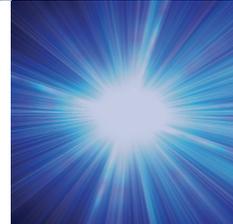


Attachment to the work programme In effect from 2018

Large-scale programme
Energy research – ENERGIX



Large-scale Programmes

The RCN initiative
to meet national
research priorities

Attachment to the work programme

In effect from 2018

**Large-scale programme
Energy Research - ENERGIX**

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Attachment to the ENERGIX work programme. In effect from 2018

Purpose of this attachment

This document is Attachment 1 to the revised version of the work programme (2017) for the ENERGIX programme. This attachment describes in detail the five thematic priority areas outlined in the work programme and how these will help to achieve the five secondary objectives of the ENERGIX programme.

Each thematic area has different needs, depending on technological maturity, current knowledge status, or stakeholders involved. These factors form a basis for selecting the funding instruments to use and the research topics to focus on in funding announcements over the next three years. The thematic descriptions of each area do not constitute prioritisations, but rather establish the qualifying thematic priority areas and frameworks for calls under the programme in coming years.

The text of the calls for proposals published on the ENERGIX programme webpages will stipulate whether there are any special guidelines or priorities for the relevant call. Any such priorities will always lie within the frameworks set out in this attachment.

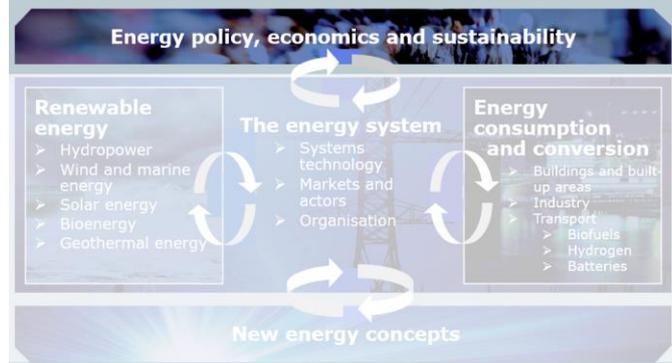
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Energy policy, economics and sustainability

Introduction

This thematic priority area encompasses the production of research-based knowledge about economics, sustainability and behaviour in the energy sector— an important basis for the long-term energy strategies of the authorities and trade and industry.



Research activities are to enhance knowledge and further develop solutions within a number of (research) areas that are closely tied to the technology-oriented areas, and will supplement research conducted under projects in the other thematic areas of the programme. Key research fields are:

- Energy and environmental policy and public instruments in a national and international context. This includes the development of the energy system towards more environment- and climate-friendly energy, as well as energy market analyses in Norway, the Nordic countries and Europe.
- Framework conditions for innovation, industrial and technological development, and restructuring in trade and industry;
- Resource efficiency, including sustainability analyses and life-cycle assessments;
- Trends in energy consumption, technological change and consumer behaviour, as well as in democratic dialogue and existing power structures.

Energy policy, economics and sustainability

Background

Renewable energy and efficient use of energy are important elements of transition strategies towards a more sustainable society. The point of departure for such a transition must be the prevailing economic, industrial, social and cultural conditions. A broad understanding of how societal framework

conditions pose opportunities for, as well as challenges to, change is therefore needed. The research portfolio in this thematic priority area must address these opportunities and challenges.

In the coming period it will be particularly important to achieve results related to:

- operationalising major Norwegian and international energy and climate policy ambitions;
- the knowledge base to design policy to facilitate effective interplay between technology and changes in behaviour to promote sustainable development;
- knowledge about the prerequisites for sustainability and efficiency intrinsic to the greater focus on active energy consumers, smart cities and communities, industrial parks, renewable energy production and interaction between these.

Opportunities and challenges

Research activities in this thematic priority area will help to achieve all five secondary objectives of the ENERGIX programme. The research portfolio in this thematic priority area has been divided into the following four subject areas, which must be viewed in relation to one another:

Policy and economics

There is a need for knowledge about public policy and instruments as a basis for achieving overall energy and environmental policy objectives. This includes studies on how policy and management are manifested in the form of investments and financial instruments (taxes, subsidies, quotas), as well as studies of the statutory framework, directives and standards.

The knowledge base for policy design is dependent on understanding the impact of institutional and political shifts in the national and international arena on developments in Norway. Furthermore, there is a need for knowledge about: Norwegian, Nordic and European energy markets; how to improve governance principles, processes for granting concessions, and cooperation between public agencies and between public and private actors; and, the role of security of supply and other risk factors in this context.

Industrial development, innovation and technology diffusion

A thorough understanding is needed of the characteristics of innovation processes for development and diffusion of energy technologies, and of mechanisms that can improve the ability to exploit Norwegian expertise. The interaction between new technology and environmental, social, cultural and societal factors must also be studied.

Innovation and technology diffusion are often hampered by imperfections in framework conditions, markets, industry structures, etc. Understanding these factors is vital as a basis for designing instruments. There is significant uncertainty and risk related to public and private investment in R&D, demonstration and commercialisation activities in the energy sector. It is important to understand this uncertainty as well as to identify the barriers to a smooth transition between the various phases of the value chain.

Sustainability and resource efficiency

Sustainability and resource efficiency perspectives must be an integral part of all projects within the ENERGIX programme's thematic priority areas. More generic projects and projects aimed at developing this research field will lie within the scope of the thematic priority area "Energy policy, economics and sustainability". Research activities will generate knowledge about resource efficiency, lifecycle

perspectives and sustainability in the interface between local and global climate and environmental challenges.

There is a need for knowledge about the degree to which various individual technologies and/or energy technology mixes are sustainable given the available resource base and their environmental impacts. Topics include resource use and emissions from the energy system and their impacts on biological diversity, ecosystem services, and human health and welfare. There is also a need to shed light on, assess and compare various types of environmental impacts.

Society and behaviour

Society and behaviour encompasses factors that promote and/or prevent the transition to a low-emission society. Among other things, knowledge is needed on the factors that influence the attitudes and actions of the various stakeholders, and how energy consumption changes in relation to social structures and new technology, including cultural change, gender perspectives and more.

A better understanding of the processes of democratic dialogue and public governance and planning is needed as well, as are insights into how existing power structures affect the window of opportunity for change.

