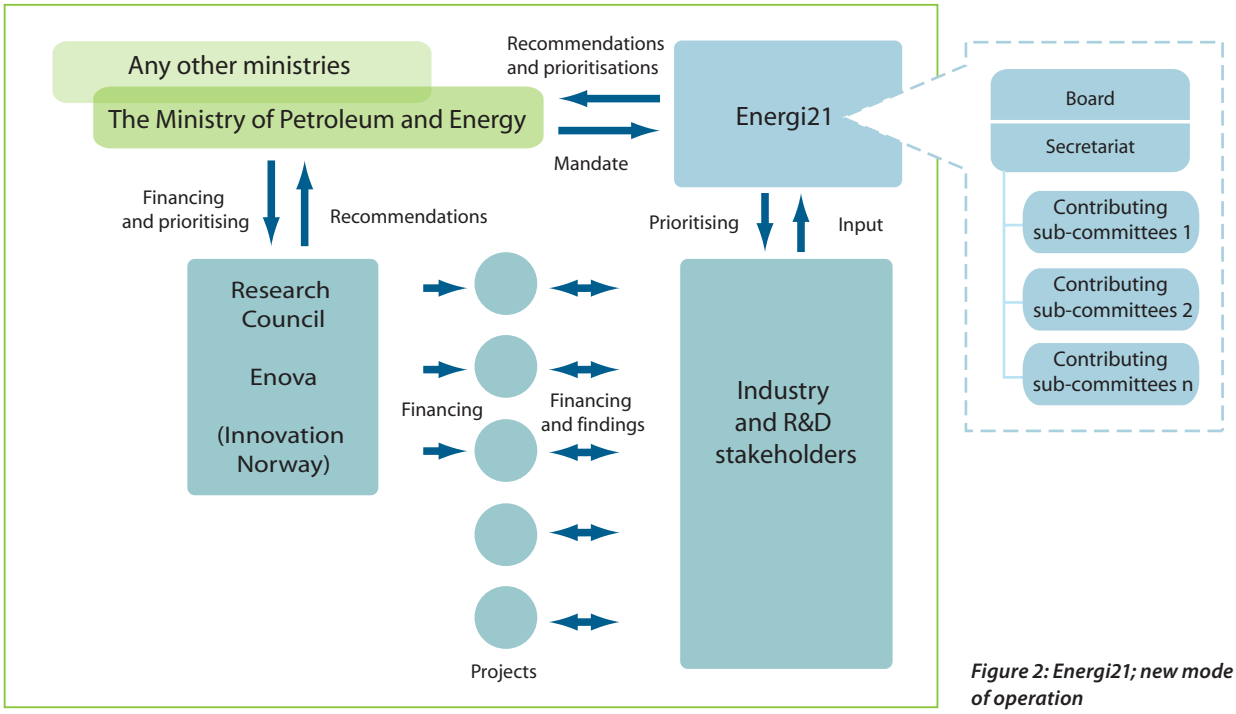


Figure 2: Energi21; new mode of operation

8. APPENDICES

Appendix 1: Priorities recommended by the contributing sub-committees.

