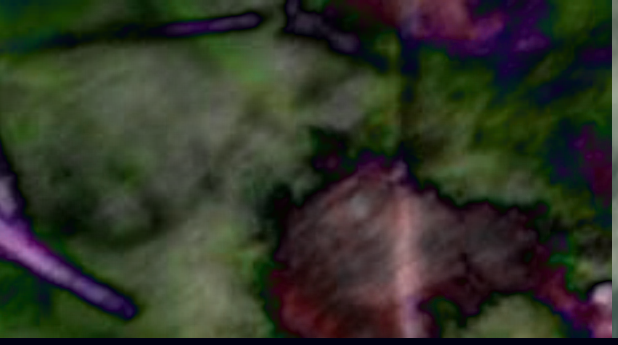
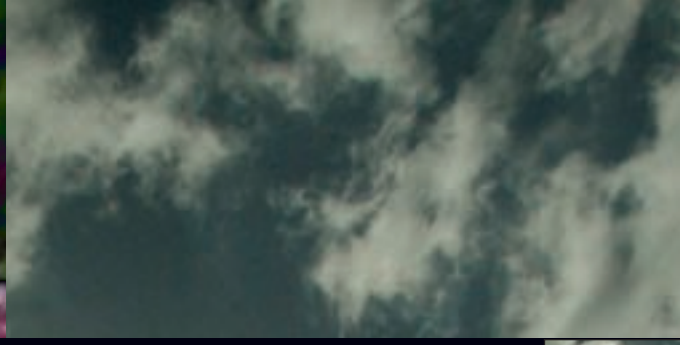
Appendix





Appendix 1: Energy definitions, conversion factors and the theoretical energy content of various fuels

Energy units

Energy is defined as the ability to carry out work.
The basic unit of energy is the joule (J).

1 MJ,	megajoule	=	10^6	J	=	1 million J
1 GJ,	gigajoule	=	10^9	J	=	1 billion J
1 TJ,	terajoule	=	10^{12}	J	=	1 000 billion J
1 PJ,	petajoule	=	10^{15}	J	=	1 million billion J
1 EJ,	exajoule	=	10^{18}	J	=	1 billion billion J

Units of power

Power is energy per time unit.
The basic unit for power is the watt (W), and the following units are used:

1 W,	watt	=	1	J/s		
1 kW,	kilowatt	=	10^3	W	=	1 000 W
1 MW,	megawatt	=	10^3	kW	=	1 000 kW

Sometimes, the following are also used for electrical energy:

1 kWh,	kilowatt-hour	=	10^3	Wh	=	1 000 Wh
1 MWh,	megawatt-hour	=	10^3	kWh	=	1 000 kWh
1 GWh,	gigawatt-hour	=	10^6	kWh	=	1 million kWh
1 TWh,	terawatt-hour	=	10^9	kWh	=	1 billion kWh

PJ is obtained by multiplying TWh by 3.6.

1 MWh is about the amount of electrical energy needed to heat a detached house during one week in winter.

1 TWh is about the amount of electricity used in one year by a town with around 50 000 inhabitants.

Conversion factors and average theoretical energy content of various fuels:

	MJ	kWh	toe	Sm^3 natural gas	barrel of crude oil	cord of firewood
1 MJ, megajoule	1	0,278	0,0000236	0,025	0,000176	0,0000781
1 kWh, kilowatt-hour	3,6	1	0,000085	0,09	0,000635	0,00028
1 toe, tonne oil equivalent	42 300	11 750	1	1190	7,49	3,31
1 Sm^3 natural gas	40	11,11	0,00084	1	0,00629	0,00279
1 barrel of crude oil (159 litres)	5650	1569	0,134	159	1	0,44
1 cord of wood* (2.4 loose m^3)	12800	3556	0,302	359	2,25	1

*Depending on the moisture content.

Appendix 2: Energi21 – R&D strategy for the energy sector

In 2006, the Ministry of Petroleum and Energy initiated work to devise a comprehensive strategy for research and development of technology within the energy sector – Energi21. The main goal of this strategy is to increase value creation by investing in research and development (R&D) and new technology. It will contribute to coordinated, efficient and strengthened research and technology initiatives in the sector, where increased commitment in the energy industry is key. Energy for transport is not included in the strategy. The strategy is the result of close cooperation by the authorities, research institutions and the industry.

The Energi21 strategy covers topics that are relevant for stationary production of energy and the distribution (transport) and use of energy. It covers the entire innovation chain from strategic basic energy research to the introduction of new technology in the market. Relevant social science research is also included. The Research Council's RENERGI (clean energy for the future) programme will be key in following up the strategy, in addition to relevant instruments under Enova.

In February 2007 the Ministry established an industry-headed strategic committee for Energi21 consisting of representatives of energy companies, suppliers, research institutions and the authorities. The strategic committee was tasked with making proposals for an R&D strategy with associated priority areas. The strategic committee has had a close dialogue with a large number of experts from a broad range of players in the energy sector. Based on this the strategic committee prepared a draft strategy presented to the Minister of Petroleum and Energy on 5 February 2008.

