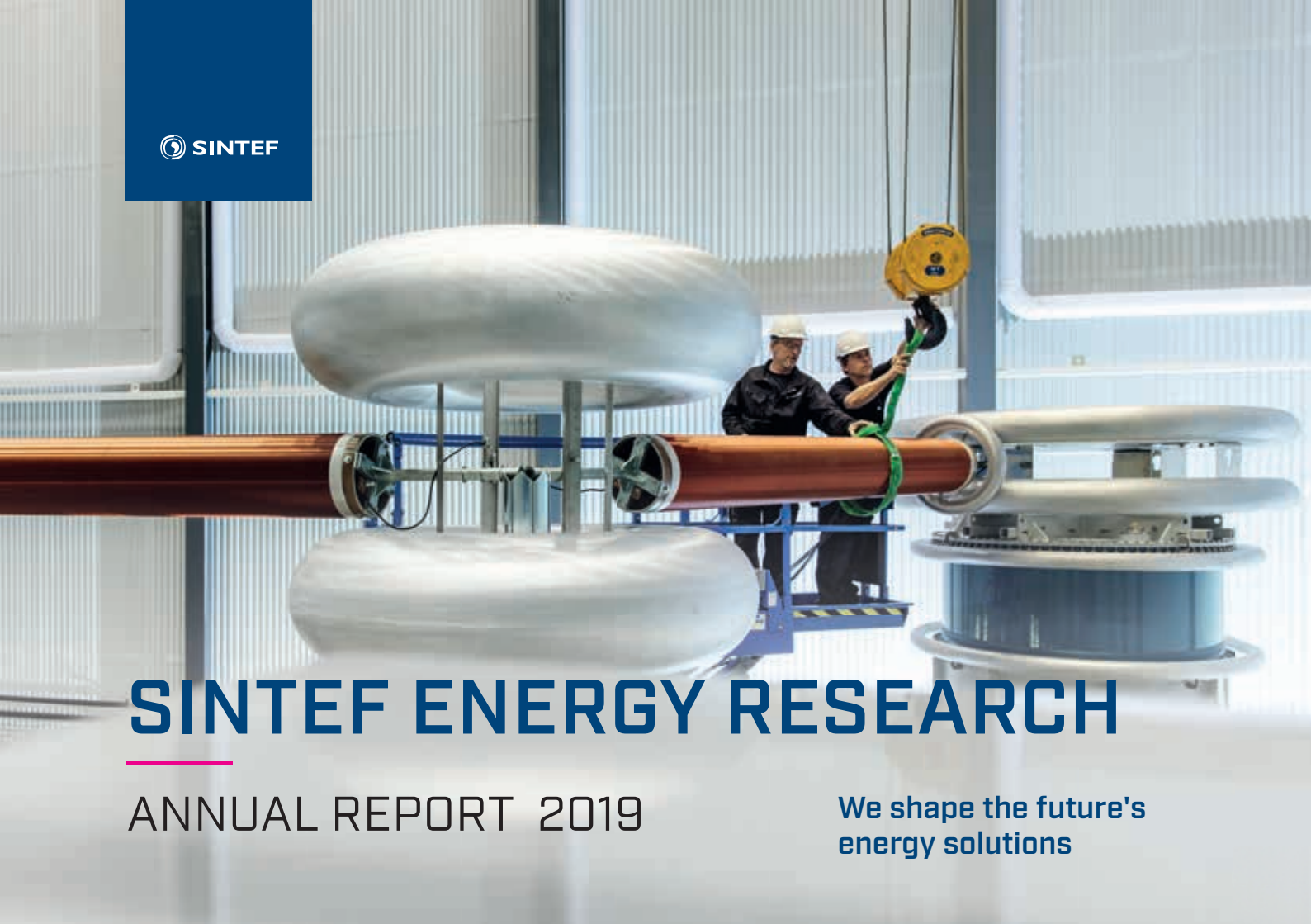


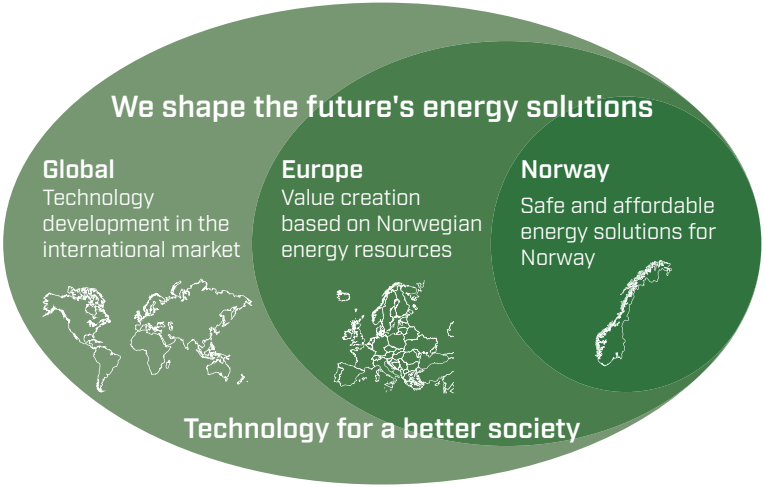
SINTEF

SINTEF ENERGY RESEARCH

ANNUAL REPORT 2019

We shape the future's energy solutions

Who we are and what we do



SINTEF Energy Research is an applied research institute dedicated to creating innovative energy solutions. We offer cutting-edge research-based knowledge and infrastructure both in Norway and globally with the aim of providing our clients with added-value solutions and services. SINTEF Energy Research is part of the SINTEF Group, which is one of Europe's largest independent contract research centres.

With the aim of supporting the UN's Sustainable Development Goals, SINTEF Energy Research carries out world-leading research in fields such as offshore wind, solar energy, bioenergy, batteries, smart grids, electrical power components, hydropower market modelling, energy efficiency, zero-emissions transport, hydrogen, CCS, and low-emission oil and gas production. We work closely with industry to boost Norwegian competitiveness in global markets. We offer world-leading laboratories and test facilities, supported by state-of-the-art digital software and systems. We occupy a strong position in the EU's Framework Programme and are involved in six of the Research Council of Norway's Centres for Environmentally-Friendly Energy Research (FMEs). We also act as coordinator for LowEmission, a recently established centre promoting research into low-emission oil and gas production on the Norwegian shelf.

Cover photo: Senior technician Morten Koksæther and senior engineer Erik Bjerrehorn working in the high voltage hall at the SINTEF Energy Lab.


SINTEF Energy Lab

Our effort to mitigate climate change

The Covid-19 pandemic and its health-related and economic impacts present us with an entirely new global challenge. It has also illustrated how intense levels of international research and development will aid in halting its spread. The challenge of climate change must also be addressed globally, and collaborative international research will be decisive in this area. The work carried out by SINTEF Energy Research and our partners during 2019 clearly demonstrates that we have made a major contribution in the collective effort to address this challenge.

