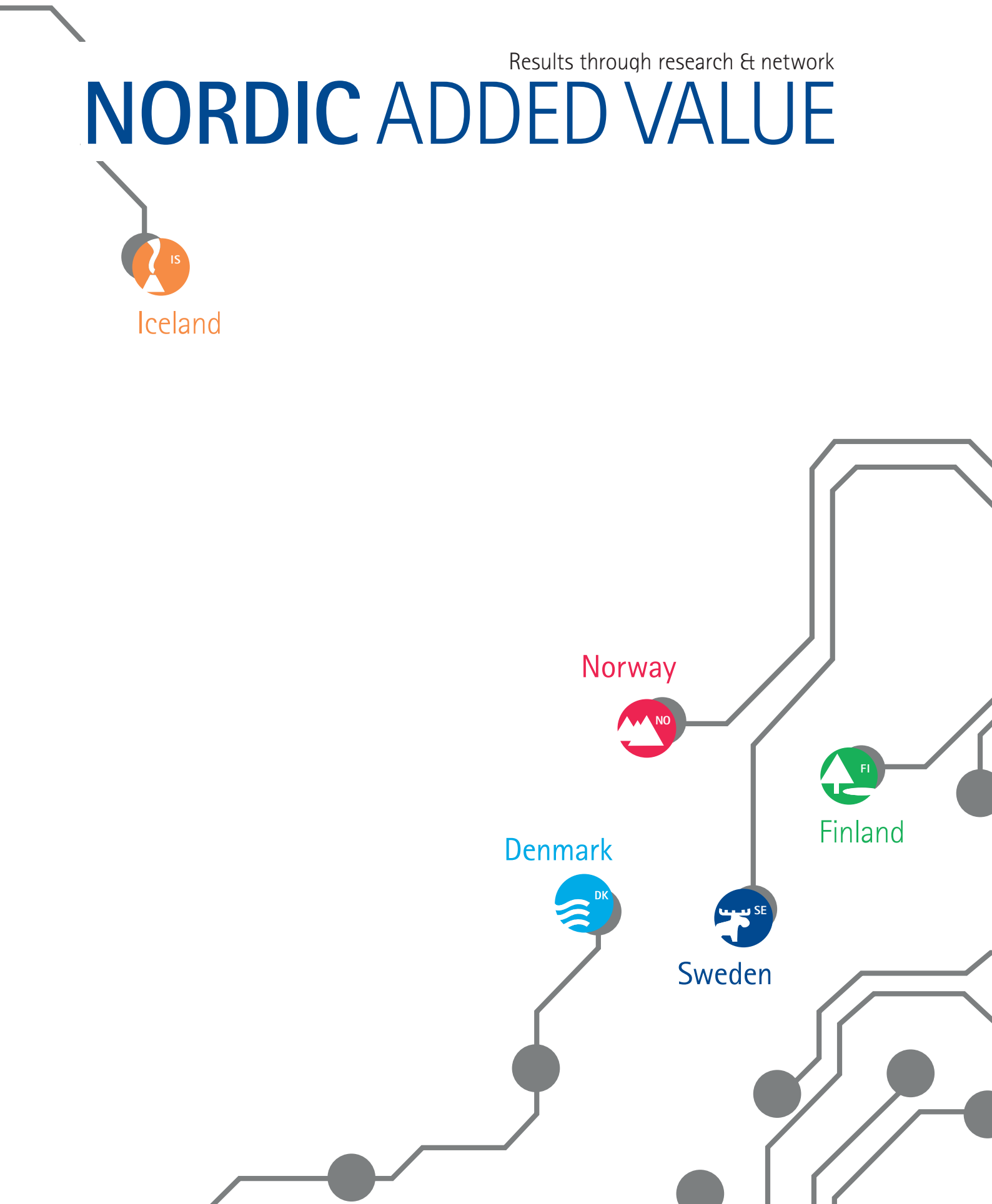
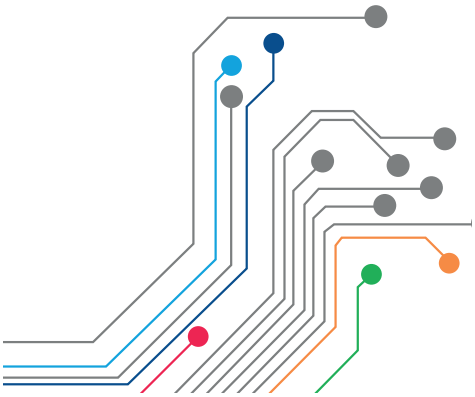
Nordic Energy Research

Results through research & network

NORDIC ADDED VALUE





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Nordic Added Value – Three small words with big meaning. They also form the title of this magazine, as it aims to show how research institutions, policy makers and industries can benefit from working together. The magazine showcases how cross-border research may offer advice on policy making and creates new networks and alliances.

As individual countries, the five Nordic countries are too small to have a significant influence. However, together they form the 10th largest economy in the world and comprise 25 million people. Together we provide Nordic Added Values. But what is Nordic Added Value? This of course may depend on the eye of the beholder; however, if you break it down word by word it becomes a bit clearer.

"Nordic", the region known for being at the forefront of green energy both when it comes to policymaking, energy production and usage. Sometimes referred to as the guiding star in renewable energy. At the same time, the Nordic region has become the benchmark for well-functioning liberalized energy markets.

"Added" means to provide more than the sum of what the individual countries can deliver. And this is just what energy research on a pan-Nordic level does.

"Value" is offering research-based, new or improved knowledge to decision-makers in business and society on energy in a sustainable context. And creating unique networks among research, policymaking and industry.

Nordic Energy Research is the funding agency for the eight projects portrayed in the magazine. They not only adhere to Nordic Added Value, but also provide knowledge and insight, as well as build networks, to be benefit of both political decision makers as well as provide new business opportunities.

We hope you will find your Nordic Added Value too from the articles and videos in the magazine.

Hans Jørgen Koch
Excecutive Director

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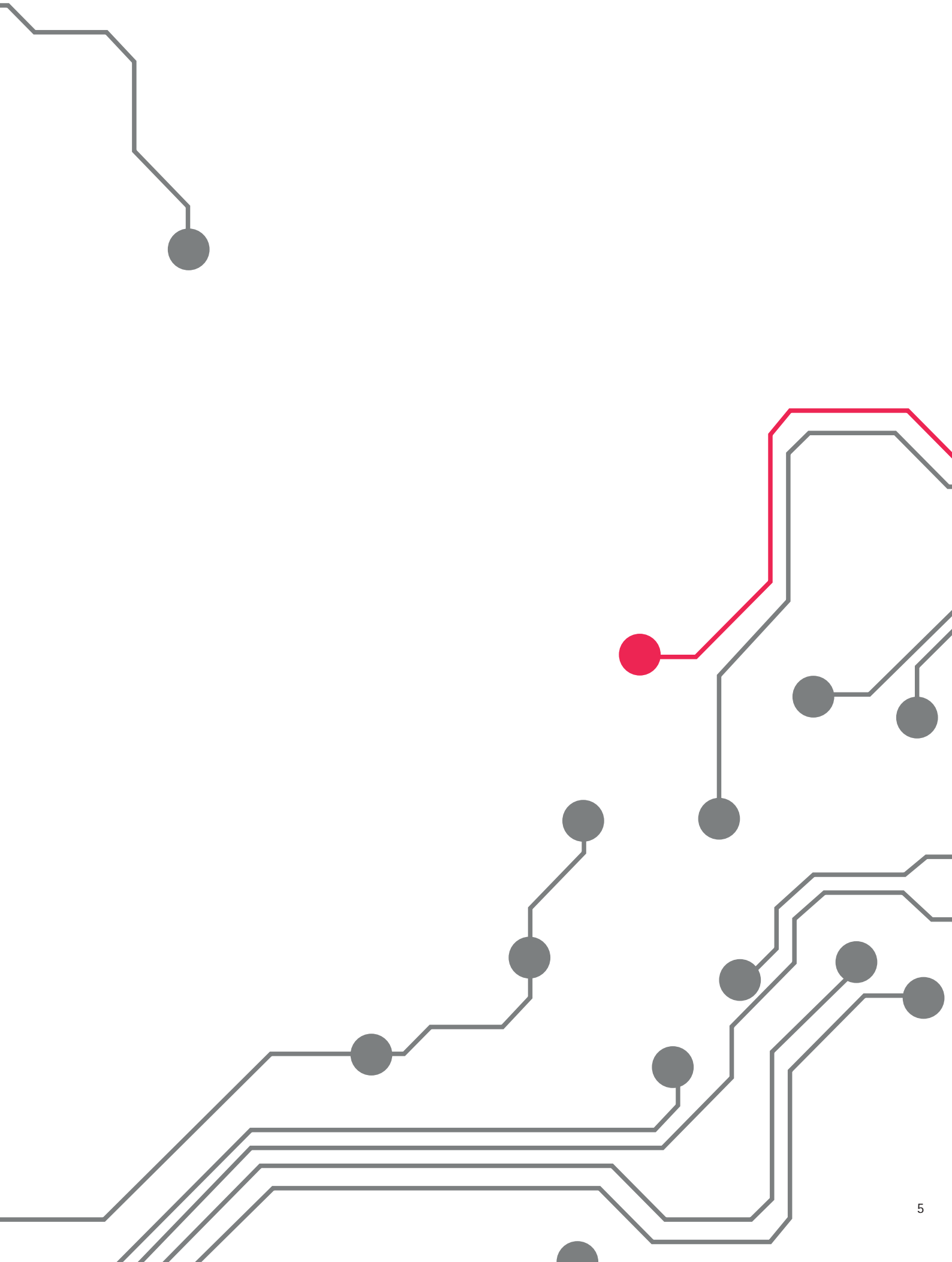
Nordic Energy Research



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Research to make the timber industry more competitive

The Nordic timber industry is facing serious challenges regarding its competitiveness. New, efficient processes to produce bioethanol could, however, help create many new jobs.

