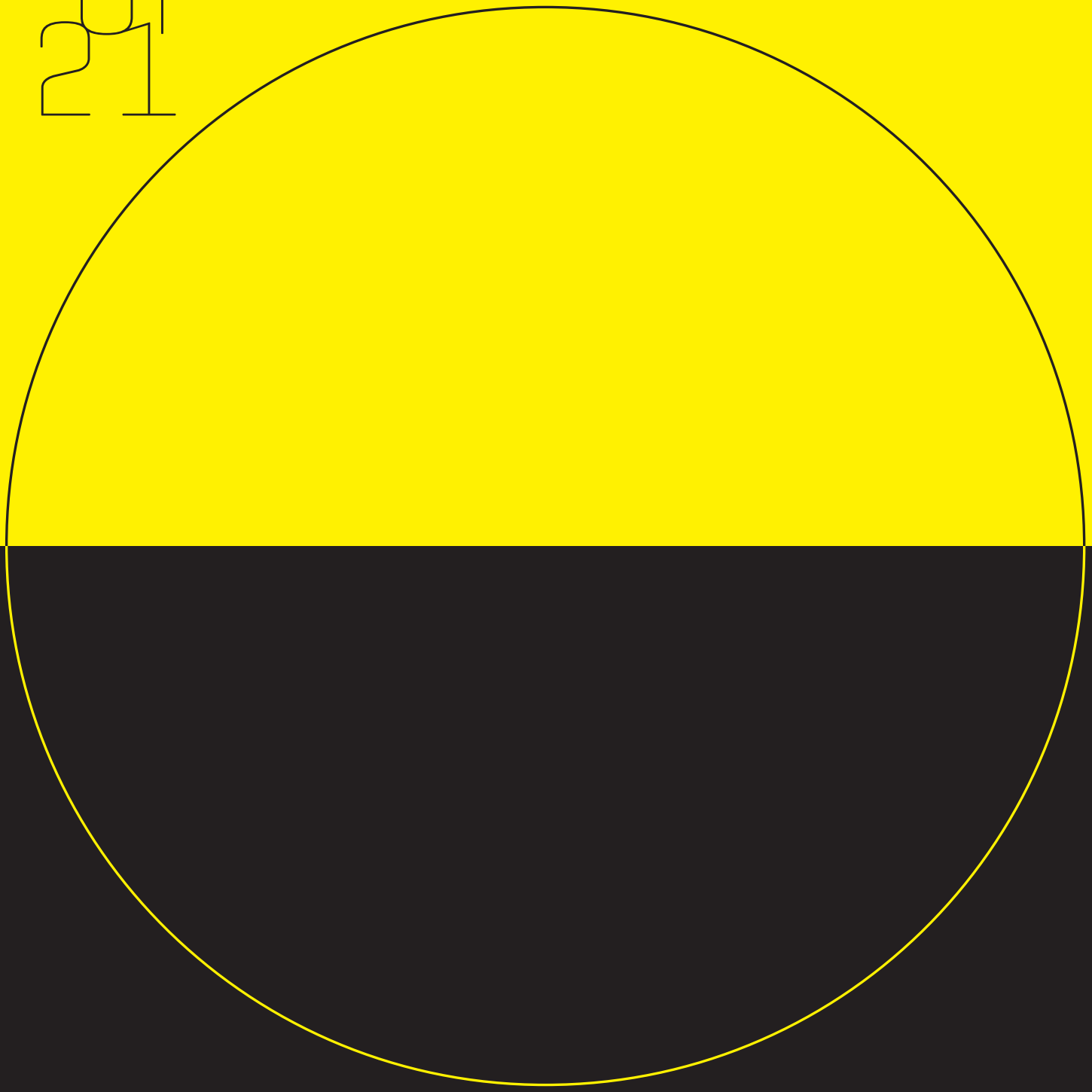
ENERGI 21



Summary Strategy 2022
National strategy for research, development and commercialisation of new climate-friendly energy technology.