Energi21 recommends a combination of wide-scale initiative and a focus on a few selected priority areas. There will be a wide-scale focus on energy research through basic and applied R&D, demonstration of new technologies and training of specialists. In addition, the strategy calls for targeted initiatives in five priority areas:

- Efficient energy use in buildings, households and industry
- Climate-friendly power from water, wind and the sun
- CO_2-neutral heating from bioresources and heat pumps
- Flexible energy systems (including infrastructure, transmission grid)
- framework conditions for research and innovation (energy and business, and industry policy)

In July 2008 the Ministry established an Energi21 board charged with evolving and following up the strategy. This includes the establishment of sub-committees in the priority topic areas in the strategy. The board consists of representatives of energy companies, supplier and service industries, organisations, research and institutions of higher education and authorities. Close coordination between Energi21 and programme boards that appropriate public money (primarily the Research Council's RENERGI programme) is ensured through mutual representation on each other's boards.

Further details about the recommendations of the Energi21 strategic committee

Below follow the recommendations of the strategic committee as presented in their final report: Energi21 – a collective R&D strategy for

Figure 0.1 Final report of the Energi21 strategic committee

the energy sector. In the report, the vision of Energi21 is 'Norway: Europe's leading energy and environment-conscious nation – from a national energy balance to green energy exports'. The strategic committee's entire report can be found at www.energi21.no. The report forms the basis for further work on the strategy.

1. A broad-based initiative with clearly identified priorities

Norway is a small country 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.
- A 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 (excluding CO_2 management and nuclear power), which over time is expected to attract private investments of at least NOK2.4 billion annually.
- A strengthening of the national system for demonstration and commercialisation of research findings and spread of new technology.
- 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.

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 allocations to these areas, since they are expected to be dealt with through other programmes and initiatives.

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.

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).

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 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.

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.

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

Onshore wind power

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

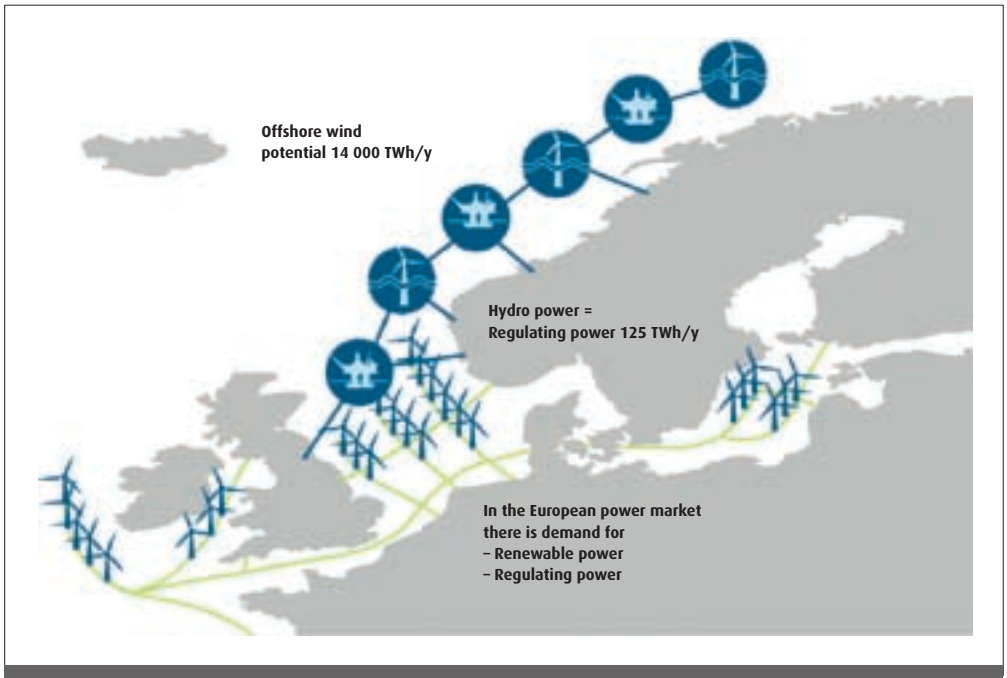


Figure 0.2 Potential is great in Norway for further renewable power production and increased interaction with the European power market.

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

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

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.

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.