Interaction between social science research and technology research

The thematic priority area “Energy policy, economics and sustainability” is closely linked to the technology-oriented thematic priority areas under the ENERGIX programme. In many cases it will be best to carry out social science research as an integral component of technology projects, and interdisciplinary projects of this type are encouraged. Research related to energy markets is a key topic in the thematic priority area “The energy system and markets”, and social science research on this topic is discussed under that area.

The portfolio will be coordinated with the Centres for Environment-friendly Energy Research (FME) within the social sciences and the social science research carried out at the technological FME centres.

Activities and instruments

The portfolio is to include projects that:

- help to generate adequate understanding and knowledge in the four research fields described above;
- involve users to ensure that research results are applied in policy design and by trade and industry and society at large.
- help to build strong social science research groups.
- incorporate international cooperation, particularly on topics that address the larger-scale international integration of energy and market systems.

To achieve the above, funding announcements are planned for:

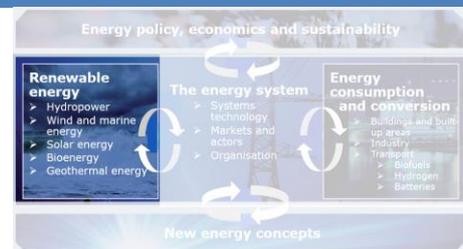
- Innovation Projects and Knowledge-building Projects in all of the above-mentioned subject areas;
- Researcher Projects in selected areas.

In areas where the public sector and the government administration will be the main users of the results, funding may be sought for Knowledge-building Projects with public users as partners. The government administration or public actors may contribute in-kind activity in addition to or in lieu of cash financing.

Renewable energy

Introduction

Sustainable production of renewable energy is a cornerstone of the Norwegian energy system. Fully 96 per cent of Norway's electricity production comes from hydropower, while a growing share of heat production comes from biomass, waste and low-grade energy sources.



In its mandate for the Energi21 board, the Ministry of Petroleum and Energy sets out three objectives for the Energi21 National strategy for research, development, demonstration and commercialisation of new energy technology. The first of these is to *increase value creation on the basis of national energy resources and utilisation of energy*. The ENERGIX programme will encourage research in this area to achieve sustainable utilisation of renewable energy resources in Norway while protecting the natural environment and safeguarding security of supply. Research activities will also promote industrial development in areas where Norwegian actors have competitive advantages and opportunities.

Renewable energy – Hydropower

Background

Norway remains a leader in the planning, development and operation of hydropower plants. While there has been an increase in reinvestments related to upgrading, expansion and maintenance in recent years, the decline in energy prices may bring this activity to a halt. It is vital for Norway to maintain and renew its hydropower expertise through research and development, among other things. Research is essential to developing knowledge for and ensuring recruitment to the hydropower industry, which is a major contributor to value creation and fills a very important role in Norwegian society.

Opportunities and challenges

Research activities in the area of renewable hydropower will play a key role in achieving the ENERGIX programme's objectives of promoting sustainable utilisation of renewable energy resources and strengthening Norwegian trade and industry. Research activities will also enhance Norway's security of supply and promote strong research and educational institutions. To ensure that these objectives are achieved, focus must be placed on the following areas, among others:

- Upgrading and expansion of existing power plants and hydropeaking will have great socioeconomic benefits. There is also potential for power exports and sale of balancing services. This will require the establishment of new markets for such services; see the thematic priority area "The energy system and markets".
- There are major opportunities for suppliers of expertise and equipment to the national and international markets for hydropower equipment and services.
- All regulatory concessions will be subject to revision in the years up to 2022, and the environmental impacts of hydropower are therefore an important research field. Steps should be taken to generate knowledge and solutions that promote environmental design for sustainable and efficient production.

Hydropower is an area with strong commercial interests and it is important to target R&D activities towards industry priorities. This is also in keeping with the recommendations of the Energi21 strategy. An FME centre has been established for hydropower technology, and this covers much of the need for competence development. Development of models and tools for hydrology and production planning should therefore be carried out by means of Innovation Projects.

Activities and instruments

The portfolio is to include projects that:

- support export-oriented trade and industry;
- promote increased, sustainable energy production from new and existing facilities;
- generate greater knowledge about the environmental impacts of and environment-oriented solutions for hydropower;
- generate greater knowledge about the role of hydropower in a balancing power system, either targeted towards Europe or towards increased renewable energy production in Norway.

To achieve the above, funding announcements are planned for:

- Innovation Projects and Knowledge-building Projects on the above-mentioned topics.
 - With regard to R&D on models and tools for weather, hydrology and production planning, priority will be given to Innovation Projects.

Other key activities will include:

- encouraging partners in FME centres to launch Innovation Projects.

Renewable energy – Wind and marine energy

Background

Wind power: Norwegian actors have in-depth expertise in installing and operating offshore installations, which provides a sound basis for further development of an industry targeted towards the international market for offshore wind power. Investment in research activities on offshore wind power in Norway has been substantial in recent years. The development of the international market is the most important driver of Norwegian efforts in this area in the short term. Exploitation of national offshore wind resources lies somewhat further in the future.

Marine energy: This is an immature area and it will take a long time to achieve a commercial market. Development of marine energy technologies will require considerable investment and resources over a period of many years, and there appear to be few actors who have the capacity needed. Lower costs for wind power and solar energy combined with a lack of technological breakthroughs have diminished the energy production companies' interest in marine energy.

Opportunities and challenges

Research activities in the area of renewable wind and marine energy will play a key role in achieving the ENERGIX programme's objective of strengthening Norwegian trade and industry targeted towards global markets. Research activities will also help to reduce global emissions of greenhouse gases.

Norwegian actors have considerable experience in constructing and operating offshore installations. Based on this type of expertise and experience, there are opportunities for Norwegian actors in wind power, particularly as an alternative to the oil and gas market. Offshore wind power is maturing, and

facilities are being constructed in deeper waters. There are still opportunities for Norwegian suppliers to develop and deliver products and services to this segment. Offshore wind power must be made more reliable, and costs must be reduced significantly. These will be the main challenges in the short and medium term. Knowledge-building Projects and Innovation Projects should be used to develop suppliers to the international market.