Photo: Shutterstock

Karin Øyaas from the Paper and Fibre Research Institute in Trondheim has great ambitions. She is responsible for the successful *New, innovative pre-treatment of Nordic wood for cost-effective fuel-ethanol production* project from the Nordic Energy Research 2007–2010 research programme. Together research institutions and the industry have obtained valuable new knowledge about pre-treatment processes and fermentation methods to convert wood into bioethanol.

BIO-REFINERIES ARE THE GOAL

The broadly composed project group from all the Nordic countries experimented with four different processes to pre-treat fir and ash wood. The project group has also analysed the interplay of the processes with subsequent fermentation into bioethanol.

> *"Norway, Sweden and Finland have huge timber resources and these could be important raw materials in an innovative and competitive bio-economy. Development of actual bio-refineries could contribute to managing the climate challenge, improving security of energy supply and potentially create tens of thousands of new production jobs," said Karin Øyaas*

VALUABLE BIO-CHEMICALS

One of the major challenges on the road to the bio-economy of the future is the high cost of raw materials, production equipment and operating processes to convert wood into bioethanol. Timber is a relatively expensive type of biomass, and, according to Karin Øyaas, bioethanol should be considered as a low-value product. Therefore, Nordic research collaboration will have to generate lower operating costs and an industrial concept, which combines bioethanol with valuable biochemicals.

INTEGRATION MEANS LOWER COSTS

The project group has simulated the costs of a bioethanol factory with a capacity of 600,000 tonnes of timber per year. Depending on the type of pre-treatment and fermentation chosen, such a factory could produce approximately 150,000–200,000 m^3 ethanol a year at a price of about EUR 325–500 per m^3.

In comparison, the current price of first-generation bioethanol production in northern Europe is around EUR 450–500 per m^3. However, if the factory is integrated with for example an oil refinery, or a paper factory, production costs could be reduced to EUR 200–300 per m^3 because bioethanol can then be produced using surplus energy from the paper factory or oil refinery.

The project group is working to further this potential in the Top Level Research Initiative project, SusBioFuel, which is part of the sub-programme; Sustainable Biofuels. The project group has now come far enough for the next phase, which could be to demonstrate the special Nordic competencies within bio-economics in a larger project under the EU 2020 programme.

"Nordic timber could be the raw material in an innovative and competitive bio-economy"

Karin Øyaas, research manager at the Paper and Fibre Research Institute

Watch the interview with Karin Øyaas (1:53 min)

Facts

- In 2007, the "New, innovative pre-treatment of Nordic wood for cost-effective fuel-ethanol production" project was granted funding as part of the Nordic Energy Research 2007-2010 research programme.
- The project had a total budget of NOK 12.7 mill., of which around 60% is being funded by Nordic Energy Research.
- The project was headed by the Paper and Fibre Research Institute (Norway) with the following research partners:
  - Matis-Prokaria (Iceland)
  - INNVENTIA (Sweden)
  - SINTEF (Norway)
  - VTT (Finland)
- As well as partners from industry:
  - Novozymes (Denmark)
  - SEKAB E-technology (Sweden)
  - Norwegian Forest Owners, Norske Skog, Borregaard and Statoil (all from Norway)

PFI

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Nordic bio-hydrogen research at the leading edge internationally

Research into producing hydrogen using synthetic biological systems can be extremely important for the sustainable energy systems of the future, but the technology must become more efficient before biohydrogen can compete on the commercial market.

Photo: Shutterstock

In the long term, exploiting energy from the sun to produce hydrogen from water using algae and blue-green algae (cyanobacteria) has great potential because resources are, more or less, infinite. With grants from the Nordic Energy Research, for in total a decade of years (2005–2015), and through close collaboration, researchers from the Nordic countries have been able to come a long way forward in the international race to use synthetic biology in the production of sustainable hydrogen.

NEW RESEARCHERS PROVIDE A SPRINGBOARD FOR THE FUTURE

Professor Peter Lindblad from the Department of Photochemistry & Molecular Science at Uppsala University is one of the key people in this scientific venture. He was the project manager on the Nordic BioH2 project completed in 2010, and which made Nordic bio-hydrogen research very attractive internationally.

Universities from all the Nordic countries as well as Latvia took part in the project, and four transnational seminars were held during the project. Participants in the project have had 200 scientific articles published, and five post.docs and 17 PhDs have been successfully completed.

> *"Thanks to financial backing from Nordic Energy Research, we have been able to achieve results so significant that they have aroused great international interest in Nordic bio-hydrogen research. The many new researchers who have qualified in the Nordic BioH2 project also provide us with a good springboard for continued Nordic work," said Peter Lindblad.*

Thanks to funding from Nordic Energy Research, Nordic bio-hydrogen research has become very interesting in an international context."

Professor Peter Lindblad from Uppsala University

IMITATING PHOTOSYNTHESIS

Researchers have to imitate nature's own photosynthesis in algae and blue-green algae in such a way as to enable these microorganisms to produce hydrogen more efficiently than in nature. This is done by combining biological photosynthesis with a catalytic process, which uses a class of enzymes known as hydrogenases. The challenge is to identify and develop the microorganisms with the greatest potential for efficient hydrogen production.

The research programme "Sustainable Energy Systems 2050" from Nordic Energy Research is contributing to continuing research with the AquaFeed project (read about this on pages 24–25). Furthermore, Peter Lindblad has through his Nordic projects, also been afforded a key role in European research, among other things in the EU-funded Solar-H and SolarH2 (2005–12) projects, and most recently as the project manager on the large CyanoFactory EU-project, which includes ten partners from seven EU countries. Nordic and European bio-hydrogen research has so far primarily been at universities as it still entails long-term technological development, but both the Nordic BioH2 and the AquaFeed projects have managed to involve commercial partners.

Facts

- In 2007 the "Renewable production of hydrogen using algae" (Nordic BioH2) project was funded as part of the Nordic Energy Research 2007–2010 programme.
- The project has a total budget of NOK 8.15 mill., of which around 75% is being funded by Nordic Energy Research.
- The project is being led by Uppsala University (Sweden) with the following partners:
  - Bergen University (Norway)
  - The University of Turku, Tampere University of Technology and Jyväskylä University (all Finland)
  - LIFE at the University of Copenhagen (Denmark)
  - Akureyri University (Iceland)
  - Riga Technological University (Latvia)
  - Stockholm Environment Institute Tallinn Centre, SEI-Tallinn (Estonia)
  - As well as the private companies Latvia Prokaria and Iceland Mannvit.

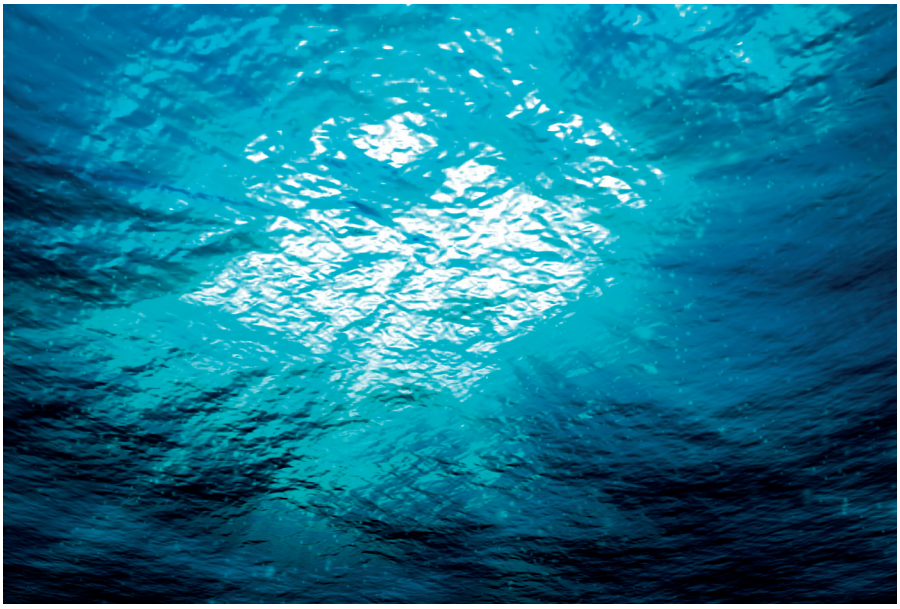

Photo: Colourbox

Marine algae and blue-green algae are an inexhaustible resource for biohydrogen production.