The current energy system is the main contributor to greenhouse gas emissions. This means that the key solution lies in more sustainable energy systems.

In 1987, the UN published a report “Our Common Future”, drafted by the Brundtland Commission which was chaired by a former Norwegian Prime Minister, Gro Harlem Brundtland. This report first used the term "sustainable development", defining sustainability in three aspects: climate and the environment, economics, and societal factors.

As the years went by, the concept of sustainability became overshadowed by other global challenges. However, in 2015, the UN announced its Sustainable

Development Goals, and in the same year, the Paris Agreement was signed. The sustainable development goals have led to a realisation by both public authorities and commercial businesses that action has to be taken. If their activities are to keep growing and remain profitable in the long-term, new strategies must be developed.

Now, there is a sense of urgency. We have only ten years left in which to achieve the UN's goals. In the last couple of years, we have started to see that young people are losing their patience. This is important because it is their future at stake. Even in the face of other issues such as the Covid--19 pandemic, climate change remains one of the biggest global challenges that has to be addressed by all of us, together.

In our collective effort to mitigate climate change, we need to use all the tools available to us. At SINTEF Energy Research we have many tools to offer, and many of them are described in this report.

SINTEF Energy Research is an important, progressive research institute, and what we do is meaningful. We continue to grow, and in 2019 we once again delivered an excellent financial result. In collaboration with our Norwegian and overseas partners we are shaping a more sustainable future for us all.

Inge R. Gran,
CEO SINTEF Energy Research

Our 10 areas of focus

Smartgrids

Transmission

Offshore energy system

Offshore wind

Hydrogen

Energy efficiency in industry

CCS

Hydropower

Bioenergy

Zero-emission transport

SINTEF Energy Research and the UN's Sustainable Development Goals

SINTEF's vision of "technology for a better society" and the objectives of SINTEF Energy Research are focused on shaping the sustainable energy solutions of the future. Sustainability is at the heart of all our research activities.