Land-based wind power is more mature. The challenges here are further cost reductions, more efficient operation and maintenance, and greater knowledge about environmental and social impacts of and solutions for the establishment of wind farms.

Activities and instruments

The portfolio is to include projects that:

- boost the knowledge and innovation capacity of actors that are capable of delivering to an international market. Knowledge-building Projects should focus on competence development for suppliers.
- generate greater knowledge about environmental impacts and solutions.

To achieve the above, funding announcements are planned for:

- Innovation Projects and Knowledge-building Projects on the above-mentioned topics;
- Researcher Projects on environmental impacts and solutions.

Renewable energy – Solar energy

Background

The solar energy industry has grown dramatically over the past 15 years, and this international market will continue to expand. There has been a period of tremendous growth in production capacity (particularly by Chinese actors) and falling prices. This has primarily affected the European and US industries; the majority of Norwegian actors survived and are now in the process of consolidating. The market is large and still expanding rapidly, with opportunities for industrial actors along the entire value chain.

Up to now, the solar energy industry in Norway has primarily centred around the early phases of the value chain. Many of these actors compete with one another, while others are subcontractors. The Norwegian solar energy cluster is made up of technology developers, technology suppliers and technology users. In addition, an entirely new market for solar cells is gradually emerging in Norway, and solar panels are being installed in new and existing buildings. This is being driven by a drop in costs and the introduction of requirements to reduce energy use in buildings. Many new actors are emerging and the contours of entirely new business models in this area are becoming visible. This is the start of what may be a growth period for use of solar cells in Norway.

Opportunities and challenges

Solar energy is a major growth area with an already large-volume international market. Research activities in this area will provide a good basis for achieving the ENERGIX programme's objective of strengthening export-oriented Norwegian trade and industry. Lower prices will lead to rapid growth in the use of solar cells, also in Norway. This in turn will help to achieve sustainable utilisation of national renewable energy resources, reduce emissions of greenhouse gases and safeguard Norway's security of supply.

There is unlimited potential for solar energy, and use of solar energy already represents a major market. Substantial price and cost reductions for solar energy still pose a challenge to the industry in terms of earnings, but at the same time they are stimulating market growth beyond all expectations and projections. Lower prices also make solar energy relevant for many new markets, and facilities are currently being constructed in several places without the help of special grants.

The reality today is that only solar energy and wind power, together with hydropower, can contribute significantly to fulfilling the demand for renewable energy on the scale needed to achieve the targets set. Norwegian actors have a wide range of expertise and are well equipped thanks to the solar cluster that has been built up in Norway. The market volume and growth rate make it possible for these actors to gain a foothold in various segments of the solar value chain. New Norwegian actors are emerging that can combine the knowledge of the cluster with their own specialist expertise, using this to target niches in the solar energy market. Cost reductions in recent years have led to the construction of solar cell facilities in Norway as well. Building-integrated solar energy systems are promising, and will become very relevant in light of coming building regulations requiring all new buildings to be nearly zero-energy by the end of 2020.

Activities and instruments

The portfolio is to include projects that:

- strengthen research groups' expertise in materials for use in solar cells;
- expand the opportunities for utilisation of solar energy in Norway.

To achieve the above, funding announcements are planned for:

- Innovation Projects and Knowledge-building Projects on the above-mentioned topics;
- Researcher Projects on solar cell materials.

Other key activities will include:

- encouraging participation of the new companies emerging in connection with the use of solar energy in Norway;
- encouraging participation of new and existing companies within larger and smaller segments of the solar value chain for manufacturing materials and solar cells and segments farther along the chain;
- strengthening research groups to enable them to serve the Norwegian industry;
- encouraging partners in FME centres to industrialise research of relevance to their own activities.

Renewable energy – Bioenergy

Background

More sustainable biomass and waste can be utilised and processed to provide energy for the stationary sector and for transport. In Norway bioenergy is primarily utilised for heating purposes, so there is a need to develop new solutions for utilising biomass on a wider scale. New pre-processing methods for biomass may facilitate this. There is potential for increased production and better utilisation of bioenergy within the Norwegian energy system, particularly for transport.

It is important to consider the factors of sustainability, efficient utilisation and profitability when utilising bioenergy. Considerations relating to protecting biological diversity, preserving ecosystem

services and maximising net CO₂ uptake and carbon binding over time are of key importance. This will require more knowledge about the potential for sustainable extraction of biomass and waste-to-energy generation. Increased, more cost-effective utilisation of Norwegian bioenergy resources may help to improve management and use, reduce emissions that are harmful to the climate and the environment, enhance security of supply and encourage new biorefining methods.

Opportunities and challenges

Research activities in the area of renewable bioenergy will play a key role in achieving the ENERGIX programme's objectives of promoting sustainable utilisation of national renewable energy resources, reducing emissions of greenhouse gases, and safeguarding Norway's security of supply and flexibility. Research activities will also strengthen Norwegian trade and industry, promote effective collaboration between technology researchers and biology researchers, and foster a dynamic interdisciplinary environment in the field of sustainability.

The increased use of biomass and waste for energy and transport purposes holds great potential in Norway both for better resource utilisation and for effective phasing out of fossil energy. Exploiting this potential will require improvements along the entire value chain, and new solutions for sustainable harvesting and pre-processing, particularly of forest-based biomass, will be vital. Harvesting and logistical solutions for residual raw materials and waste from agriculture, aquaculture, algae and other marine biomass, livestock, households and industry will also play a key role in increasing the use of these resources for energy purposes. Bioenergy may thus promote a more circular economy for social and industrial development in Norway.

Sustainability is pivotal in the management and utilisation of biomass. Research activities must generate fact-based knowledge to determine the level of sustainable extraction. The most pressing challenges are protecting biological diversity, ecosystem services and utilisation, while new biorefining methods represent the greatest opportunity. Although the main focus of the new FME centre Bio4Fuels is on biofuels, the centre also looks at challenges related to resources, climate and the environment that will be of relevance for all increased use of bioenergy.

More extensive and integrated use of biomass, waste and low-grade energy sources may promote the further development of the heating system and better flexibility in the energy system as a whole.