UPPSALA UNIVERSITET

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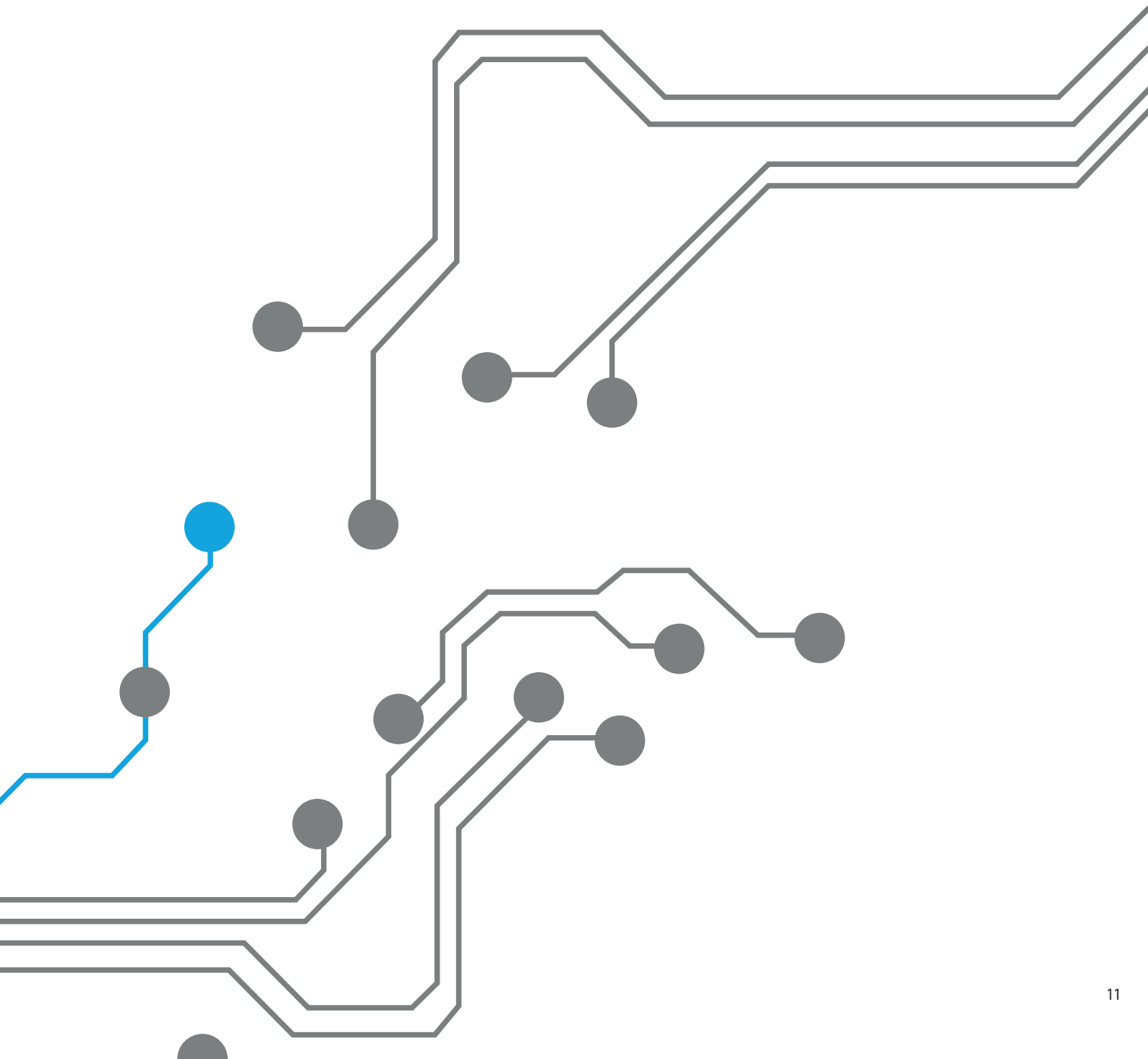
WHO IS NORDIC ENERGY RESEARCH?

Nordic Energy Research is the platform for joint Nordic Energy Research and policy development under the auspices of Nordic Council of Ministers. We promote cooperation in research and policy that adds value to the national initiatives in the Nordic countries.

Through 25 years of action, Nordic Energy Research has built strong networks both among researchers, and between researchers and policy-makers. Hundreds of PhDs have been awarded as part of the Nordic projects we have supported.

Knowledge production is a social process, and Nordic Energy Research offers researchers the chance to interact on a transnational level.



The Nordic region at the leading edge in carbon-neutral fuels

Because of their ambitious climate policies, different types of energy supply and large resources of biomass, the Nordic countries are probably the best in the world at developing and testing production of carbon-neutral fuels for heavy transport.

> We have been able to analyse costs of different processes to convert to synthetic green fuels"
>
> Claus Friis Pedersen, senior researcher at Haldor Topsøe A/S

According to senior researcher Claus Friis Pedersen, Haldor Topsøe A/S applied for research funding in connection with the call launched in 2010 by Nordic Energy Research, because of the specific good conditions in the Nordic countries. The company wants to develop its technology to convert electricity and CO_2 to synthetic fuels based on the company's energy-efficient solid oxide electrolysis (SOEC) process. He also sees Nordic Energy Research (NER) as an unbureaucratic and flexible research secretariat, which is ready to adapt its projects to changing conditions.

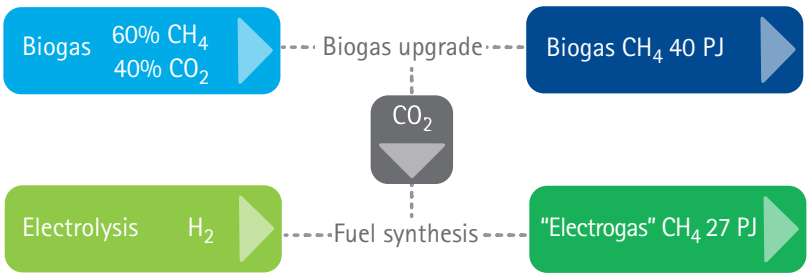
PRICE IS A CHALLENGE

Haldor Topsøe A/S already has the knowhow to produce methane, methanol and DME from carbon-neutral sources such as biomass and electricity from wind turbines and photovoltaics through its technological expertise in catalysis and electrolysis. However, the process cannot yet compete with the prices of fossil fuels.

"Because of the different conditions in the Nordic countries, the CO_2 Electrofuels project has been able to analyse costs of different processes to convert to synthetic green fuels. Among other things, we have analysed black liquor from paper production, biogas from livestock manure, biogas recovery from landfills, and use of geothermal energy," said Claus Friis Pedersen.

GOOD CONDITIONS IN ICELAND

The analyses of the project have shown that it is probably best to demonstrate the technology in Iceland. Iceland is already working with conversion of landfill gas to fuel for use in various types of public transport, and an infrastructure exists through which it is possible to distribute and sell the sustainable fuels. The project is also analysing opportunities to exploit geothermal energy and imported wood.



Source: Haldor Topsøe A/S
By combining surplus CO_2 from upgraded biogas with hydrogen from electrolysis, the amount of green gas can be increased by 65%. One of several processes for carbon-neutral fuels.

The project group for the project CO_2 Electrofuels believe that in the long term there are good chances to develop cost-effective production of sustainable fuels in Iceland. Using SOEC electrolysis it is possible to achieve very good system efficiency.

Residues from a sub-process could be exploited as raw materials elsewhere, as there are synergies in integrating the conversion process into existing production plants. This can benefit from low and stable electricity prices which enable production at full capacity throughout the year.

In order to enable the project group behind CO_2 Electrofuels to test this potential, Nordic Energy Research has decided to extend the project period by one year to the end of 2015. In this phase, the project group is working with the Icelandic company Carbon Recycling International, which already produces methanol using CO_2 from geothermal energy.

Facts

- The "CO_2 Neutral Electrolysed Synthetic Fuels for Heavy Transportation and Electricity Load Balancing" (CO_2 Electrofuels) project was granted funding in 2011 as part of the Nordic Energy Research programme: Sustainable Energy Systems 2050.
- The project has a total budget of NOK 11.9 mill., of which 60% is being funded by Nordic Energy Research.
- The project is being headed by Haldor Topsøe A/S (Denmark) with the following partners:
  - Innovation Centre Iceland, SORPA and Olíudreifing (all Iceland)
  - CHEMREC AB, E.ON Nordic and Volvo Powertrain (all Sweden)
  - EA Energianalyse A/S and DTU Energy Conversion (Denmark)
  - Wärtsilä OY (Finland)

Watch the interview with Claus Friis Pedersen (1:21 min)

HALDOR TOPSOE

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NO

It will be possible to design offshore wind farms more efficiently

A new simulation tool, the OffWind Toolkit, will make it possible to localise and design the offshore wind farms of the future more efficiently, and will provide more reliable forecasts for operators.

Photo: DONG Energy A/S

There is great potential to expand offshore wind farms in the Nordic countries and in the British and German parts of the North Sea. As the number of offshore wind farms grows, so does the need to be able to designate optimal locations. The OffWind project supported by Nordic Energy Research is developing a simulation tool to enable more efficient design and localisation of these installations.

According to the project manager of OffWind, Jafar Mahmoudi from IRIS in Stavanger, is the tool will also make it possible for operators of offshore wind farms to predict electricity generation more accurately on the basis of meteorological data and forecasts. With more reliable data on the expected electricity production, operators can expect a better price on the Nordic Electricity Exchange-NordPool.