The UN's Sustainable Development Goals represent a global joint strategy to eradicate poverty, combat inequality and arrest climate change by the year 2030. The UN has defined 17 sustainable development goals, and SINTEF Energy Research is contributing towards many of these. SINTEF Energy Research focuses on these UN sustainable development goals:

Affordable and clean energy

To ensure access to affordable, reliable, sustainable and modern energy for all

It is crucial that our research into various energy solutions contributes towards achieving a low carbon footprint and high levels of supply security, but it is also important that the solutions are both efficient and economically viable. The vast majority of our research projects contribute towards achieving this goal.

Climate action

To take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy

It is important to limit the global average rise in temperature to 1.5°C above pre-industrial levels if the planet is to avoid the worst impacts of climate change. Our work with innovative and sustainable solutions to replace less eco-friendly systems, and with emissions-reducing solutions, is making a direct contribution to the achievement of this goal.

Industry, innovation and infrastructure

To build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation

A well-functioning energy supply infrastructure, both onshore and offshore, is key to the maintenance of a robust society. Many of the projects carried out by SINTEF Energy Research contribute towards the development of a resilient energy infrastructure and a more innovative industrial sector. Many of our projects that promote industrial energy efficiency make an active contribution towards more sustainable industrialisation processes.

Sustainable cities and communities

To make cities and human settlements inclusive, safe, resilient, and sustainable

SINTEF Energy Research is working to promote smart cities and low-emission transport solutions that will contribute to more sustainable cities with more resilient infrastructures.

Life on land

To protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

SINTEF Energy Research is working to develop energy solutions that safeguard the natural world. We have accumulated extensive experience in this field in connection with our hydropower projects.

These four examples illustrate how we contribute towards achievement of the UN sustainable development goals

#1
Hydropower

Our hydropower production scheduling models contribute to the achievement of many of the UN sustainable development goals. Our models ensure that hydropower systems are operated with high profitability and optimal use of resources, while at the same time safeguarding local ecosystems in and around regulated river systems. Our models promote the added value of renewable energy generated from hydropower. They also enhance flexibility, making it possible to exploit other renewable energy sources such as wind and solar power.

Read more about this here:
blog.sintef.com/sintefenergy/hydropower/shop-hydropower-scheduling-creates-value

#2
SF_6

SF_6 (sulphur hexafluoride) is a powerful greenhouse gas that exacerbates global warming. Considering a 100-year perspective, SF_6 has a warming potential that is between 22,000 and 23,500 times greater than CO_2. SF_6 is used in equipment such as electrical switchgear. In collaboration with the energy sector, SINTEF Energy Research is working to regulate the use of SF_6 by gathering and reporting emissions data through its participation in the "Gas-Insulated Switchgear User Group". The EU and other organisations are currently evaluating the possibility of a future ban on the use of SF_6 in low- and medium-voltage switchgear. However, this cannot happen unless effective alternatives are available such as vacuum technologies or more eco-friendly gas mixtures. For this reason, we are also working to identify alternatives to SF_6.

#3
Refrigerant applications of CO_2

According to the Drawdown project, the single most important action that can be taken to mitigate climate change is to replace refrigerants in air conditioning systems, heat pumps and refrigeration units. HFC gases make a powerful contribution to the global greenhouse effect and are still widely used in such systems across the world. A phasing down of the use of HFCs has the potential to save as much as half a degree of global warming. Since the 1980s, SINTEF and NTNU have jointly been conducting research into the use of CO_2 as a natural refrigerant (not in this context a greenhouse gas). We have assembled world-leading research teams in this field that have developed technologies for application in the majority of Norwegian supermarket chains, some European supermarket chains, and in six million Japanese heat pumps. We also participate in projects that plan to introduce the technology to India.

Read more about this here:
www.sintef.no/en/latest-news/co2-refrigerant

Ranisha S. Sitlapersad.