Activities and instruments

The portfolio is to include projects that promote:

- Enhanced value creation by using bioenergy from all forms of sustainable biomass;
- Efficient, sustainable value-chain development, pre-processing and production;
- Knowledge and a basis for decision-making related to climate and environmental impacts;
- Increased and better-integrated energy production from biomass, waste and low-temperature heat sources.

To achieve the above, funding announcements are planned for:

- Innovation Projects and Knowledge-building Projects on all the above-mentioned topics;
- Researcher Projects that address pressing sustainability issues, particularly climate-related issues.

Other key activities will include:

- encouraging increased Norwegian participation in Horizon 2020-funded projects.

Background

There have been significant developments in research and innovation related to reservoirs and drilling in recent decades as access to new oil and gas deposits has become more marginal. Due to its well-developed, innovative petroleum activities, Norway is in a unique position to extract geothermal heat. This has encouraged investment in research and technology development for deep geothermal applications, and national networks between the most central actors have been established. Interest in deep geothermal energy in Europe is growing. A number of new projects have been launched under Horizon 2020, and Norwegian actors are participating in several of these. According to the International Energy Agency (IEA), commercialisation of deep geothermal energy will be critical to achieving the transition from fossil energy production to renewable energy production.

Opportunities and challenges

Research activities in the area of renewable geothermal energy will help to achieve the ENERGIX programme's objective of developing new knowledge, technology and solutions for the international market. Effective collaboration between the research sector and the business sector will enable Norwegian companies to develop competitive specialist expertise for the transition from oil and gas production to deep geothermal energy production, and can help companies to seize opportunities in new energy markets. Together this will also help to increase renewable energy production and reduce global greenhouse gas emissions.

Direct utilisation of geothermal energy in district and local heating may become an export market for Norwegian drilling services in the short term. Norway is a leader in drilling and operating shallow geothermal wells with storage to supply heating to large customers with complex energy needs. R&D needs in this area are addressed under the thematic priority area "Energy consumption and conversion/Buildings and built-up areas" in this work programme.

The potential for deep geothermal energy in the medium term (2030) lies primarily outside Norway. Norwegian companies and research groups are already involved in activities to produce geothermal energy from supercritical fluid near magma chambers, and will be able to contribute to Norwegian exports of materials, drilling equipment and services in the future. Equinor also has ambitions to become an operator in this field, which can further enhance opportunities for Norwegian actors. Norwegian researchers are also involved in experimental deep hard rock drilling, and the potential for energy production from such heat is very great, although the level of risk is currently high.

Activities and instruments

The portfolio is to include projects that promote:

- business-oriented transition from oil and gas production to deep thermal energy production;
- competence development in deep geothermal energy;
- increased export of Norwegian goods and services;
- increased Norwegian participation in important international networks.

To achieve the above, funding announcements are planned for:

- Innovation Projects and Knowledge-building Projects on all of the above-mentioned topics.

Other key activities will include:

- encouraging increased participation of Norwegian researchers under Horizon 2020;
- considering Norwegian participation in the ERA-NET Cofund Geothermica.

The energy system and markets

Background

The energy system comprises infrastructure and marketplaces for the exchange of energy and energy-related services. The future energy system must be able to efficiently accommodate unregulated and distributed energy production with low marginal cost, new energy consumption patterns and rising potential for consequential losses, while at the same time safeguarding security of supply, consumer privacy and ethical considerations. Integration between energy carriers and with other countries will put new demands on technological solutions, system design and flexibility. In addition, more knowledge is needed about stakeholder roles, marketplaces, framework conditions and business models that promote the innovation and dynamics needed to make the energy system the arena for sustainable development that is sought.

At present, the development of Norway's energy system is focused mainly on launching two-way electricity meters, digitalisation, and improving the system technology, although some actors are also in the process of developing better user services. Several countries have now constructed full-scale demonstration facilities for smart energy systems, and initiatives are underway to restructure the system tasks to encourage new and existing actors to increase the pace of innovation and be more active. The EU points to the free flow of energy across national boundaries as a prerequisite for ensuring the effectiveness of sustainability initiatives. In this context, new standards (grid codes) have been approved to improve the exchange of information between transmission and distribution, enhance coordination between production, transmission and consumption, and develop self-regulated microgrids complete with storage, production, user flexibility and coordination of multiple energy carriers.

In light of the main challenges, the thematic priority area of the energy system has been divided into "system technology", "actors, services and markets" and "organisation and regulation".

For a more detailed organisation of the research and innovation challenges, please see:

- ETIP-SNET R&I roadmap 2017-2026, which outlines R&D activities needed for the implementation of the future European energy system according to the EU;
- 2013 SmartGrids Strategic Research Agenda (SRA) 2035, European Technology Platform (ETP) SmartGrids, 2012;
- Norwegian Smart Grid Research Strategy, Norwegian Smartgrid Centre, June 2015.

R&D activities under the thematic priority area of "The energy system and markets" primarily address the ENERGIX programme's objective of safeguarding Norway's security of supply, but also aim to enable integration and efficient utilisation of Norway's renewable energy resources as well as promote industrial development.

System technology

The portfolio is to include projects that promote:

- Sufficient systems knowledge (including environmental and resource knowledge) for cost-effective development and operation of electrical, heating and cooling systems;
- technology and solutions targeting efficient utilisation of resources through increased use of renewable energy, both distributed and centrally produced;
- technology and solutions that facilitate a smarter, sufficiently reliable transmission and distribution system as set out in the SET Plan roadmap, while safeguarding consumer privacy and ethical considerations;
- better transmission solutions that promote sustainable electricity exchange and the exchange of system services with other countries;
- integration of storage solutions for district heating, gaseous energy carriers and underground storage of thermal energy.

To achieve the above, funding announcements are planned for:

- Knowledge-building Projects on areas not covered by the FME Centre for Intelligent Electricity Distribution (CINELDI) or ERA-NET and where there is an important international dimension;
- Innovation Projects to promote Norwegian industrial development and innovation in Norway's energy system.

Other key activities will include:

- coordination with activities at the FME centre CINELDI;
- participation in ERA-NET Smart Grids Plus;
- support for Norwegian applications for Horizon 2020-funded projects.