CLOSE COLLABORATION WITH INDUSTRY

The universities and research centres taking part in the project have worked closely with industry and the energy companies developing the Nordic offshore wind turbine projects. This dialogue has been enhanced through the Ph.D. and post.doc programmes, and it has helped make the tool operational:

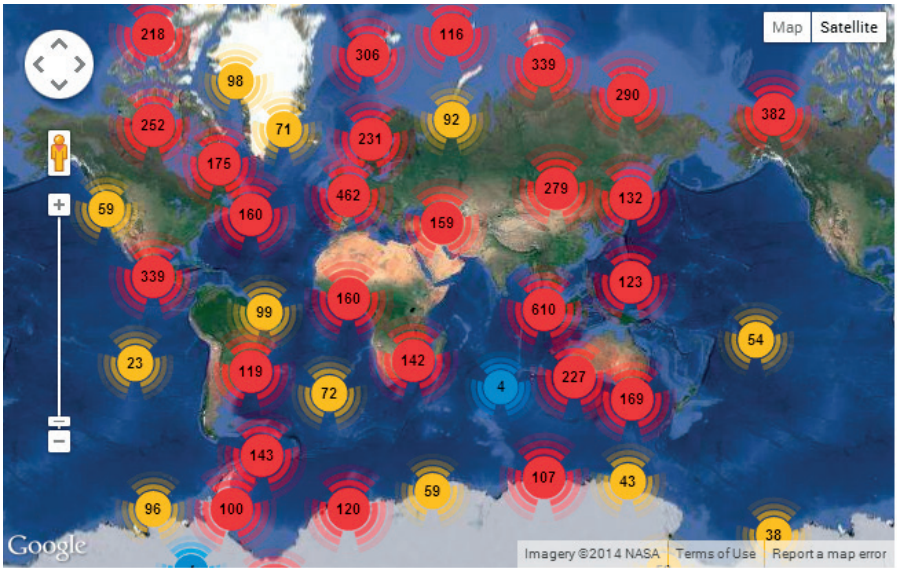
> *"The OffWind Toolkit is a user friendly and flexible tool which can be used by all developers and other stakeholders in the Nordic countries and globally. The tool makes it possible to optimise operational finances and thereby it can contribute to reducing costs of electricity generation from offshore wind farms," said Jafar Mahmoudi.*

> The OffWind Toolkit is a user friendly and flexible tool which can help reduce costs of electricity production from offshore wind farms."
>
> Jafar Mahmoudi from the International Research Institute of Stavanger

OPEN-SOURCE-BASED

The OffWind Toolkit may also be used to train wind energy engineers specialising in offshore wind farms. As the tool is based on open-source software, and as it has been developed with support from Nordic Energy Research, the project group can make OffWind freely available to stakeholders, who can supplement with their own facilities.

Jafar Mahmoudi also expects specific versions of the OffWind Toolkit to be used by consultants, authorities and others in planning and priority-setting for future offshore wind turbine projects. Practical utilisation of the results of the project is just around the corner: The project group has already released a beta version of the simple version of the tool, which can be downloaded from the project website, *www.offwind.eu,* and which uses simple algorithms. The more advanced version can model at mesoscale and it can be used for Computational Fluid Dynamics (CFD) simulations.



Screenshot from the Offwind Toolkit which can be used in CFD simulations, forecasts of electricity production from offshore wind farms, meso-micro-scale coupling, etc.

Facts

- In 2011, the "Prediction tools for offshore wind energy generation" (OffWind) project was granted funding from the Nordic Energy Research programme; Sustainable Energy Systems 2050.
- The project has a total budget of NOK 12.1 + 2 mill., of which around 60% is being funded by Nordic Energy Research.
- The project is being headed by the International Research Institute of Stavanger IRIS (Norway) with the following partners:
  - Lund University (Sweden)
  - Aalborg University and Vattenfall (both from Denmark)
  - SINTEF and NorskVind AS (both from Norway)
  - Furthermore, partners from Portugal (Megajoule), Russia (NRG-Soft) and USA (NREL) are taking part in development work.

IRIS

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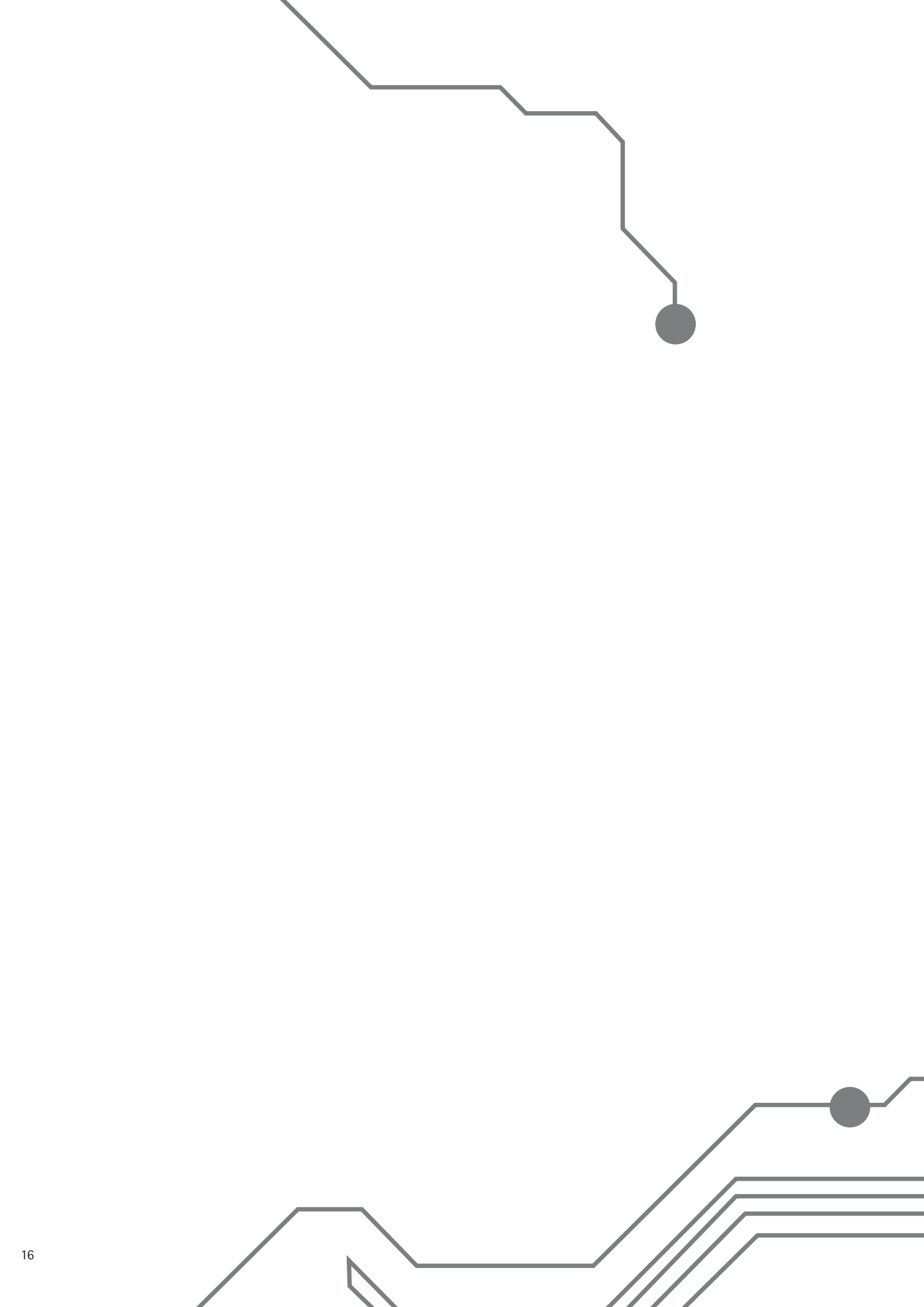
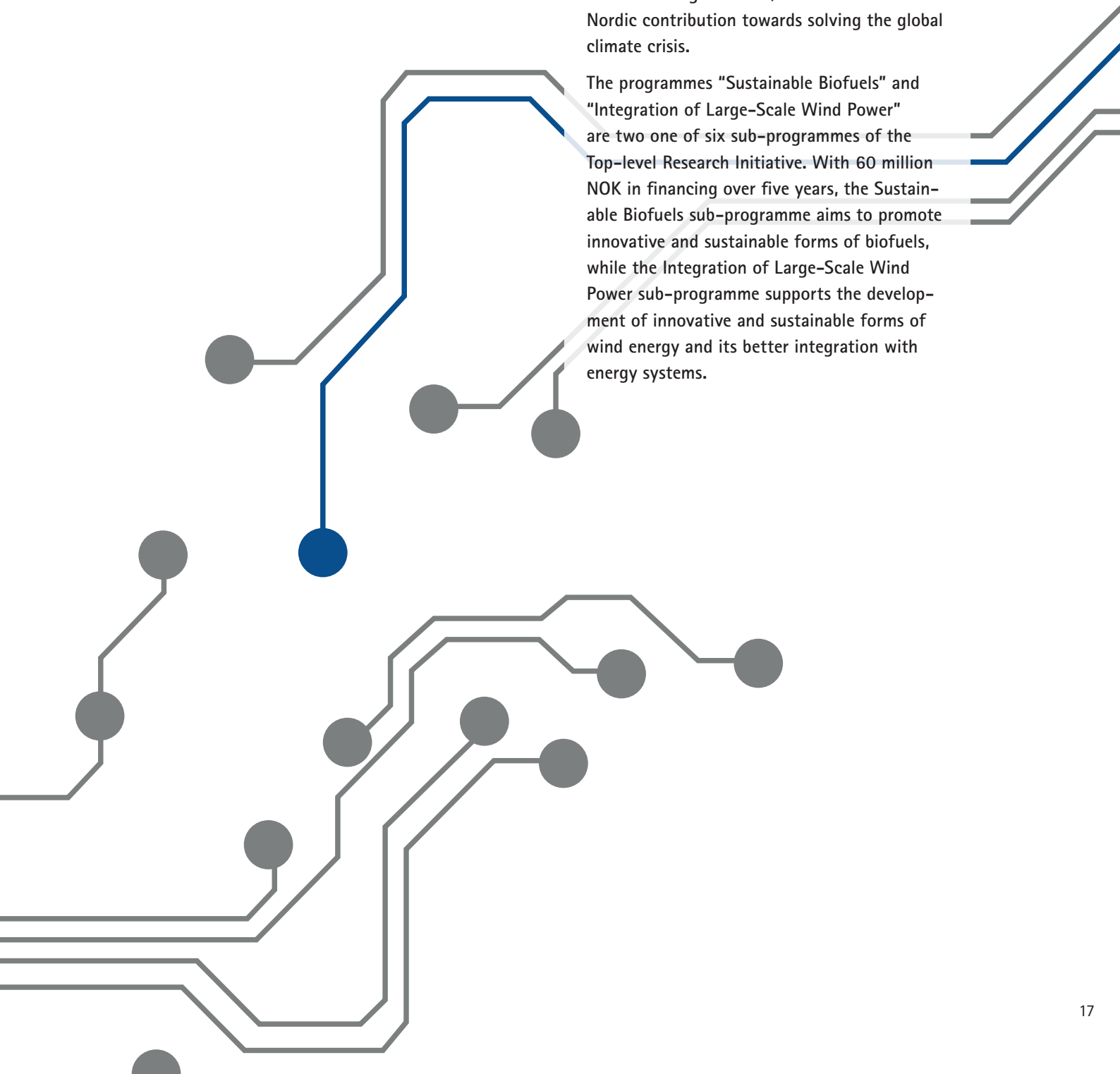