#4
CCS

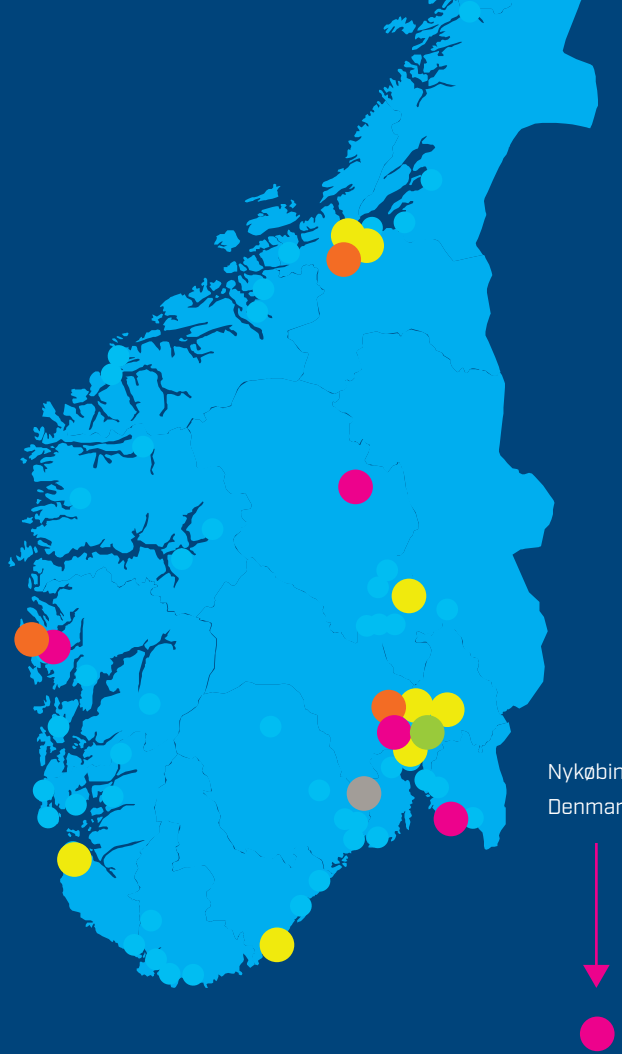
The term CCS covers a set of technologies involving the capture, transport and safe storage (or sequestration) of CO_2 in underground reservoirs. In order to limit the average rise in global temperatures to 1.5°C, it will not be enough to reduce emissions. In the future, we will have to remove them from the atmosphere too. CCS is the only technology that offers sectors such as steel, fertiliser and cement manufacturing an opportunity to achieve net-zero CO_2 emissions. CCS can also offer negative emissions in situations where, for example, CO_2 is extracted from biological waste. CCS also offers the potential to remove CO_2 emissions from natural gas sources, with pure hydrogen as the end product. In collaboration with NTNU, SINTEF has established world-leading research teams in the field of CCS and has been working on these issues since the 1980s.

SINTEF Energy Research has clients and projects all over Norway and across the world

EXAMPLE:
Wood-burning stoves in Otta, Oslo, Fredrikstad and Nykøbing in Denmark

EXAMPLE:
ArbaFlame – from Norway to Europe

EXAMPLE:
Testing batteries in the electricity grid



EXAMPLE:
GoNorth

Svalbard

EXAMPLE:
Tomorrow's medium-voltage load switches for ABB

Find out more about the cases on
www.sintef.no/energy_2019


House of Research & Innovation
Norwegian House of Research & Innovation
NTNU
SINTEF
#NOHRI

SINTEF Energy Research is very active in global research – especially in Europe

In order to contribute towards meeting the UN's Sustainable Development Goals, as well as the needs of the industrial markets, it is important that our research activities attain the highest global standards and that they contribute towards building alliances with overseas partners. The close collaborative relationship that SINTEF Energy Research enjoys with its industrial clients provides us with a sound basis for the exploitation of global market opportunities, especially those offered by EU research programmes. This is why SINTEF Energy Research has had an office in Brussels since 2015. 13% of the institute's sales are generated from foreign organisations, most notably from the EU and USA.

SINTEF Energy Research is closely involved in global collaborative research as part of organisations such as the European Energy Research Alliance (EERA) and a number of the EU's technology platforms. We are also involved in CIGRÉ (the International Council on Large Electrical Power Systems). In May 2017, Nils A. Røkke, who is Executive Vice-President for Sustainability at SINTEF, was appointed to head the EERA, an organisation that represents more than 55,000 European energy research scientists.

« From left: Bjarne Foss, Pro-Rector for Research, NTNU; Margareth Hagen, Pro-Rector, University of Bergen; Alexandra Bech Gjørv, President & CEO, SINTEF; Elisabeth Maråk Støle, CEO, NORCE. The picture was taken on May 3, 2019, at the opening of the new joint Brussels office, shared by SINTEF, NTNU, University of Bergen and NORCE.

HighEFF **World's cleanest industry**

-30%

Specific energy consumption

FME
FORSKNINGS-SENTER FOR MILJØVENNLIG ENERGI
Norges forskningsråd

SINTEF Energy Research hosts three Norwegian Centres for Environmentally-Friendly Energy Research (FMEs)

FME NCCS

The main objective of NCCS is to apply industry- and research-driven innovation to bring about the rapid implementation of carbon capture, transport and storage (CCS) technologies. NCCS shall also ensure that Norway remains a global leader in the field of CCS and shall contribute towards achieving the large-scale storage of CO_2 in North Sea reservoirs.