Markets

Opportunities and challenges

The future energy system will have users with new needs and will involve new actors and more energy services than is currently the case. New energy intensive and power intensive applications will be implemented; end users may become active suppliers of energy, storage and flexibility; and energy producers may be providing power and balancing services. To address these challenges and take advantage of coming opportunities, Norway needs to build up competence and experience with marketplaces that ensure efficient exchange of energy and energy-related goods and services and support sound business models for the actors.

Activities and instruments

Research activities will promote the development of the services, actors and marketplaces needed for developing, operating and utilising a reliable, renewable energy system.

The portfolio is to include projects that:

- capitalise on the value of hydropower by developing services for flexibility and balancing;
- identify business models that help good, environment-friendly actors to succeed;

- identify, develop and evaluate new energy-related services and market design – locally, nationally and across national boundaries.

To achieve the above, funding announcements are planned for:

- Knowledge-building Projects focused on marketplaces that safeguard efficient exchange of energy and energy-related goods and services and support sound business models for the actors;
- Innovation Projects for developing new services and market solutions.

Other key activities will include:

- participation in ERA-NET Smart Grids Plus and the Temporary Working Group for SET Plan Action 4: “Increase the resilience, security and smartness of the energy system”;
- encouraging greater participation among existing and new actors.

Organisation

Opportunities and challenges:

To enable new actors to develop better services and effective, sustainable business models, it is essential that sector regulation encourages innovation, competition and measures that benefit society, and that this is harmonised across countries.

Activities and instruments:

Research activities will target sector organisation and regulation that encourage innovation and good development projects on the way to the future energy system.

To achieve the above, funding announcements are planned for:

- Knowledge-building Projects targeting sector regulation that promotes innovation and competition between new and existing actors at the local, national and international levels;
- Innovation Projects for developing new actor roles, business models and framework conditions for effective implementation of measures that benefit society;
- Researcher Projects under the thematic priority area of “Energy policy, economics and sustainability”.

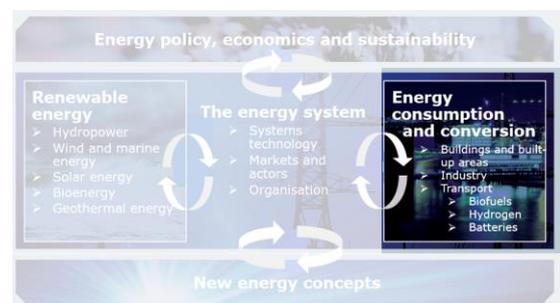
Other key activities will include:

- participation in ERA-NET Smart Grids Plus and the Temporary Working Group for SET Plan Action 4: “Increase the resilience, security and smartness of the energy system”;
- encouraging greater participation among the regulating authorities and industry organisations.

Energy consumption and conversion

Background

Energy consumption and conversion encompasses energy for stationary purposes, e.g. buildings and built-up areas and industry, as well as transport and the technologies of hydrogen, biofuels and batteries. Annually, the construction sector consumes roughly 50 TWh and industry roughly 60 TWh (excluding energy used as raw materials), while transport and other use of motor fuels account for roughly 80 TWh. If we exclude energy consumption in the petroleum sector, this represents some 85 per cent of energy consumption in Norway.



Energy consumption – Buildings and built-up areas

Background

Together, Norwegian residential and commercial/industrial buildings account for roughly a third of the nation's total energy consumption. Norway's total needs for heating and cooling amount to 45–50 TWh. In addition, a significant amount of energy is used for operating fans, lighting, ventilation and other electrical equipment. Each year in Norway, over NOK 160 billion is spent on construction of new buildings and another NOK 70 billion on renovation of existing buildings. To a large extent, the energy efficiency of these investments will influence Norway's energy situation for decades into the future.

The white paper on Norwegian climate policy submitted on 25 April 2012 signalled a tightening of building regulations to passive-house standard in 2015 and close to zero-energy standard by 2020. Revised energy-efficiency requirements of the TEK10 technical building code entered into force in 2016, with a transition schedule of one year. Among other things, the code requires better insulation properties, lower U-values and higher efficiency for heat recovery than previous energy requirements. The code also requires more realistic energy budgets and energy-flexible heating systems for large buildings, while banning fossil fuel use. Certain segments of the industrial sector have high ambitions and began planning and constructing plus-energy buildings in Norway as early as in 2012. These are buildings which in the course of their lifetime will generate more energy than they consume. New breakthrough building solutions will also have to provide a healthy indoor environment and sound functionality, be cost-effective and have a sustainable overall life cycle.

Buildings rarely stand isolated, and a building's energy consumption will be a vital component within the context of its surroundings, or "community", i.e. its connections to nearby buildings and surrounding energy infrastructure. Buildings' surroundings encompass thermal and electric energy supply, including low-temperature heat sources with heat pumps, other infrastructure, utilisation of solar energy, shelter from wind, indoor environment requirements, etc. As plus-energy buildings become more common, issues regarding surplus energy will emerge – how to optimise the utilisation and distribution of surplus energy. These issues are relevant for and must be considered within the context of the local energy system, the transport sector/charging of electric vehicles, and local energy storage. For this reason, the various research areas need to be more closely linked to one another.

Development of built-up areas must not take place at the cost of users' well-being, comfort and mobility or other considerations that must be weighed within the complex context of surroundings. Norway's municipalities are working to realise highly ambitious climate change mitigation and energy consumption plans using public procurement among other things.

Research on development of built-up areas will require a highly interdisciplinary approach in which new knowledge about energy and construction technology must be viewed in the context of societal framework conditions.

The Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN, a Centre for Environment-friendly Energy Research (FME)), will be a central platform for generating new knowledge in this field in the years to come. The ZEN Centre will amass valuable knowledge of the research front and stay up-to-date on any new or changing challenges that research needs to address.

Opportunities and challenges

Research activities in this area of buildings and built-up areas will play a key role in achieving the ENERGIX programme's objective of promoting sustainable utilisation and efficient consumption of Norway's renewable energy resources. This will help to reduce Norwegian emissions of greenhouse gases and enhance the flexibility of local energy systems. Good coordination between research environments, trade and industry and the public sector will be essential in this context, and will strengthen innovation in trade and industry and the public sector.