TOP-LEVEL RESEARCH INITIATIVE – A MAJOR NORDIC VENTURE FOR CLIMATE, ENERGY AND THE ENVIRONMENT

The Top-level Research Initiative (TRI) is the largest joint Nordic research and innovation initiative to date, with a totalt budget of 1 billion NOK. The initiative aims to involve the very best agencies and institutions in the Nordic region, and promote research and innovation of the highest level, in order to make a Nordic contribution towards solving the global climate crisis.

The programmes "Sustainable Biofuels" and "Integration of Large-Scale Wind Power" are two one of six sub-programmes of the Top-level Research Initiative. With 60 million NOK in financing over five years, the Sustainable Biofuels sub-programme aims to promote innovative and sustainable forms of biofuels, while the Integration of Large-Scale Wind Power sub-programme supports the development of innovative and sustainable forms of wind energy and its better integration with energy systems.



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Secure transmission requires collaboration and innovation

Unpredictable electricity production from wind turbines and photovoltaics etc. means there is a need for more dynamic control of the Nordic electricity system through development of new, advanced methods and tools.

Photo: Shutterstock

Together with collaboration partners from the rest of the Nordic region, Luigi Vanfretti, an associate professor at the Royal Institute of Technology (KTH), is involved in developing phasor measurement units (PMU). PMUs can help the system operator companies in the Nordic countries manage the challenges in the electricity system of the future. As head of the KTH SmarTS Lab in the Electric Power Systems Department, Luigi Vanfretti is responsible for setting up a network among Nordic universities to develop a common software and hardware infrastructure to implement PMU data applications.

INTELLIGENT CONTROL

The new tools could make it easier for system operator companies to intervene more rapidly when sudden large variations in electricity production from wind turbines, for example, challenge the stability of the system. During the project, SmarTS Lab has developed a visualisation tool and an app for iPads and smartphones.

> *"Without the new tools and methods for dynamic monitoring and control, the extensive expansion of renewable energy in the Nordic countries would entail a need for investments of many billions of kroner in the electricity grid. Our goal is to make management and control so intelligent so that the utilisation of transmission assets is exploited at its maximum. However, this requires much stronger collaboration between the technical universities and more innovation by the system operators," said Luigi Vanfretti.*

NEED FOR MORE RESEARCH

Luigi Vanfretti is hoping for a common vision among the Nordic system operators for the electricity system of the future, and he wants to see more awareness as the new challenges will require much greater focus on research. The

> There is a need for closer Nordic collaboration and more innovation to make the electricity system of the future resilient."
>
> Luigi Vanfretti, associate professor at SmarTS Lab at the Royal Institute of Technology

Smart transmission grid operation and control (Strongrid in the period 2011–2015) project under the Sustainable Energy Systems 2050 programme could inspire such awareness.

Closer collaboration between the system operator companies and the technical universities is also crucial to ensure an influx of qualified new electrical power engineers and other experts with the competences required for a Smart Transmission Grid.

According to Luigi Vanfretti, the Norwegian system operator, Statnett SF, has shown the way for the other companies. Statnett SF has come a long way with its innovation strategy and its focus on research and development. The company is operating the first field trials of the tools and methods developed at SmarTS Lab. During the next few years, an area in northern Norway will be operated as a pilot area for smart management of the electricity system and this will feed valuable knowledge into the Strongrid project about how research results can be implemented in ongoing operation of the transmission system.

Facts

- In 2011, the "Smart transmission grid operation and control" (Strongrid) project was granted funding from the Nordic Energy Research programme; Sustainable Energy Systems 2050.
- The project has a total budget of NOK 24 mill., of which around 70% is being funded by Nordic Energy Research.
- The project is being led by the Department of Electric Power Engineering NTNU (Norway) with the following partners:
  - Aalto University and Fingrid (both Finland)
  - The University of Iceland and Landsnet (both Iceland)
  - The Royal Institute of Technology (KTH), Svenska Kraftnät and Gothia Power (all Sweden)
  - The Technical University of Denmark (DTU) (Denmark)
  - Statnett SF and Troms Kraft Nett AS (both Norway)

Watch the interview with Luigi Vanfretti (1:42 min)

SmarTS Lab
Smart Transmission Systems Laboratory

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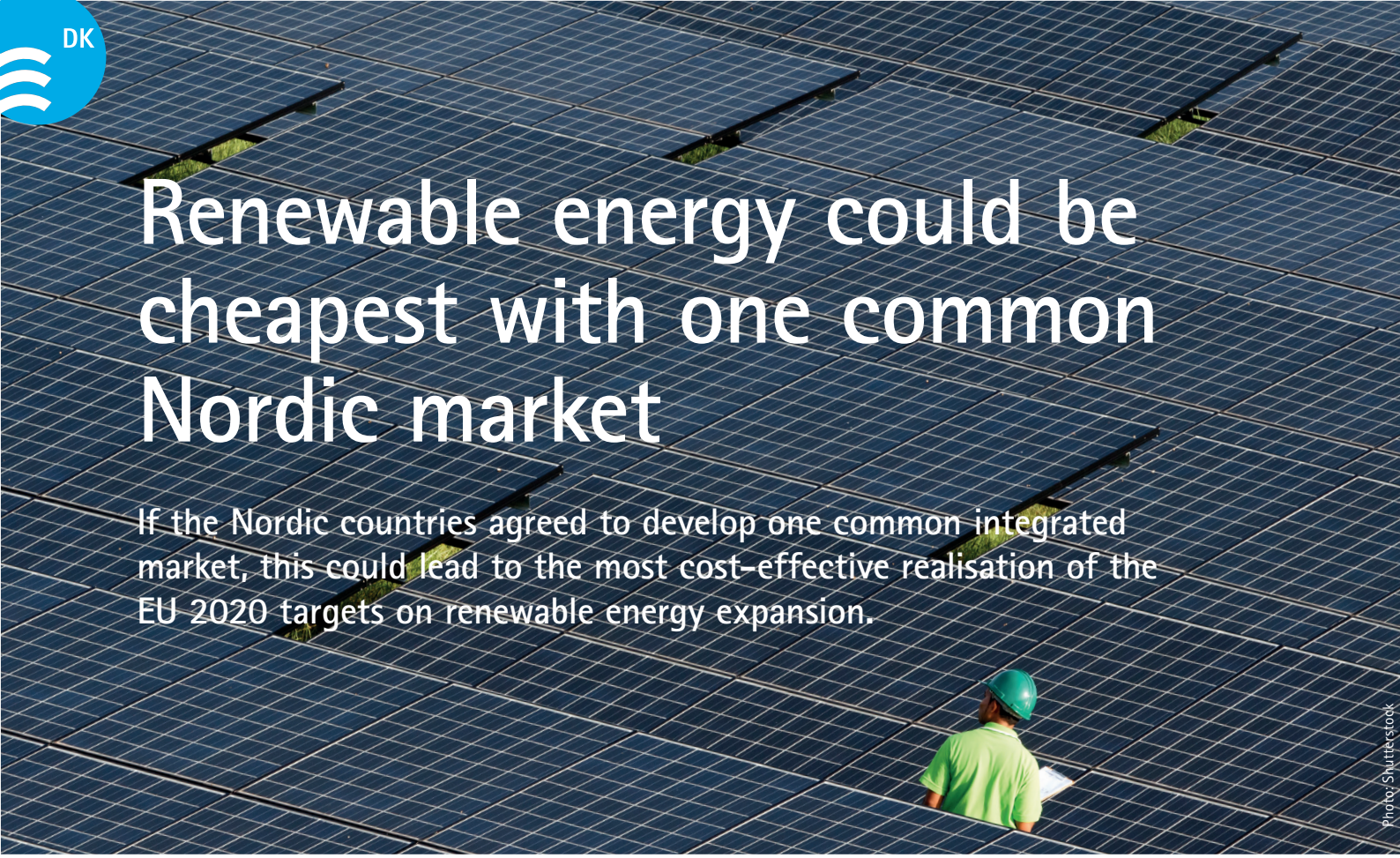

Renewable energy could be cheapest with one common Nordic market

If the Nordic countries agreed to develop one common integrated market, this could lead to the most cost-effective realisation of the EU 2020 targets on renewable energy expansion.

Photo: Shutterstock

This principal conclusion in an extensive Nordic study of methods and costs of expanding small-scale production facilities with renewable energy is still relevant according to Jesper Munksgaard, project manager. As an analyst with the consultancy firm Pöyry, in 2007–2008, he was a project manager on the Devising Policies for Integrating Electricity from many Small Sources project run by Nordic Energy Research.