Read more about the centre and its achievements in 2019.
www.nccs.no

FME HighEFF

HighEFF develops knowledge and technology that will promote more energy-efficient, competitive and environmentally-friendly industrial processes at equipment, factory and regional scales.

Read more about the centre and its achievements in 2019.
www.higheff.no

FME CINELDI

Research carried out at CINELDI into future smart energy systems facilitates the feeding of greater volumes of renewable energy into the electricity supply grid, the electrification of transport, and the more efficient use of energy both in private households and by industry.

Read more about the centre and its achievements in 2019.
www.cineldi.no

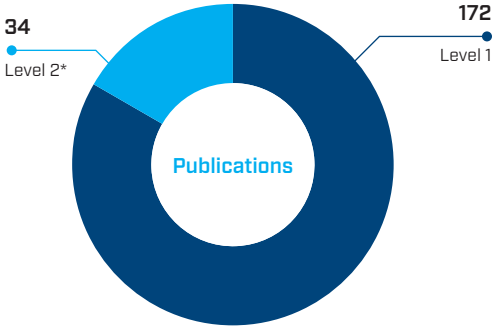
LowEmission

The centre began in 2019 and will last for 8 years. The centre will develop new technologies and concepts for offshore energy systems, energy efficiency and integration of renewable energy technologies for implementation on the Norwegian continental shelf.

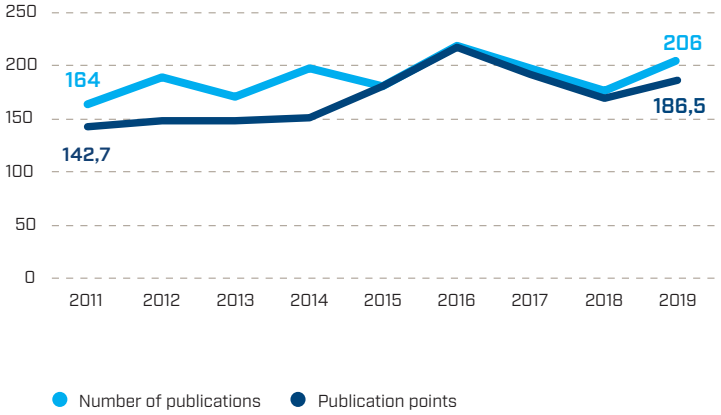
Read more about the centre and its achievements in 2019 at:
www.lowemission.no

Photo: Equinor

2019 was another excellent year for scientific publications produced by the institute

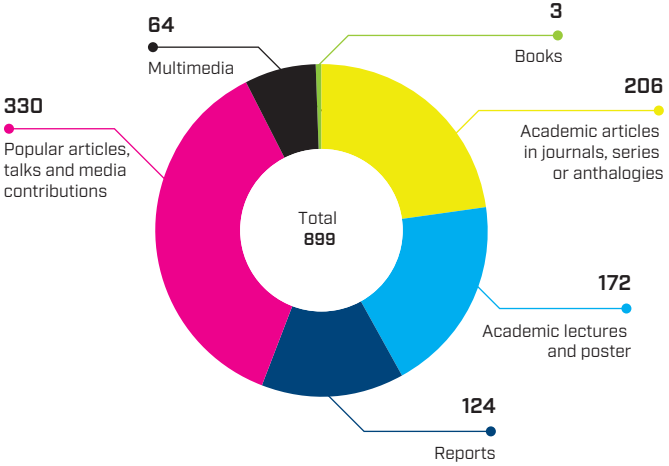


* The Norwegian scientific index divides journals and publishers into "level 1" and "level 2", where level 2 is reserved for the most prestigious international journals. No more than 20% are at level 2.



Publications

(including popular disseminiation)



A selection of scientific articles published in 2019

Norway as a Battery for the Future European Power System – Comparison of Two Different Methodological Approaches I: Proceedings of the 6th International Workshop on Hydro Scheduling in Competitive Electricity Markets. Springer Nature 2019 ISBN 978-3-030-03311-8. pp. 76-83

Graabak, Ingeborg; Jaehnert, Stefan; Korpås, Magnus; Mo, Birger.

This article compares results from two stochastic electricity market models (EMPS and SOVN). The comparison addresses a future European scenario in which the energy mix exhibits a high proportion (61%) of renewable energy generation from intermittent sources such as wind and solar. The article addresses a number of installed capacity scenarios in Norwegian hydropower plants, and the differences between the models are described together with a presentation of the absolute numerical results for each model.