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Summary

The Energi21 strategy document is Norway's national strategy for research, development and commercialisation of new climate-friendly energy technology. Its goal is to increase value creation and achieve efficient utilisation of resources in the energy sector by increasing research and innovation. The purpose of Energi21 is to ensure more coordinated and enhanced engagement in the business sector with respect to research, development, demonstration and commercialisation of climate-friendly energy technology for stationary purposes and transport. Energi21 was established by the Ministry of Petroleum and Energy in 2008.

This strategy is the fifth in the series and a revision of the previous strategy drawn up in 2018. The energy sector has undergone radical changes over the past four years. The market and technology are developing at a rapid speed and there is a greater focus on energy transition and industrialisation. As a consequence, energy carriers and sectors of society now need to work closer together.

The business sector is on board and sees value creation opportunities in the energy system of the future

The strategy is based on an extensive body of knowledge. Almost 700 actors from the business sector, research and innovation communities and academia have provided input and actively contributed to developing the strategy. The revision has included an assessment of knowledge and technology needs, the policy instruments needed to realise the industry's ambition in the energy markets of the future, and aims to help develop Norway's energy expertise and technology. The actors in the energy sector have made an incredible and highly valuable contribution, ensuring that the industry is behind common goals and that the research and innovation agenda is relevant to them.

The Energi21 strategy 2022

As an energy nation and with the national and international opportunities the energy system of the future represents, Energi21 has adopted the following vision:

Energi21's vision
Further develop Europe's best energy system

Energi21 believes that Norway can develop an energy system that can contribute both at the national and international level. These contributions may be in the form of renewable and climate-friendly energy, industrialisation and business development, and last, but not least, an energy system with a reliable supply and the right quality.

According to Energi21, there are three main challenges to achieving the goals set out by the Ministry of Petroleum and Energy, and meeting Energi21's vision. The key challenges are:

Key challenges

- Decarbonising transport and industry
- A reliable, competitive and environmentally friendly energy supply
- Developing new green industries and marine energy technologies

Figure 1 Energi21 strategy 2022

Energi21 places great importance on marine energy technologies based on the value creation potential inherent in the ocean and Norway's comparative advantages to win positions in this market.

The revised Energi21 strategy draws attention to focus areas that provide solutions to these three key challenges, given that research and innovation efforts are intensified.

Based on a comprehensive strategic analysis of all the technology and disciplines in the energy sector, Energi21 is prioritising *eight focus areas* in the revised strategy, *two of which are given special attention*. Figure 1 illustrates the Energi21 strategy and its focus areas, and there are links and transfer value between all of the strategy's focus areas.

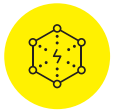
The focus areas *"Integrated and efficient energy systems"* and *"Energy markets and regulation"* are given special attention. There is a strong link between these focus areas. Key research and innovation topics in *"Energy markets and regulation"* have a huge bearing on the implementation and adoption of technologies and solutions developed in the *"Integrated and efficient energy systems"* focus area. These fields are complex and cover numerous disciplines, technologies and solutions. *Integrated and efficient energy systems* are the linchpin of society's green transition.

This focus area is hugely important to supply security in future, the integration of climate-friendly solutions and societal value creation, as well as for securing a sustainable energy supply. The focus area *"Energy markets and regulation"* covers issues relating to social sciences, market design, legal issues and regulation. Energi21 also prioritises the following six focus areas:

- *Hydroelectric power*
- *Offshore wind power*
- *Solar power*
- *Hydrogen*
- *Batteries*
- *Carbon capture and storage*

These are more technology-oriented focus areas that have a great bearing on supply security and flexibility in the energy system. They also play an important role in cutting greenhouse gases in sectors such as transport and industry, developing new industry and the green transition of society. The strategy's focus areas are described in brief in the next pages:

Grid installation at Haraheia. *Photo: Ole Martin Wold*



INTEGRATED AND EFFICIENT ENERGY SYSTEMS

An efficient and integrated energy system is the linchpin of the climate transition and a precondition for a reliable, competitive and environmentally friendly energy supply. Efficient and integrated energy systems are vital to achieving energy and climate policy goals to cut greenhouse gas emissions, boost industrialisation and achieve cost-effective utilisation of our energy resources. The power grid, systems operation and supply security are key challenges that have to be overcome to succeed with the green transition. Research and innovation activities will enable us to develop and apply solutions for a sustainable energy system for the future.

Selected key research and innovation topics

- Efficient and flexible interaction between different energy infrastructures, climate-friendly energy carriers and end users.
- Next-generation components and systems, for interaction between and efficient utilisation of existing and new energy carriers.
- Multidisciplinary analysis models, simulation tools and innovative management systems.
- Digitalisation and cyber security, efficient planning, monitoring, management and coordination across actors.
- Nature and the environment – comprehensive assessments of land utilisation in connection with the development of climate-friendly energy, handling of land-use conflicts and mitigation measures.

ENERGY MARKETS AND REGULATION

This focus area entails developing a framework for action and decisions relating to the timely transition of the energy system. The energy sector must be restructured to achieve climate and environment goals, at the same time that supply security must be safeguarded, costs kept down and unacceptable distributional effects avoided.

Onshore and offshore experience shows that technology adoption can run aground due to a lack of support from stakeholders. Knowledge of policy instruments is therefore important to ensure stakeholder involvement and efficient technology adoption in different markets and in society in general.

Selected key research and innovation topics

- Energy markets, regulation, energy security and energy consumption.
- Business and market models, private and public sector roles.
- Norway as a part of the European energy market – legal and economic topics and simultaneity in decision-making processes.
- Societal development and energy transition – resilience, efficiency, distributional effects and environmental friendliness.

HYDROELECTRIC POWER

Hydroelectric power is the backbone of the Norwegian energy supply and a competitive advantage in the transition to a climate-friendly society. The utilisation of natural water resources for power production is a key precondition for ensuring access to energy and achieving the energy transition in Norway, the Nordic countries and Europe. Hydroelectric power production is vital for ensuring sufficient supply security in the power system.

An R&DI initiative in hydroelectric power contributes to:

- ...a significant proportion of the renewable energy necessary for the electrification of transport and industry.
- ...maintaining a secure power supply through unique regulation capabilities and storage capacity, which will become more important in step with a higher proportion of variable renewable power in the Norwegian, Nordic and European power system.
- ...developing new green industries because hydroelectric power offers a competitive and reliable renewable power supply.

Selected key research and innovation topics:

- The flexible role of hydroelectric power in the national and European power system of the future.
- New technology and upgrading the hydroelectric power system due to changed production patterns.
- Digital technology in hydroelectric power production – combining physical and conceptual models with machine learning and taking advantage of new data sources to provide a better decision-making basis.
- Nature and the environment – environmental design and environmentally adapted hydropeaking, restoring nature in connection with upgrades and developing new plants.
- Climate change and effects on the hydroelectric power system.

OFFSHORE WIND POWER

Norway has natural, world-class offshore wind power resources, and utilising this power is important for securing sufficient renewable power in the energy transition. Major concrete development plans are currently underway for offshore wind power both in Norway and around the world. At the same time, many actors in Norway have ambitions in this area, and there is considerable potential for developing a supplier industry for offshore wind power.

Expertise from the oil and gas industry and the maritime industry shows that Norway is well positioned to take market shares in the offshore wind power market of the future, for both floating and fixed wind turbines. The fact that the offshore wind power industry is moving towards deeper waters, further from shore and investing in bigger and bigger turbines presents new opportunities and research and innovation needs.