MOST PRODUCTIVE PLANTS

Conditions have clearly changed since the project group published its analysis in 2008. Renewables such as wind turbines and photovoltaics have become cheaper, and the Nordic countries have adjusted the political framework conditions. However, according to Jesper Munksgaard, there would still be a socio-economic benefit from basing future renewable energy expansion on an integrated market; regulated through common green certificates, for example.

> *"Our research has showed that, with the same framework conditions throughout the Nordic countries, individual production facilities will be located at sites where they are most productive, and this will minimise the total additional costs of expanding renewable energy. The Nordic countries could have become an inspirational role model for the rest of Europe, if the Nordic governments agreed on such regulation. Now it looks as if the European Commission has taken over with its proposed common binding targets for renewable energy in 2030," says Jesper Munksgaard*

GOOD CONDITIONS IN THE NORDIC COUNTRIES

Analyses have shown that, with regard to systems and technology, there are very good possibilities in the Nordic countries to integrate electricity production from small-scale facilities such as wind turbines and photovoltaics. Varying electricity production can be balanced with electricity consumption in the

> Developing one common integrated Nordic electricity market will minimise the total additional costs of expanding renewable energy"
>
> Jesper Munksgaard, chief consultant at HOFOR

Nordic countries by using the large storage capacity at Norwegian and Swedish hydropower plants as an indirect storage facility.

Hydropower plants could take advantage of periods with high wind production resulting low prices on the NordPool electricity exchange by turning down their turbines. In calm weather with higher electricity prices, hydropower plants could supplement low electricity production from the wind turbines.

In the Devising Policies for Integrating Electricity from many Small Sources project, electricity-market stakeholders were asked to identify the greatest barriers to continued expansion of small-scale units with renewable energy. Among other things, they identified unstable political framework conditions and inadequate subsidy schemes as barriers which discourage potential investors from entering the market. In Norway, local environmental considerations make it difficult to establish new small hydropower plants, while nuisance to neighbours is a barrier for onshore wind turbines and biogas plants in Denmark, for example.

Facts

- The "Devising Policies for Integrating Electricity from many Small Sources" project was granted funding in 2007 as part of the Nordic Energy Research research programme for 2007–2010.
- The project had a total budget of NOK 4.5 mill. of which around one-third is being funded by Nordic Energy Research.
- The project was headed by the consultancy firm Pöyry (Denmark), with the following partners:
  - Norwegian Water Resources and Energy Directorate (NVE), Statnett, Enova and the Norwegian Electricity Industry Association (all Norway)
  - Elforsk (Sweden)
  - Kainuum Energia (Finland)

Photo: iStock

In a common Nordic market, Norwegian and Swedish hydropower plants act as a perfect storage facility for fluctuating electricity production from wind and solar sources.

HOFOR

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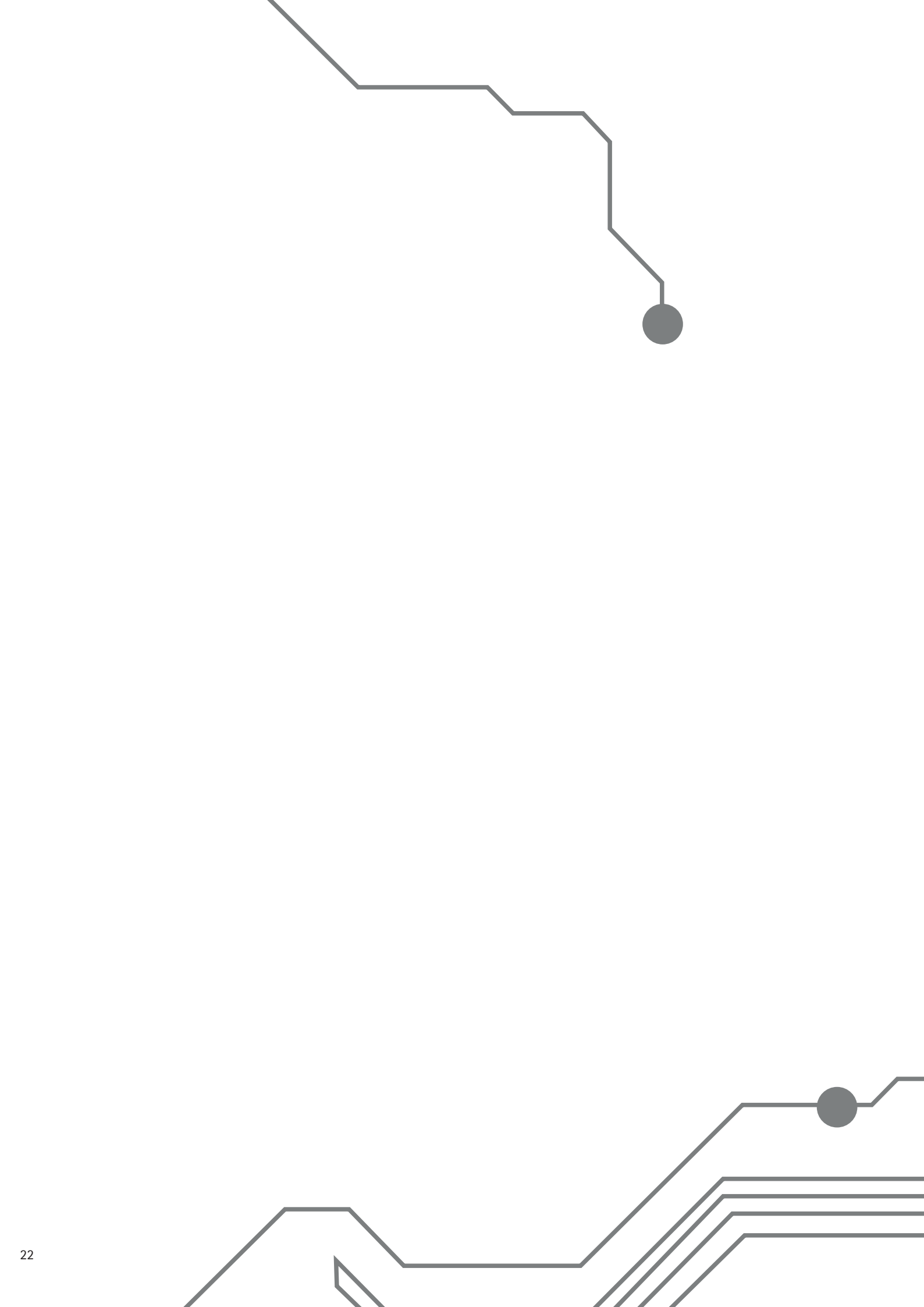
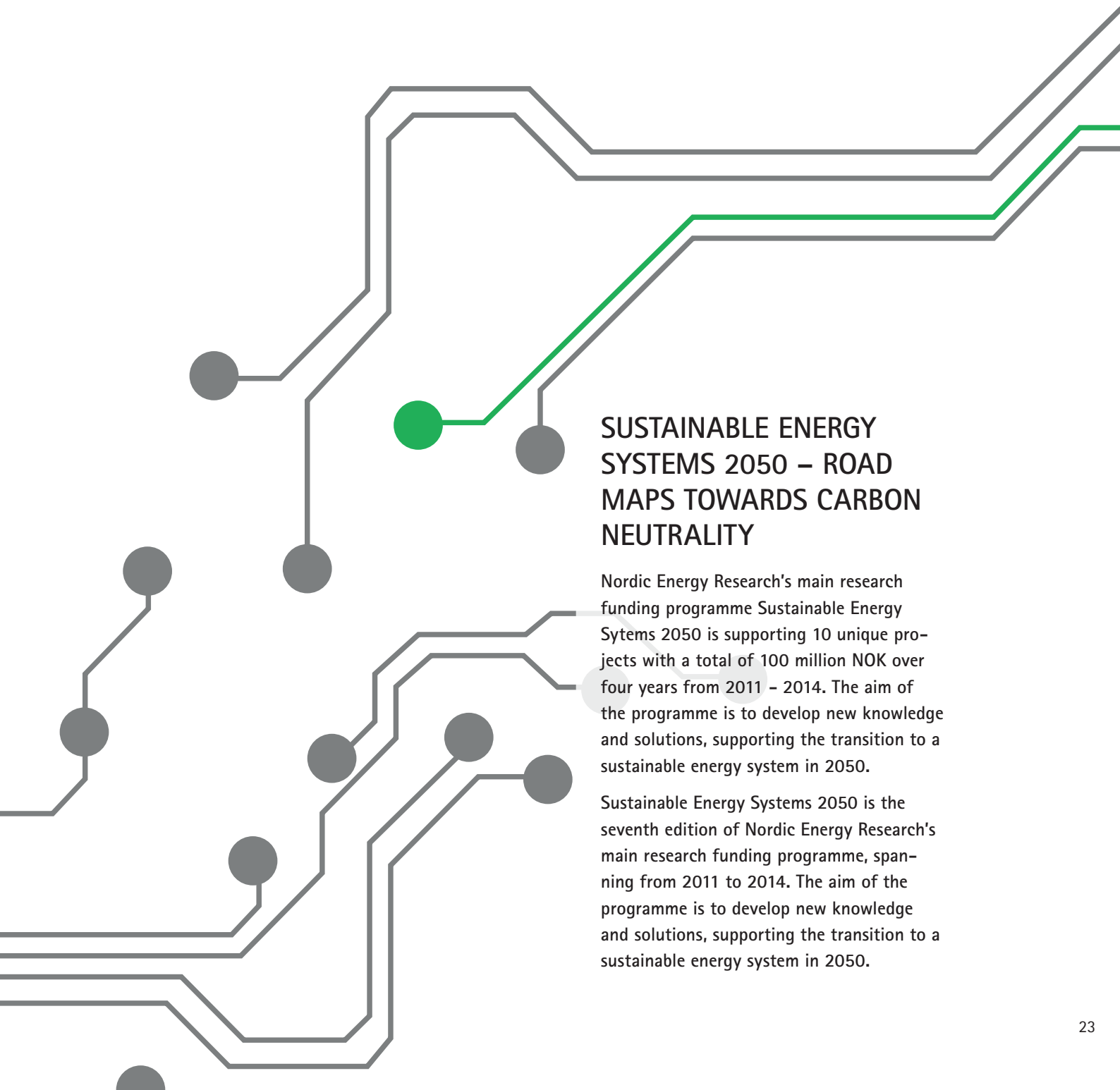




SUSTAINABLE ENERGY SYSTEMS 2050 – ROAD MAPS TOWARDS CARBON NEUTRALITY

Nordic Energy Research's main research funding programme Sustainable Energy Sytems 2050 is supporting 10 unique projects with a total of 100 million NOK over four years from 2011 - 2014. The aim of the programme is to develop new knowledge and solutions, supporting the transition to a sustainable energy system in 2050.