Equation of state and force fields for Feynman–Hibbs-corrected Mie fluids. I. Application to pure helium, neon, hydrogen, and deuterium https://doi.org/10.1063/1.5111364

Ailo Aasen, Morten Hammer, Åsmund Ervik, Erich A. Müller, Øivind Wilhelmsen**.**

A fundamental study that addresses quantum effects in the description of the thermodynamic properties of a selection of different gases. The study is relevant and future-oriented with a view to the liquefaction of hydrogen.

Dynamic modelling of a refrigerated cabinet with integrated phase change material thermal storage. 25th IIR International Congress of Refrigeration Proceedings. International Institute of Refrigeration 2019 ISBN 978-2-36215-035-7.

Jokiel, Michael; Banasiak, Krzysztof; Kauko, Hanne; Sevault, Alexis.

Phase change materials (PCMs) can be used to store thermal energy in refrigeration units in supermarkets. PCMs offer major potential for energy savings and more evenly regulated refrigeration temperatures. The design and operational strategies of a PCM-enhanced refrigeration system were assessed using a Modelica model. This research work is continuing at SINTEF Energy Research using a PCM refrigeration system set up in a laboratory, constructed in the light of the modelling results.

Compatibility of liquid and solid insulation materials for high voltage subsea connectors. IEEE transactions on dielectrics and electrical insulation 2019; Volume 26 (4), pp. 1139-1145

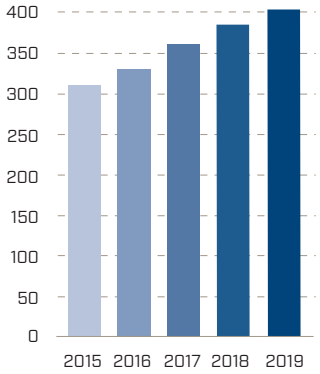
Lesaint, Cedric Michel; Hølto, Jorunn; Sæternes, Hans Helmer; Ese, Marit-Helen Glomm.

This article addresses a compatibility study of insulation materials used in high-voltage subsea connectors. Many combinations of solid and liquid insulation materials were aged under realistic conditions of pressure, temperature and moisture content for a period of three years. During the ageing process, samples of the materials were tested at regular intervals in order to measure changes in their mechanical and thermal properties. In this study, the researchers observed only very minimal effects in response to hydrostatic pressure. However, moisture saturation of a particular insulation fluid (a synthetic ester), in combination with high temperatures, resulted in the considerable degradation of certain solid insulation materials that were in contact with the fluid. This is an important finding because materials selection is crucial to the functionality and lifetime of this type of high-voltage component.

Key numbers 2019

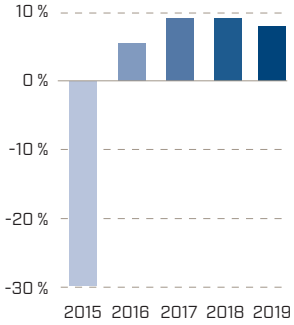
Net operating income

(MNOK)



Net operating margin

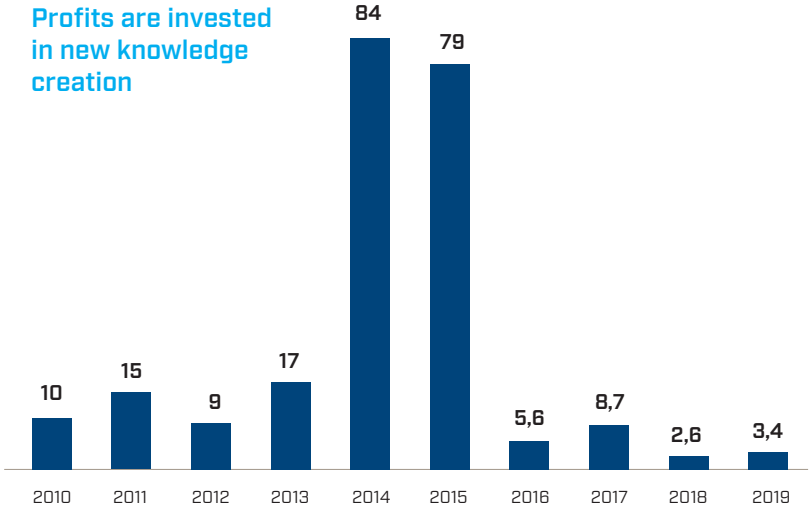
(%)



Note: The deficit in 2015 was due to a one-off accounting change related to the transition from defined benefit pension to hybrid pension.