See report on www.energi21.no

Area of commitment	Recommended efforts	Short / Medium/ Long-term	Contributing sub-committees
Part 1: Recommended efforts within prioritised areas			
Becoming energy-efficient: towards a low-emissions society	Energy-efficiency improvement in buildings	**S**	**Sub4: Energy use**
	Markets and mysteries: conversion systems, standardisation, consumer behaviour, barriers	**S**	**Sub2: Renewable heat**
	Raising energy efficiency in industry: Process heat, electrification of ships, energy economics, logistics, biofuels	**S**	**Sub4: Energy use**
Moreenvironmentally friendly power	*Hydropower:* Collaborative solutions, upgrades and expansion, nationally and internationally, micropower. Ecologically optimised regulated facilities.	**L**	**Sub1: Renewable power**
	Wind power on land: Operations, environmental impact analysis	**S**	**Sub1: Renewable power**
	Offshore wind: Technology, infrastructure, frameworks	**L**	**Sub1: Renewable power**
	Solar: Industry-driven expertise	**M-L**	**Sub1: Renewable power**
CO_2-neutral heating	Distributed solutions using the IKEA model	**S**	**Sub2: Renewable heat**
	"From woods to warmth – on a large scale": Large-scale electricity and heat	**S**	**Sub2: Renewable heat**
An energy system to meet the needs of the future	A Northern European subsea transmission grid: System design, technology	**L**	**Sub5: Systems**
	European balance market: Market design, systems development, security of supply	**L**	**Sub5: Systems**
	Optimal design of infrastructure for network-bound energy with seamless integration of distributed production	**M**	**Sub5: Systems**
Frameworks and social analysis	Commercial investments need framework conditions for technology development and operations on the same level as in other growth markets for renewable energy in Europe.	**S**	**Sub6: Innovation**
	Greater interest from the market demands greater public funding of R&D and competence building.	**S-M**	**Sub6: Innovation**
	More funding for R&D and demonstration through cooperation between the stakeholders within the framework of an Energi21 strategy	**S**	**Sub6: Innovation**

Table shows all recommended prioritisations from the contributing sub-committees.

Table is continued on next page >

Part 2: Broad initiative for technological, scientific and social research that includes the recommendations below:

Broad initiative	Production of H_2	**L**	**Sub7: Hydrogen**
	Distribution and storage solutions for H_2 system integratio	**L**	**Sub7: Hydrogen**
	Organising nationally	**S**	**Sub7: Hydrogen**
	Wave, osmotic and tidal energy: follow up professional industrial expertise	**M**	**Sub1: Renewable power**
	Bioenergy: supply, increased effectiveness, exploiting Norway's potential	**M**	**Sub1: Renewable power**
	New value creation in gas power: better gas turbines	**S**	**Sub3: Heating energy**
	Efficient co-gen/CHP based on turbines and piston engines	**S**	**Sub3: Heating energy**
	New value creation in electrolysis of radioactive material	**M**	**Sub3: Heating energy**
	New value creation in Thorium fuel cycle and breeder	**L**	**Sub3: Heating energy**
	General framework for security of supply, resource utilisation and energy ethics	**M**	**Sub5: Systems**
	Market design in general framework	**S**	**Sub5: Systems**
	Strategic system analysis: Bioresources, CCS system design	**M**	**Sub5: Systems**
	User-driven, interactive energy systems: System architecture, standard open solutions, local feed-ins	**L**	**Sub5: Systems**
	CO_2 capture Reduce costs of CO_2 capture from gas-fired plants	**M-L**	**Sub8: CCS**
	CO_2-storage Methods for safe storage of CO_2	**M-L**	**Sub8: CCS**
	New value creation in safety and conduct for nuclear plant building and operations	**S**	**Sub3: Heating energy**

Appendix 2: The strategic committee

Sverre Gotaas, leader (Statkraft),
Morten Røsæg (Norsk Hydro),
Alexandra Beck Gjørv (StatoilHydro),
Wenche Teigland (BKK),
Steinar Bysveen (EBL),
Arne Sveen (ABB),
Anne-Lise Aukner (Nexans Norway),
Monica Havskjold (Xrgia),
Petter Støa (SINTEF Energy Research),
Bjørg Andresen (IFE),
Arne Bredesen (NTNU),
Anne Kjersti Fahlvik (Research Council of Norway),
Kjell Olav Skjølsvik (Enova),
Halvor Kristian Halvorsen (NVE).

The Research Council of Norway, represented by
Hans Otto Haaland, served as the committee secretariat.

Appendix report
All the contributing sub-committees' reports can be downloaded (in Norwegian only) at www.energi21.no.

A single report file containing all the sub-reports is also available (in Norwegian).

Notes:

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The aim of Energi21 is to design a broad-based, collective R&D strategy for the energy sector in Norway. The strategy was prepared by a group of 16 persons from industry, research and the authorities. The Research Council of Norway served as secretariat.

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February 2008