Source: Energi21

Appendix 3: Key energy figures 2007

Electricity – Key figures for 2007 (TWh)

	Total	Change from 2006
Average years' production capacity for Norwegian hydropower**	121,8	0,9
Production	137,3	15,6
– Hydropower	134,9	15,1
– Thermal power	1,5	0,3
– Wind power	0,9	0,2
Net import	–10,1	–10,9
– Import	5,3	–4,5
– Export	15,3	6,4
Net consumption	110,8	2,8
– Energy-intensive industry	35,2	0,6
– Pulp and paper	5,7	–0,1
– Mining and other industries	8,8	0,4
– Households, services etc.	61,2	1,9

** Inflow series 1970–1999

Source: Norwegian Water Resources and Energy Diretorate (NVE) and Statistics Norway, Energy balance

Energy – Net domestic end-consumption in 2007 (TWh)

	Total	Coal, coke	Bioenergy	Petroleum products	Gas	Electricity	District heating
Aggregated	**225,0**	**11,7**	**11,5**	**81,1**	**7,2**	**110,8**	**2,6**
Industry	80,1	11,7	4,7	7,6	6,1	49,7	0,3
Energy- intensive	50,4	8,1	0,1	1,7	5,2	35,2	0,1
Pulp and paper	10,4	0,0	3,3	1,3	0,1	5,7	0,0
Mining and other industries	19,3	3,5	1,3	4,6	0,8	8,8	0,2
Households, services, etc.,	83,9	0,0	6,9	13,5	0,6	60,5	2,3
Transport	61,1	0,0	0,0	59,9	0,5	0,6	0,0

Source: Statistics Norway, Energy balance

Appendix 4: Cross-border transmission capacity in the Nordic region (MW)

Appendix 5: Publications from the Energy and Water Resources Department in 2006 and 2007

Propositions to the Storting	
St.prp. nr. 21 (2007–2008)	Om endringar i statsbudsjettet for 2007 m.m. under Olje- og energidepartementet
St.prp. nr. 1 (2007–2008)	FOR BUDGET PERIOD 2008
St.prp. nr. 22 (2006–2007)	Om endringar av løyvingar på statsbudsjettet for 2006 m.m. under Olje- og energidepartementet
St.prp. nr. 1 (2006–2007)	FOR BUDGET PERIOD 2007
St.prp. nr. 82 (2005–2006)	Tiltak for å begrense elektrisitetsbruken i husholdninger
Propositions to the Odelsting	
Ot.prp. nr. 61 (2007–2008)	Om lov om endringer i lov 14. desember 1917 nr. 16 om erverv av vannfall, bergverk og annen fast eiendom m.v. (industrikonsesjonsloven) og i lov 14. desember 1917 nr. 17 om vassdragsreguleringer (vassdragsreguleringsloven) [On the act amending Act no. 16 of 14 December 1917 relating to acquisition of waterfalls, mines and other real property etc. (Industrial Licensing Act) and Act no. 17 of 14 December 1917 concerning the regulation of watercourses (the Watercourse Regulation Act)]
Ot.prp. nr. 61 (2005–2006)	Om lov om endringer i lov 29. juni 1990 nr. 50 om produksjon, omforming, overføring, omsetning, fordeling og bruk av energi m.m. (energiloven) [On the act amending Act no. 50 of 29 June 1990 relating to the generation, conversion, transmission, trading and distribution of energy etc. (Energy Act)]
Reports to the Storting	
St.meld. nr. 11 (2006–2007)	Om støtteordningen for elektrisitetsproduksjon fra fornybare energikilder (fornybar elektrisitet)
Other	
Facts 2006	Energy and water resources in Norway

Appendix 6: Useful Internet addresses

The Ministry of Petroleum and Energy	www.oed.dep.no
The Barents Euro-Arctic Council	www.barentsenergy.org
BASREC	www.cbss.st
CORDIS (the EU R&D Information service)	www.cordis.lu
The Norwegian National Committee on Large Dams (NNCOLD)	www.nve.no/nncold
The Economic Commission for Europe (ECE)	www.unece.org
The International Energy Agency (IEA)	www.iea.org
Energi21	www.energi21.no
The Norwegian Electricity Association EBL	www.ebl.no
The Energy Charter	www.encharter.org
The Swedish Energy Agency	www.energimyndigheten.se
The Danish Energy Agency	www.ens.dk
Enova SF	www.enova.no
RenewableEnergy – information page	www.renewableenergy.no
Enøk i Norge	www.enok.no
Gassnova SF	www.gassnova.no
Directorate-General for Transport and Energy (DG TREN)	http://europa.eu.int/comm/dgs/energy_transport
International Centre for Hydropower	www.ich.no
The Lågdal Museum and the Museum of Water Resources Labro	http://kongsberg.net/laagdalsmuseet
The Ministry of the Environment	www.md.dep.no
Norad	www.norad.no
Nordel	www.nordel.org
Nordic Energy Research (NEFP)	www.nordicenergy.net
The Nordic Council of Ministers	www.norden.org
Nord Pool	www.nordpool.no
The Research Council of Norway	www.forskningsradet.no
Norwegian Water Resources and Energy Directorate	www.nve.no
Norwegian Petroleum Industry Association	www.np.no
OECD Environment Directorate	www.oecd.org/env
Statistics Norway's Focus on Energy pages	www.ssb.no/energi
Statkraft SF	www.statkraft.no
Statnett SF	www.statnett.no