HIGH
VOLT

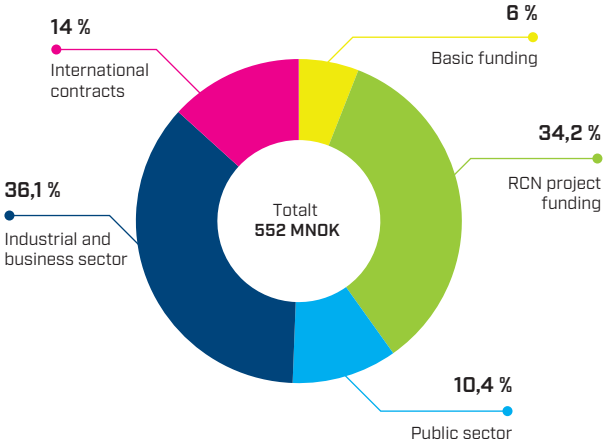
Profits are invested in new knowledge creation



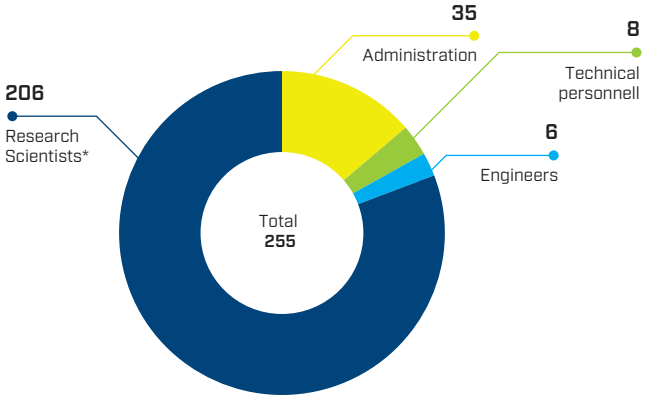
SINTEF Energy Research's profits are invested in laboratories, scientific equipment, facilities and the development of new knowledge. The accounts show an investment of NOK 234 million over the last ten years.

Sources of finance

(% of gross operating income)



Employees



* 130 Research scientists with PhD

Finances

MNOK	2015	2016	2017	2018	2019
Result					
Gross operating income	397	439	438	494	552
Net oprating income	310	331	362	385	403
Operating result	**(92)**	**18**	**33**	**35**	**32**
Annual result	**(63)**	**14**	**28**	**28**	**32**
Balance					
Fixed assets	252	237	221	210	202
Current assets	292	288	384	408	470
Sum assets	**544**	**524**	**605**	**618**	**672**
Equity capital	325	339	368	396	428
Liabilities	219	185	237	222	244
Sum equity and liabilities	**544**	**524**	**605**	**618**	**672**
Profitability					
Operating margin %	-29,7 %	5,4 %	9,1 %	9,1 %	7,9 %
Total profitability %	-15,2 %	4,6 %	7,0 %	6,5 %	6,4 %
Profitability of equity capital %	-27,0 %	6,1 %	10,6 %	10,0 %	10,1 %
Liquidity					
Net cash flow from operational activities	49	33	98	14	57
Degree of liquidity	1,3	1,6	1,6	1,8	1,9
Solidity					
Equity capital %	59,7 %	64,7 %	60,8 %	64,1 %	63,7 %
Operating working capital	74	104	148	187	227

LOWEMISSION

Low Emission- Moving towards Zero Emission Oil and Gas Production

Energy Change Conference @ Trondheim Kommune, Trøndelag Fylkeskommune, Stjørdal kommune
Oct 23, 2019

Marit Jagtøyen Mazzetti
Centre Manager and Acting Director, LowEmission

SINTEF NTNU

LOWEMISSION

Highlights from 2019

January 2019

In 2018, SINTEF and NTNU launched the development of a joint profile template, which was completed in the spring of that year and put on show at the thermal power engineering laboratories. The photo shows an "innovation safari", designed for politicians and clients who often visit the laboratory.

February 2019

On Friday 18 February, the Research Council of Norway presented the Norwegian Ministry for Petroleum and Energy with a report showing that investment in energy-related research during the last ten years has proved to be highly profitable. The presentation took place at the SINTEF Energy Lab in connection with a ministerial visit. The report showed that NOK 4 billion has been invested in renewable energy projects over the last ten years. Qualitative gains were also achieved in the form of security of supply, knowledge development and,

FME Leaders with representatives from the Norwegian Ministry for Petroleum and Energy at the launch of the Impact Study. »

not least, climate change mitigation. The various FME centres provided data to support the conclusions contained in the report.