Activities and instruments

The portfolio is to include projects that:

- Develop new solutions for realising the authorities' ambitions and requirements for energy-efficient new buildings. Solutions must be cost-effective, energy-flexible, user-friendly and well-adapted to individual users and residents' needs.
- Develop new solutions for functional, cost-effective upgrading of existing buildings to higher energy standards.
- Develop solutions for planning, project management and smart operation of cities and communities, with more energy-efficient buildings and flexible energy infrastructure.
- Incorporate an interdisciplinary approach and combine disciplines in new ways. Disciplines within construction, energy and ICT must be linked together more closely. Furthermore, industrial actors, municipalities and research groups need to establish good consortia for partnership.

To achieve the above, funding announcements are planned for:

- Innovation Projects for the Industrial Sector and Innovation Projects for the Public Sector;
- Knowledge-building Projects within generic areas where more knowledge is needed;

- under special circumstances, Researcher Projects on topics in need of a stronger scientific foundation and where user involvement is not desirable.

Other key activities will include:

- encouraging greater participation of actors from the public sector and ICT sector in project consortia;
- Norwegian participation in projects under Horizon 2020 targeted towards urban areas;
- consideration of Norwegian participation in joint calls/ERA-NET Cofund projects targeting technological challenges in urban areas;
- coordination with activities at the FME centre ZEN.

Energy consumption – Industry

Background

In Norway, land-based industry consumes roughly 60 TWh annually, just over one-fourth of the national energy consumption. Some 70 per cent of energy supplied is in the form of electricity. Energy-intensive industry accounts for the majority of energy consumption related to land-based industry. In recent years, total energy consumption by land-based industry has remained relatively stable. Efforts towards more energy-efficient solutions for industry have succeeded in reducing energy consumption per unit produced. There is still significant potential for further energy efficiency measures and the transition to renewable energy sources, but there are a variety of barriers to achieving these, including industry's need for economic returns. Additionally, Norwegian industry tends to be located in sparsely populated areas, which prevents optimal utilisation of waste heat. Nevertheless, the high level of Norwegian expertise coupled with good availability of renewable energy resources could lay the foundation for developing a new energy-refining industry and promote increased value creation based on national energy resources.

Opportunities and challenges

Research activities in the area of “Energy consumption – Industry” will play a key role in achieving the ENERGIX programme’s objectives of reducing emissions of greenhouse gases, achieving sustainable utilisation and efficient consumption of Norway’s renewable energy resources, safeguarding Norway’s security of supply, and strengthening innovation in Norwegian trade and industry. Research activities in this area will also further develop Norwegian research and educational institutions. Taking advantage of these opportunities will require activities targeted towards the challenges yet to be overcome. The opportunities and challenges are described below.

Energy-refining industry produces for a global market. Norwegian industrial production thus represents a kind of “frozen” renewable energy that is suitable for export. The industry also plays a central role as a provider of flexible consumption in the energy system. There are important opportunities and challenges associated with developing:

- more energy-efficient production methods and processes in industry;
- generic and industry-specific processes and solutions for phasing in renewable energy carriers while phasing out fossil fuels;

- improved automation and control systems for achieving major gains in energy efficiency;
- solutions for better utilisation and upgrading of waste heat, including cooling and heating methods;
- energy-efficient industrial clusters.

The FME Centre for an Energy Efficient and Competitive Industry for the Future (HighEFF) will spearhead and consolidate key Norwegian knowledge in these research areas in the years to come. It is important that the activities under the ENERGIX programme and the HighEFF Centre are coordinated nationwide and internationally.

Activities and instruments

The portfolio is to include projects that:

- lead to knowledge and solutions targeting both industry-specific and pan-industrial opportunities and challenges;
- generate new knowledge about how to establish and operate functional, energy-efficient industry clusters.

To achieve the above, funding announcements are planned for:

- Innovation Projects for R&D of an industry-specific nature;
- Knowledge-building Projects for R&D of an industry-specific or pan-industrial nature;
- under special circumstances, Researcher Projects on topics in need of a stronger scientific foundation and where user involvement is not desirable.

Other key activities will include:

- encouraging greater participation of actors from a wide range of Norwegian industry;
- encouraging greater participation of actors in the ICT sector to participate in projects;
- coordination with activities under the FME centre HighEFF;
- consideration of participation in ERA-NET Cofund projects.

Energy consumption in the transport sector – General

Background

The annual consumption of 80 TWh for Norway's transport purposes represents nearly half of the country's total greenhouse gas emissions. Most of this transport relies on fossil fuels. The energy consumption generates extensive local pollution in the form of NO_x, unburnt particles and other substances harmful to health. Despite Norway's relatively high number of rechargeable vehicles, emissions from road traffic increased from 2014 to 2015. The rising energy efficiency of vehicles is still offset by the growing volume of transport.

Opportunities and challenges

Energy consumption in the transport sector will play a key role in achieving the ENERGIX programme's objective of reducing Norwegian and global emissions of greenhouse gases, and is also significant for achieving the other secondary objectives described in the work programme. Achieving greenhouse gas targets quickly and optimally will require a broad-based approach to the priorities described below.

In the Storting's deliberations on the 2016 white paper on energy policy, 12 of the 18 recommendations pertain to transport. This is a strong political signal indicating the need for energy-

system conversion within the transport sector, and thus the need to step up efforts in a number of areas. More research is needed on policy instruments as well as on technological solutions as seen from a transport perspective, an energy perspective and various systems perspectives. Research activities must address all modes of transport (road, rail, sea and air) as well as other sectors with mobile energy needs (fisheries, installations and agriculture). Research must also address energy supply and relevant energy infrastructure as well as energy use from various perspectives, as mentioned above. Technology-oriented research must be integrated with social science research in this area.

In addition to research on the transition to renewable energy carriers such as battery electric, hydrogen and biofuels, it is also important to promote more efficient energy consumption through:

- restructuring towards more energy-efficient modes of transport, e.g. from personal vehicles to cycling, walking and using public transport, and shifting goods transport from road to rail and/or sea;
- raising the efficiency of vehicles and vessels by generating new knowledge about materials, components and technical systems.