An R&DI initiative in offshore wind power contributes to:

- ...the renewable power needed for electrification, for new green industry and for the production of green hydrogen for transport and industry.
- ...considerable potential for exploiting offshore wind resources for power production. Expectations of rapidly falling costs mean that offshore wind power will contribute to a competitive power supply and export of power to Europe.
- ...the development of value chains for marine energy technologies. The development of a Norwegian offshore wind power industry can contribute to new jobs and further value creation for Norwegian suppliers in the maritime and offshore sectors.

Research and innovation needs are related, among other things, to industrialisation and commercialisation of the value chain, integration of offshore wind power plants in the power system and offshore area management. Reducing the costs of offshore wind power is an important goal for research and innovation initiatives.

Selected key research and innovation topics:

- *Offshore wind power plants* – efficient production, installation, operation and maintenance of floating and fixed turbines, methods and technology for cutting costs.
- *Offshore infrastructure and integrated systems* – flexible grids with upscaling opportunities and solutions for system integration and interaction with storage, production and transmission technologies.
- *Market design and legal issues* – design of energy auctions and tenders, and interaction between production onshore and offshore.
- *Environment and society* – methods for investigating and assessing environmental impacts, area and resource management and offshore planning and overall effects.
- *Digitalisation and cyber security* – weather monitoring and prediction models, interaction with the energy system, system security and big data management.

SOLAR POWER

The international solar power market is undergoing strong growth, and Norwegian industry actors in the processing industry have export ambitions based on the development of low-emission materials, by taking advantage of access to competitive renewable power and circular production processes. There is also growth in the domestic market, and research and innovation needs are linked, among other things, to the integration of solar power in the energy system. Norwegian actors are also involved in developing new solutions for floating and building-integrated solar power.

An R&DI initiative in solar power contributes to:

- ...decarbonisation in the form of distributed solutions for power and heat, particularly in areas with a poorly developed grid network.
- ...developing competitive renewable power and heat production, and giving consumers ownership of power and heat production.
- ...further value creation in the Norwegian processing industry targeting a growing solar market that emphasises low-emission materials and developing new concepts such as floating solar power and solar power integrated in infrastructure and buildings.

Selected key research and innovation topics:

- *Solar power in the system and digitalisation* – local solar power and heat solutions, flexibility and storage solutions for solar power and smart control of solar plants.
- *New concepts and technologies* – solar power plants, building-integrated solar power concepts and hybrid power plants.
- *Society and the environment* – framework conditions for local energy solutions, waste management and circular and industrial production.

BATTERIES

Developing and applying electric battery technology is crucial to the decarbonisation of transport, while it also presents an opportunity for developing new green industry. Norway already has an established processing industry based on key battery materials, and is a world-leading manufacturer of battery packs for the maritime sector. Several actors have also implemented plans for large-scale battery cell production. Developing a national battery value chain will require considerable investment in education and competence-building, access to international markets and maintaining Norwegian comparative advantages.

An R&DI initiative in batteries contributes to:

- … decarbonisation of the transport sector.
- … balancing the power grid and reducing peak demand, thereby improving delivery and supply security in a power system marked by growing variable renewable power production.
- … developing new green industry that will generate thousands of jobs in the form of a Norwegian battery value chain based on established processing industry and newly established cell production that takes advantage of competitive renewable power and local access to important raw materials.

Selected key research and innovation topics:

- *Materials and raw materials* – materials and concepts to further develop li-ion batteries to improve their performance and reliability and competitive battery chemistry. Efficient battery cell production – energy-efficient, environmentally friendly, automated production and upscale design.
- *Battery utilisation* – integration in the power grid and adaption of battery properties for different end user applications.
- *Reliability, reuse and recycling* – sorting methods, battery design and materials selection for recycling. Nature and environment impacts in and of battery value chains.
- *Digitalisation* – digital traceability, robotisation and automation throughout the value chain.