Sustainable Energy Systems 2050 is the seventh edition of Nordic Energy Research's main research funding programme, spanning from 2011 to 2014. The aim of the programme is to develop new knowledge and solutions, supporting the transition to a sustainable energy system in 2050.

Aquatic algae could make transport more sustainable

By combining solar energy and concentrated carbon dioxide, it should be possible to produce biofuels more efficiently from aquatic organisms like algae and blue-green algae than from traditional onshore biomass.

Photo: Shutterstock

There is good technical potential in exploiting solar energy to produce sustainable fuels. Yet this requires more detailed insight into the fundamental nature of photosynthesis. Therefore, researchers from several Nordic universities are exploring the potential of algae and blue-green algae as fuel sources. This is being done in the Aquafeed project funded by the Nordic Energy Research programme; Sustainable Energy Systems 2050.

CROSS-DISCIPLINARY RESEARCH

Esa Tyystjäri, a visiting professor at the University of Turku, is the project manager on Aquafeed, and he points out that the huge technological challenges in exploiting algae and blue-green algae (cyanobacteria) for biofuels mean that experts from several different disciplines are required. In the Aquafeed project, materials chemists, biologists and biochemists are working side by side on developing new methods and materials to exploit solar energy more effectively during photosynthesis.

> *"We believe that we can achieve more efficient biomass production by feeding the aquatic organisms with concentrated carbon dioxide, appropriate nutrients and strong sunlight. We have yet to make this process adequately efficient to compete with the more conventional production of biomass and fuels. Therefore we are working on developing more advanced methods," said Esa Tyystjäri.*

VALUABLE BIOCHEMICALS

The Aquafeed project is using photobioreactors in which algae and blue-green algae can be tested in closed circuits, and there are expectations that high-value biochemicals can be produced in addition to fuels, and this could help make the process commercially interesting for industry.

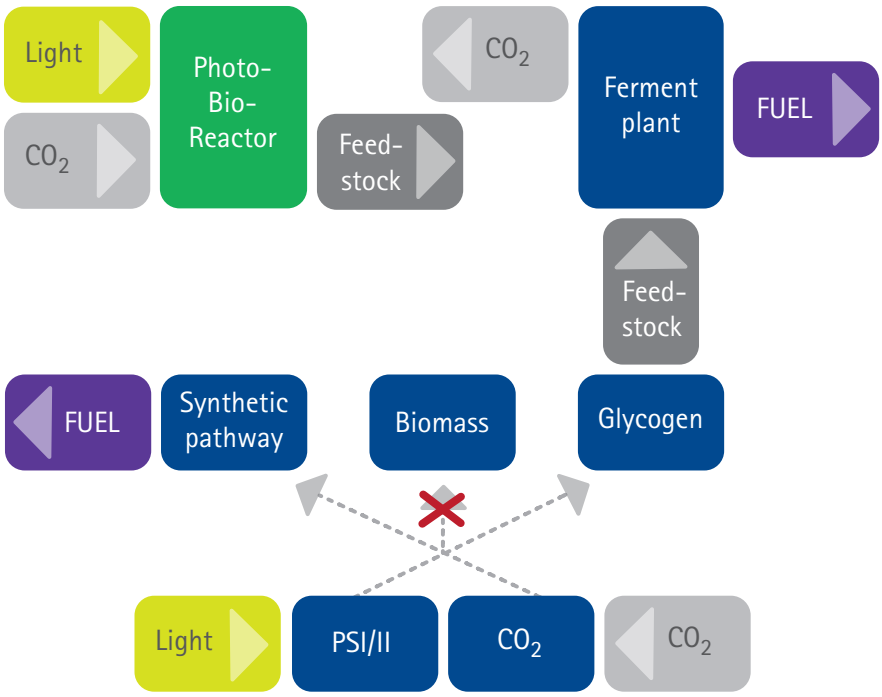
> We are working on developing biological building blocks which can convert solar energy to transport fuels using blue-green algae and other algae"
>
> Dr. Esa Tyystjäri from the University of Turku

The project is working on several different end products. One group of researchers is seeking to design synthetic biological pathways to produce hydrocarbons with blue-green algae. Another group hopes to develop effective ethanol production by making the blue-green algae form easily converted carbohydrates. The project is also working on producing biohydrogen and biodiesel.

The project group has high hopes that it will be possible to scale-up the research results to commercial scale. Aquafeed's Finnish manufacturer, St1 Biofuels Oy, is already running several bioethanol factories, and the project group believes that the first pilot photobioreactor can be operational during 2016. In addition, the project group will profile this new Nordic knowledge through several articles in scientific journals.

Facts

- In 2011 the "Conversion of solar energy to infrastructure-ready transport fuels using aquatic photobiological organisms as the hydrocarbon feedstock producer" project (Aquafeed) was sponsored as part of the Nordic Energy Research programme; Sustainable Energy Systems 2050.
- The project has a total budget of NOK 15.2 mill., of which around 80% is being funded by Nordic Energy Research.
- The project is headed by the University of Turku (Finland) with the following partners:
  - University of Copenhagen (Denmark)
  - Uppsala University (Sweden)
  - Bioforsk (Norway)
  - St1 Biofuels Oy (Finland)



Source: University of Turku
Diagram of the process flow in an integrated Aquafeed concept.

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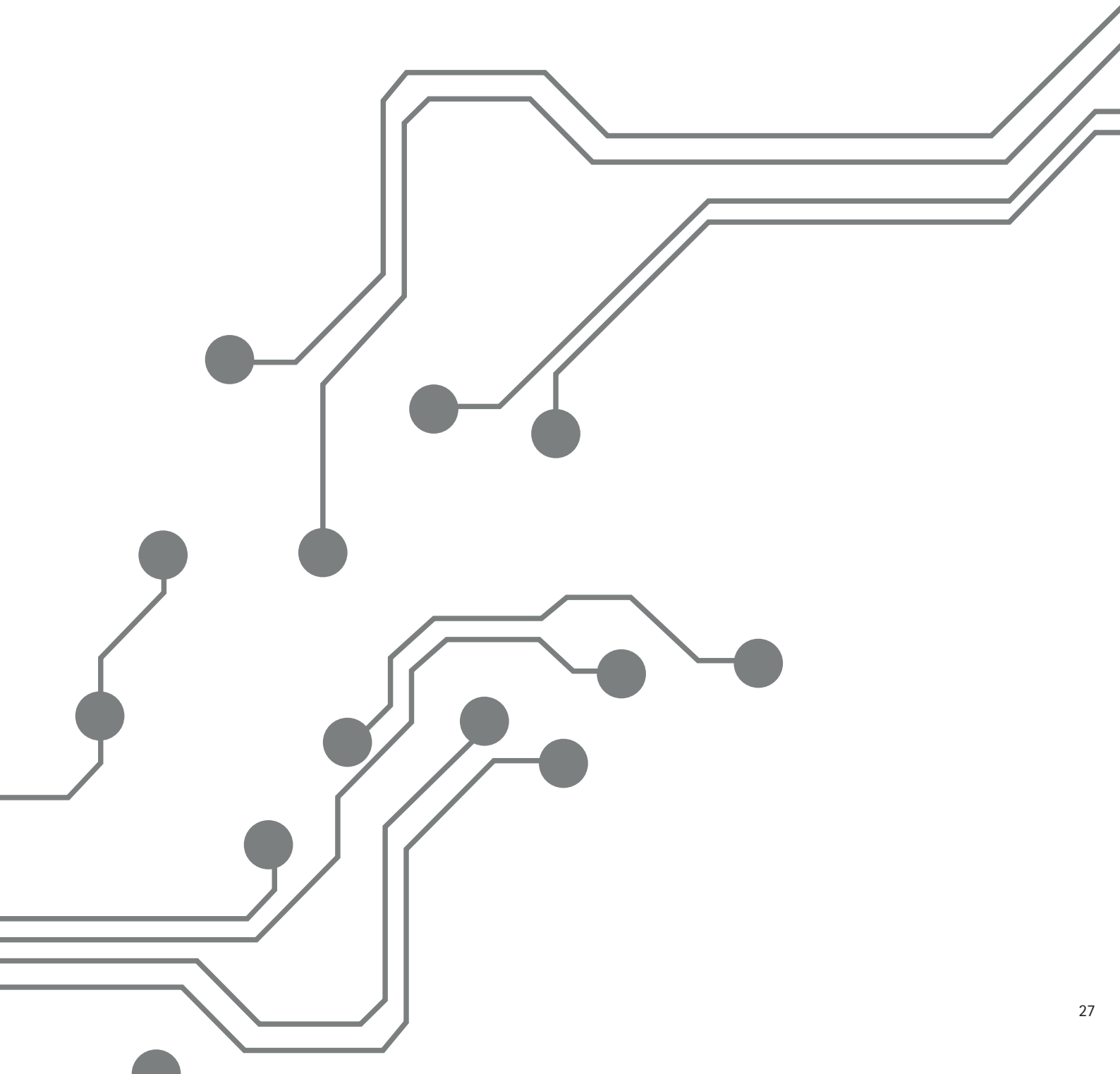
6th RESEARCH PROGRAMME FROM NORDIC ENERGY RESEARCH 2007–2010 – 5 THEMATIC APPROACHES

Nordic Energy Research's main research programme for 2007-2010, had a total budget of 150 million NOK, with 86 million NOK provided by Nordic Energy Research. The program consisted of 16 high quality cooperative projects. The thematic areas of the program were; climate and energy, energy efficiency, renewable energy, hydrogen technology and energy markets.