Activities and instruments

The portfolio is to include projects that:

- promote energy efficiency in transport work in both passenger-km and tonne-km;

To achieve the above, funding announcements are planned for:

- Innovation Projects and Knowledge-building Projects on technology targeting energy efficiency;
- interdisciplinary Knowledge-building Projects targeting a sustainable transport system with reduced physical transport work – which is also in line with the ambitions of the broad-based political agreement on climate policy achieved in the Storting in 2012 (Klimaforliket);
- under special circumstances, Researcher Projects on topics in need of a stronger scientific foundation and where business-sector involvement is not desirable/possible;
- applied research (Innovation Projects and e.g. joint calls for proposals with Enova and Innovation Norway) to promote Norwegian value creation related to energy restructuring and raising efficiency in the transport sector.

(See also the priority area of “Energy policy, economics and sustainability”.)

Hydrogen

Background

In the span of a few years, hydrogen for fuel cell vehicles has progressed from purely demonstration projects to an early commercial phase. In early 2017 there were a few hundred hydrogen refuelling stations worldwide, five of them in Norway. Rapid expansion of refuelling station availability is taking place, particularly in Japan, South Korea, Germany, France, Denmark and the US (predominantly California). By 2020, according to approved plans, these countries will have roughly 1 000 refuelling stations and nearly 100 000 hydrogen vehicles. Norway has specific plans for at least 20 stations by 2020. Car manufacturers Toyota and Hyundai currently sell hydrogen models, while Honda and Mercedes-Benz have launched models in 2017. In specialised niche markets such as forklifts, over 11 000 hydrogen-powered units have already been sold in the US alone.

Hydrogen/fuel-cell technology may become an important supplement to battery electric systems, particularly for heavy goods transport, long-distance transport and ship transport. There is great interest among Norwegian shipowners and shipbuilders to test out hydrogen-powered ships.

Interest in hydrogen as an energy storage solution has also grown significantly due to large-scale production of solar and wind energy in Germany and other countries.

Norway is home to commercial suppliers of hydrogen-related equipment, especially for electrolysis. Considerable R&D expertise in this area has been developed in Norway over the past decade, including through a number of EU-funded projects. Additionally, Norway has become a demonstration arena for the use of hydrogen vehicles, complete with hydrogen cars, buses and refuelling stations.

The new FME centre Mobility Zero Emission Energy Systems (MoZEES) will be working on zero-emission technology in the transport sector, with a particular focus on maritime applications. Zero-emission technology activities will target propulsion systems based on hydrogen and/or battery electric solutions.

Opportunities and challenges

Research activities in the area of hydrogen will play a key role in achieving the ENERGIX programme's objective of promoting sustainable utilisation and efficient consumption of Norway's renewable energy resources by converting renewable energy to an energy carrier to replace fossil fuels. Using hydrogen for transport will thus reduce greenhouse gas emissions. R&D in this area will also promote new industries and further develop the Norwegian R&D sector.

The main challenge in hydrogen technology lies in reducing costs by increasing volume and minimising the use of expensive materials, etc. There are important opportunities and challenges, including research and knowledge challenges, associated with:

- value creation in Norwegian industry related to the emerging market for hydrogen technology;
- development of infrastructure for production, transport and distribution of hydrogen;
- knowledge and technology advancement for developing more cost-effective solutions;
- export of hydrogen from surplus renewable energy in Norway;
- Norway as an early market for the use of hydrogen in vehicles and the maritime sector.

Activities and instruments

The portfolio is to include projects that promote:

- increased value creation related to production and use of hydrogen, primarily in the transport sector;
- important knowledge for establishing cost-effective value chains for hydrogen in Norway;
- opportunities for large-scale export of hydrogen from Norway.

To achieve the above, funding announcements are planned for:

- Researcher Projects, Knowledge-building Projects and Innovation Projects related to technology development in areas where Norway can become a supplier of equipment;
- Researcher Projects, Knowledge-building Projects and Innovation Projects to generate knowledge about all aspects of hydrogen use, including safety and applications in the maritime sector;
- Knowledge-building Projects and Innovation Projects to promote knowledge for realising hydrogen export from Norway within a 2020–2030 timeframe.

Other key activities will include:

- promoting increased participation by Norwegian R&D groups and companies in the EU Fuel Cells and Hydrogen Joint Undertaking, the IEA hydrogen programme and other international arenas for cooperation;
- encouraging greater participation targeting the maritime sector in particular but also heavy goods transport;
- cooperation with the Norwegian Hydrogen Forum on meeting places and events to promote Norwegian expertise and international cooperation.

Background

Norway has pledged to reduce emissions for transport by 40 per cent by 2030. Roughly half of this reduction is expected to come from phasing in biofuels to replace petrol, diesel and jet fuel. The Norwegian authorities want at least part of this biofuel supply to be produced in Norway and a number of Norwegian industrial actors are investigating the possibility of establishing new production of advanced biofuels. Short and medium-term plans for new processing facilities tend to be connected to existing infrastructure for waste management and for production and industry based on forestry raw materials, and there is substantial potential for raw materials associated with these infrastructures.

In recent years agriculture, aquaculture, industry and the waste management sector have developed wide-ranging expertise in biogas solutions to address major environmental and climate issues. Norway already has demonstration facilities for production, and new biogas facilities are under construction or being planned for supplying liquefied biogas, among other products.

In 2017 the authorities are looking into recommendations for blending 20 per cent biofuels into petrol and diesel. Eight per cent of this is to be biofuels from advanced sources (resources approved as sustainable). This increase is expected to be supported through good instruments for alleviating risk and for building pilot, demonstration and large-scale, “first-of-a-kind” facilities.

Since the broad-based political agreement on climate policy achieved in the Storting in 2009, Norway has been developing interdisciplinary research environments for technology and sustainability. The new FME centre Norwegian Centre for Sustainable Bio-based Fuels and Energy (Bio4Fuels) is providing Norway with a strong platform where the research community, trade and industry and the public administration can cooperate on developing and implementing biofuels.

Opportunities and challenges

Norway, with its abundant national resources, can make a contribution by producing biofuels that reduce greenhouse gas emissions from transport, create jobs, and promote sustainable management for increased, intensified utilisation of biomass. This will require a more interdisciplinary, integrated approach in biological and technological research. This will lay a foundation for new expertise and new companies.