Cable installation vessel Nexans Aurora. *Photo: Nexans*

HYDROGEN

Hydrogen plays a vital role in decarbonising the world's energy consumption, and the biggest need is found in the transport and industry segments. Considerable international investments are being made in hydrogen. Norway's biggest export market for natural gas, the EU, assigns hydrogen a key role in achieving the zero-emission goal for 2050. Norwegian industry and energy actors have implemented several large-scale and concrete development plans for producing and using hydrogen and hydrogen carriers such as ammonia.

Key research and innovation needs relate to the development of cost-effective, full-scale value chains and secure handling of hydrogen and ammonia.

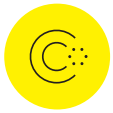
An R&DI initiative in hydrogen contributes to:

- … highlighting key technology for decarbonising industry and transport segments that are incompatible with electrification.
- …developing a reliable energy carrier with transport and storage properties that provides the necessary flexibility, and thus supply security in an emission-free energy system.
- …taking advantage of the great potential for developing new green industries in Norway throughout the value chain, with significant international export potential.

Selected key research and innovation topics:

- Secure use of hydrogen and hydrogen carriers.
- *Further developing cost and energy-efficient hydrogen value chains* – developing technologies and components throughout the value chain from production processes to end user applications. Standardisation of the value chain.
- *Integration of hydrogen value chains in the existing energy system* – interaction between national and international demand and available production resources.
- *Enabling framework conditions for establishing markets* – market design, legislation, regulations and incentive schemes.

There is great potential for CO_2 storage on the NCS, image shows Johan Sverdrup. *Photo: Ole Jørgen Bratland, Equinor*



CARBON CAPTURE AND STORAGE

The world is dependent on large-scale carbon capture and storage to reach the 1.5°C goal, especially sectors without good decarbonation options, and to achieve negative emissions. This focus area covers the capture, transport and permanent storage of carbon. Norway has a unique opportunity to take on a role in this area due to its leading technology and competence base, and its natural advantages.

This technology and competence base, which gives us an advantage over many other countries, has been developed over the course of many years of industrial experience and research in the field linked to the oil and gas, and maritime industries. Our natural advantages for participating in an international carbon capture and storage value chain are the storage potential in the North Sea and proximity to the demand for storage in Europe. Norway's strong global position in carbon capture and storage will be further consolidated when the Longship project becomes a reality in 2024.

Norway also has several ambitious business actors investing in the capture of industrial emissions both nationally and internationally. The main focus going forward will be on upscaling the technology into a commercial value chain by reducing costs and risk, and realising gains from the Longship project.

An R&DI initiative in carbon capture and storage contributes to:

- ...decarbonising industry and transport by capturing and storing carbon emissions from industrial processes and producing low-emission hydrogen.
- ...a reliable and competitive energy supply by increasing access to decarbonised energy resources based on Norwegian gas.
- ...establishing new green industry in Norway with international potential. A Norwegian carbon value chain also provides opportunities for exporting capture, storage and transport technology and increasing value creation for Norwegian suppliers in, among other things, the processing industry and the maritime and offshore sectors.

Selected key research and innovation topics:

- *New technologies and upscaling into a commercial value chain* – upscaling the value chain for storage on a gigatonne scale, efficient capture solutions for existing and new value chains and developing climate-positive solutions such as DACCS and BECCS.
- *Business and market models and frameworks for carbon capture and storage* – developing the market in a Norwegian and European perspective and efficient cooperation constellations between actors. Society and the environment – life-cycle emissions for carbon capture and storage and comparing concepts and application areas, and increasing society's acceptance.

Realising the strategy will require rapid, flexible policy instruments and green risk capital

Energi21 believes that research and innovation initiatives first succeed when new competence and new solutions are applied and used. It is particularly important to develop policy instruments that enable new technology to be commercialised and implemented more quickly, to keep up with the changing pace in the restructuring of the energy system, which is now needed to achieve the climate goals.