The main objectives were to pave the way for long-term research, capacity and competence building while simultaneously provide a useful and knowledge-based background for decision-makers.

This research periode had its activities directed towards more applied research and knowledge development with slightly less emphasis on basic research.



Fuels of the future can be produced from the sun, water and CO_2

Direct conversion of CO_2 and water into methanol by using the sun's energy addresses both climate-change and fuel-supply challenges at the same time.

"Direct conversion of CO_2 and water into sustainable fuels by using the sun's energy addresses some of the most important economic and environmental global challenges."

Professor Oddur Ingolfsson from the University of Iceland

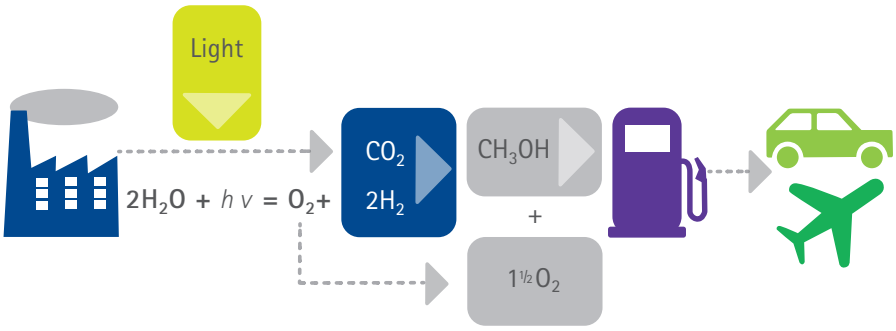
Universities from all five Nordic countries are attempting to realise their common scientific competences within energy conversion and nanotechnology in efficient, sustainable and competitive production of environmentally friendly fuels for transportation.

The NISFD project is being supported by the Nordic Energy Research programme, Sustainable Energy Systems 2050, and it is the start of a long-term technological development which may bring the Nordic countries to the leading edge within the production of sustainable fuels. The project is being conducted in collaboration with the Icelandic company Carbon Recycling International (CRI), which has built the world's first plant to produce methanol using CO_2 as the raw material.

NANOTECHNOLOGY IN FOCUS

Professor Oddur Ingolfsson from the Faculty of Physical Sciences at the University of Iceland is one of four founders and the former Director of Research at CRI. He said that the company is already able to produce methanol using renewable electric energy and CO_2. However, CRI is always striving to make the process more efficient and more economical. This may be achieved through nano-technology helping in the development of more effective catalysts and eventually by replacing the energy-demanding electrolytes with a direct conversion of solar energy and CO_2 to methanol. Developing such technology is the main goal of the current NISFD project.

"Through this project, the five Nordic universities have enhanced their competences and now have good opportunity to take the lead internationally. At the same time, the NISFD project is addressing some of the most important current economic and environmental global challenges," said Oddur Ingolfsson.



The NISFD process converts CO_2 and water into sustainable transportation fuel by using the sun's energy.

LONG-TERM PERSPECTIVE

There are great economic and environmental perspectives in the NISFD project. By storing the inexhaustible supply of solar energy as chemical energy in the form of fuels, CO_2 can be transformed from being the biggest climate challenge into a valuable raw material. The fuels can be stored and transported using the existing infrastructure and therefore this efficient use of CO_2 can also relieve pressure on the world's existing bioenergy resources.

The NISFD project may prove very beneficial for the future development of CRI's methanol process, "Emissions to Liquid", at the plant in Svartengi in Iceland, which has led to the commercial product called Vulcanol. The process uses CO_2 from point sources and Iceland's environmental friendly geothermal energy to produce methanol for use as environmental friendly transportation fuel. Even though the electrolyzes process is becoming ever more efficient and durable, in the long term CRI would like to change the existing electrolysis process to direct conversion of solar energy. Implementing results from the NI-SFD project Oddur Ingolfsson is looking forward to achieving this goal within the "foreseeable future".

Photo: CRI

The George Olah Plant in Svartsengi, which has a production capacity of 5 mill. litres a year, is the first plant in the world to produce sustainable methanol using CO_2 as the raw material.

Facts

- In 2011, the "Nordic initiative for solar fuel development" (NISFD) project was granted funding from the Nordic Energy Research programme; Sustainable Energy Systems 2050.
- The project has a total budget of NOK 16.25 mill., of which around 60% is being funded by Nordic Energy Research.
- The project is being headed by Chalmers University of Technology (Sweden) with the following partners:
  - University of Oslo (Norway)
  - DTU (Denmark)
  - University of Iceland and Carbon Recycling International (both Iceland)
  - Aalto University (Finland)
  - Ulm University (Germany)

CARBON RECYCLING INTERNATIONAL

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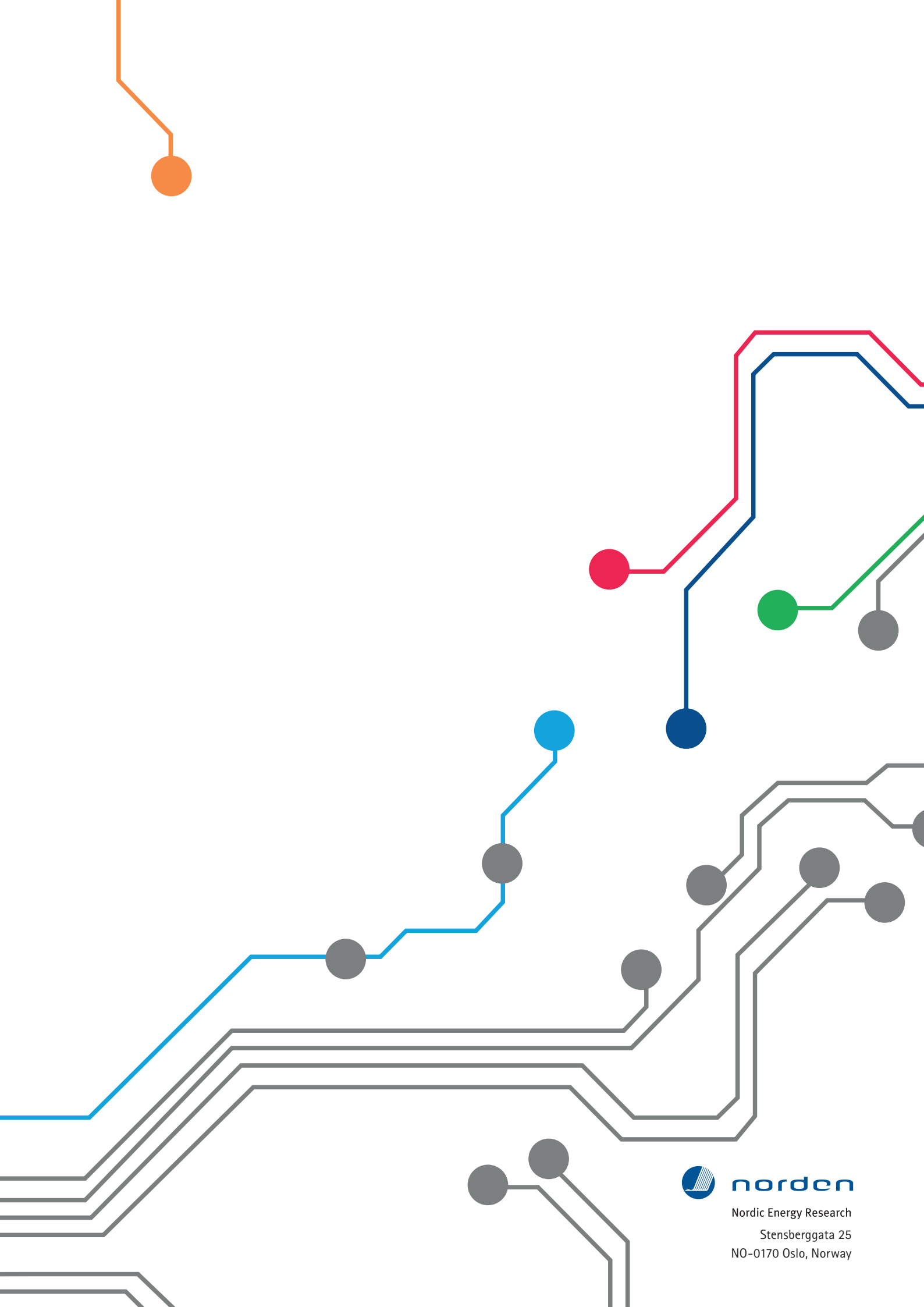

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