The forestry industry is undergoing major change in Norway and internationally, driven in particular by the market downturn for newsprint and magazine paper. There are, however, major opportunities in biorefining, where Norway possesses strong expertise in processing techniques. To safeguard jobs and value creation in the various segments of the value chain, it is vital to develop new, advanced conversion processes for biofuels. The waste management sector, agriculture, aquaculture and trade and industry are further developing their efforts to utilise waste for biogas and biofuels through R&D and new demonstration facilities. This is important for creating a circular economy in Norway.

Much remains uncertain with a high risk level, however, and there is a need to:

- realise pilot/demonstration facilities taking various technology pathways;
- generate new, profitable forest-based value creation that builds upon advanced processing of biomass;
- achieve optimal compatibility with existing markets and infrastructure for fuels;
- promote efficient, integrated energy refining of waste streams from households, agriculture, aquaculture and industry;
- introduce new biorefining that can produce fuels, chemicals and other products to enhance profitability and sustainability;

- minimise emissions to air and discharges to water, with maximal recycling of important nutrients;
- establish international frameworks and criteria for sustainable utilisation of biomass.

Activities and instruments

The portfolio is to include projects that:

- build cooperation between the ENERGIX programme and the FME centre Bio4Fuels and identify specific measures to generate optimal, shared knowledge about production and use of biofuels;
- develop solutions for using new biomass while increasing the efficiency of biogas facilities;
- promote the establishment of new, profitable pilot and demonstration facilities for biogas and bioethanol;
- promote technological breakthroughs for biodiesel production from forestry raw materials and other lignocelluloses;
- can upgrade pyrolysis oil to marine fuel quality standards.

To achieve the above, funding announcements are planned for:

- Innovation Projects and Knowledge-building Projects towards solutions to the challenges described;
- Researcher Projects that help to advance the knowledge front through strategic international cooperation and that promote new innovation.

Other key activities include:

- encouraging increased Norwegian participation in Horizon 2020-funded projects.

Batteries

Background

The collective market for batteries for electric vehicles, grid balancing and industrial applications is soon expected to surpass the market for batteries for consumer electronics. Globally in 2016, over 1.5 million electric vehicles were sold, more than 100 000 of them in Norway, a quantity that has increased tenfold since the ENERGIX programme was launched. In Norway the maritime industry has begun to use battery power for full or partial electrification of propulsion systems. In addition, comprehensive plans have been announced for implementing battery electric buses in most of Norway's larger urban areas. The markets for stationary, heavy-duty battery applications have grown large and are expanding rapidly.

Lithium-ion batteries are by far the dominant battery type. An important emerging trend is that researchers and producers are continually finding new ways to incorporate more silicon into carbon anodes to boost energy density. Norwegian actors, too, are beginning to make their mark in this area. In addition, extensive R&D efforts are focused on radical new material composites and battery concepts that may increase energy density many times over and further reduce costs. An associated area undergoing strong growth is supercondensators with important new application areas, especially grid balancing.

Norway is home to some pioneering companies, and at least five research institutions are focusing heavily on further expanding their already outstanding expertise in materials and other disciplines relevant for electrochemical energy storage.

The new FME centre MoZEES will be working on zero-emission technology in the transport sector, with a particular focus on maritime applications. Zero-emission technology activities will target propulsion systems based on hydrogen and/or battery electric solutions.

Opportunities and challenges

The battery electric area may be of relevance for all five secondary objectives for ENERGIX, but of all the research areas, the greatest potential is found within transport. Research activities in the area of batteries may also lead to new business activities and reorient activities at Norwegian research and educational institutions towards future challenges. To achieve the programme's objectives quickly and optimally, there are certain areas and topics that must be given a stronger focus. These are described below.

As for most technology areas under the ENERGIX programme, the main challenge for battery-related research is to reduce the costs of the technologies. Important topics for achieving this are:

- energy density
- fire and explosion safety
- materials recycling
- environmental analyses
- charging solutions and associated system effects

The above topics may also partly belong under the thematic priority areas "The energy system and markets" or "Energy policy, economics and sustainability".

Activities and instruments

The portfolio is to include projects that promote:

- new value creation relating to sustainable production of battery materials, cells, modules and systems;
- cost-effective electrification of as much of the transport sector as possible, and new Norwegian value creation associated with this.

To achieve the above, funding announcements are planned for:

- Knowledge-building Projects and Innovation Projects on the above-mentioned topics;
- Researcher Projects targeting new value creation in new structures and materials for batteries.

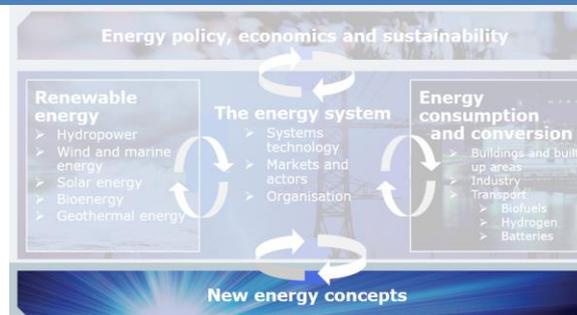
Other key activities will include:

- special mobilisation activities targeting maritime applications, heavy goods transport and public transport;
- special mobilisation activities regarding Norwegian efforts to be an early market for introducing electric vehicles – for promoting development of and laying a foundation for new value creation.

New concepts in the energy sphere

Background

The ENERGIX programme works to encourage R&D projects based on radically new ideas and solutions. These may have their origin in both research groups and companies, and can involve anything from basic scientific research to new ways of putting together existing solutions. The aim is to reduce energy consumption and emissions dramatically, to produce renewable energy with the help of entirely new methods, or to develop radically new solutions for organising and utilising the energy system.



The scope of the programme encompasses development of renewable energy and the management and efficient use of energy in the energy system and in buildings, industry and transport. Under this thematic priority area, the programme seeks to cultivate ground-breaking innovation for the development of entirely new energy concepts and solutions.

The programme will also develop instruments and assessment criteria that will encourage innovation and creative thinking and ensure that research activities are of the highest quality.

Opportunities and challenges

New concepts play an important role in achieving the objective of developing Norwegian research groups and facilitating innovative research on future conditions and development trends that are not yet known.

Relevant funding announcements may be targeted towards:

- New concepts – projects targeted towards finding entirely new ways of solving a challenge.
- Various funding instruments for short-term projects where applicants explore whether an idea has potential.



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