The upscaling and industrialisation of climate technology is pivotal to realising Norway's ambitions in the climate technology fields set out in the Energi21 strategy. It is important to establish knowledge of the challenges and opportunities relating to the supply of capital, financing and investor competence. Norway has unique preconditions for building a world-leading green business sector, but a great deal more risk capital is required to establish and lead the development of green value chains. One element of uncertainty if the government is to realise its goal of developing green industry is that the need for green risk capital may exceed its availability. State capital instruments may be a suitable means of raising risk capital and would reduce risk for projects in the Energi21 strategy's focus areas.

Energy research budgets must be increased

The rate of restructuring in energy systems is now much higher than previously. Energi21 therefore believes budgets must be increased to strengthen organisations' and enterprises' work on developing new technologies and solutions in order to bolster competitiveness and the green transition. It is also important to secure long-term knowledge development and further develop national research and education communities.

The business sector should take responsibility for technology leadership

Norway's comparative advantages in energy must be continuously developed in step with resource needs and developments in technology and markets. This will require the business sector, the authorities, and research and education communities to pull together.

The business sector must become involved in developing knowledge and technology by taking a risk and investing time and capital in research and innovation activities. The authorities should take steps to ensure efficient oordination of the ministries' different policy instruments, to enable the business sector to allocate resources to research and innovation projects.

Educational capacity and programmes must reflect the energy system of the future

The extensive restructuring and high level of investment require an increase in educational capacity to meet the needs in the years to come. This applies to every link in the chain, from fitters to PhD candidates in almost all disciplines. Multidisciplinarity is key to developing good solutions. For many of the challenges we need to solve, developing competitive technology is not enough, we also have to develop good framework conditions, markets and business models to be able to use low-emission technology on a grand scale.

Photo: Norwegian Institute for Nature Research (NINA)

Further develop a broad, robust technology and competence platform in the field of energy

Securing technology and competence is important across the thematic breadth of climate-friendly energy technologies. Continuous developments in both specific and generic technologies and disciplines will generate new opportunities and new solutions. The field of energy has a broad reach and covers many sectors. There is great transfer value between the disciplines and, based on the development of the energy system, interdisciplinary competence development and new collaboration constellations will become increasingly important. In addition to the strategy's eight focus areas, Energi21 believes it is important that efforts are also made to further develop other technology and knowledge areas. The other technology and knowledge areas and the strategy's focus areas benefit mutually from the results of research and innovation activities and together comprise Energi21's broad, robust technology and competence platform.
The other technology and knowledge areas that Energi21 believes must be further developed are:

- Energy-efficient, smart buildings and cities
- Energy-efficient industry
- Climate-friendly energy technologies for maritime transport
- Climate-friendly energy technologies for onshore transport
- Climate-friendly energy technologies for air transport
- Bioenergy and biofuels
- Onshore wind power
- Geothermal energy
- Nuclear power of the future
- Fusion energy
- Wave and tidal energy
- Airborne wind

Some of the other technology and knowledge areas are immature and/or do not contribute as much to our national energy mix. Following the developments in these areas will nevertheless be worthwhile, and may prove useful to research and innovation efforts if technology and market developments show that they are significant to our energy system in purely technical terms and to national value creation (industrialisation and business development).

International research and innovation collaboration increases competitiveness

A targeted and prioritised focus on internationalisation in research, and technology and competence development is vital to bolstering and further developing the competitiveness of the energy industry. A presence in the international research and innovation arena increases the quality of knowledge development and internationally recognised R&D communities, and provides more opportunities for the business sector to win positions in the international energy market.

Other important measures for realising the Energi21 strategy

- Policy instruments for the green transition should be in line with the Energi21 strategy
- Further develop joint initiatives and sector collaboration at authority level
- Collaboration between NORWEP and Energi21
- Collaboration between the ministries' 21 processes

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