March 2019

A new joint Swedish-Norwegian research project coordinated by SINTEF will look into the possibilities and costs of transporting CO_2 captured in Sweden for storage in reservoirs on the Norwegian shelf. This is the first project to ever investigate this possibility. The aim is to investigate the possibilities of establishing a full-scale facility for the capture and transport of CO_2 from the Preem refinery and wet gas plant at Lysekil. The project would reduce CO_2 emissions by up to 500,000 tons per year, and the demonstration plant is a step towards establishing a full-scale facility by 2025.

Preem's refinery. »

April 2019

Coordinated by SINTEF, the Energytics project arranged a hackathon event for students on 25 April. 28 students from NTNU and the University of Tromsø took part. They worked together in seven groups using data obtained from smart meters, meteorological data, measurements taken from household devices, and electricity prices. Their task was to create something innovative from this data, either in the form of a new business idea or programming code that would be of value to electricity customers.

May 2019

John Olav Tande, an offshore wind technology researcher, was selected as a Norwegian Mission Innovation Champion. The Champions received their honours at the fourth Ministerial Meeting in Vancouver, Canada, on Monday 27 May. The prize was inaugurated by Bill Gates and former US President Barack Obama, among others, during the COP 21 Climate Change Summit in Paris in 2015. The prize is awarded to people that develop future products and services in response to climate change challenges.

During a long and productive scientific career, Senior Research Scientist John Olav G. Tande has made significant contributions to developments in the field of obtaining clean energy from offshore wind, especially in connection with the concept of floating wind farms. Tande's achievements have made a huge impact on scientific advancement in this field, resulting in proven cost reductions within the industry.

John Olav Tande.

John Olav Tande.

May 2019

After several years of commissioning and subsystem testing, the new NorBioLab gasification reactor is now operational at the SINTEF Energy Lab at Blaklia in Trondheim. The reactor enables the conversion of biomass into sustainable fuel.

Results from the reactor are already being used as input to three parallel projects; GAsPro (a researcher project), Bio4Fuels (an FME centre) and GAFT (a knowledge and skills development (KPN) project). Funding was in place in 2014, both from in-house sources and from the Research Council of Norway via the research infrastructure project NorBioLab. NorBioLab is led by the Norwegian Paper Industry Research Institute (Rise PFI), in collaboration with NTNU, SINTEF Energy Research and the Norwegian University of Life Sciences (NMBU).

From left: SINTEF employees Franziska Kausch, Morten Seljeskog, Jørn Bakken and Roger Khalil.

Former Petroleum and Energy Minister Kjell-Børge Freiberg.

June 2019

The new LowEmission research centre was opened on 14 June. The Norwegian Minister for Petroleum and Energy cut the tape with research scientists and project partners looking on. In the lead up to 2050 the centre will develop new knowledge and technologies that will be applied to reduce greenhouse gas emissions from the Norwegian oil and gas sector to zero. The targets also include a reduction of 40 percent by 2030.

The Norwegian Ministry of Petroleum and Energy, via the Research Council of Norway, is providing NOK 120 million in public sector funding to support research carried out at the centre. Oil companies and industry suppliers are also contributing with private sector funding. The total budget for the centre is close to NOK 350 million over a period of eight years.

June 2019

TCCS-10, also known as the Trondheim CCS Conference, was held with the aim of addressing carbon management and CCS issues. Arranged jointly by NTNU, SINTEF and FME NCCS in June every second year, TCCS attracts more than 400 CCS researchers from around the world. There were ten keynote speeches, more than 100 presentations and approximately 150 posters. The conference was held over two days, followed by a Mission Innovation workshop with CCS as its key topic.

Nils A. Røkke, Executive Vice President Sustainability, SINTEF.

Mona Jacobsen Mølnvik, Research Director and NCCS Centre Director.

July 2019

In 2019, for the thirteenth successive year, SINTEF Energy Research welcomed students to work as researchers during the summer. The institute received 248 applications for 26 summer internships. The students get to work on real research projects under the guidance of a mentor from SINTEF Energy Research. The internships provide an important opportunity for network building and skills development, and for publication and dissemination on the part of SINTEF Energy Research. An open technical seminar was held on completion of the internship period. One of the aims is that all students produce a draft of a scientific publication together with one of our researchers.

August 2019

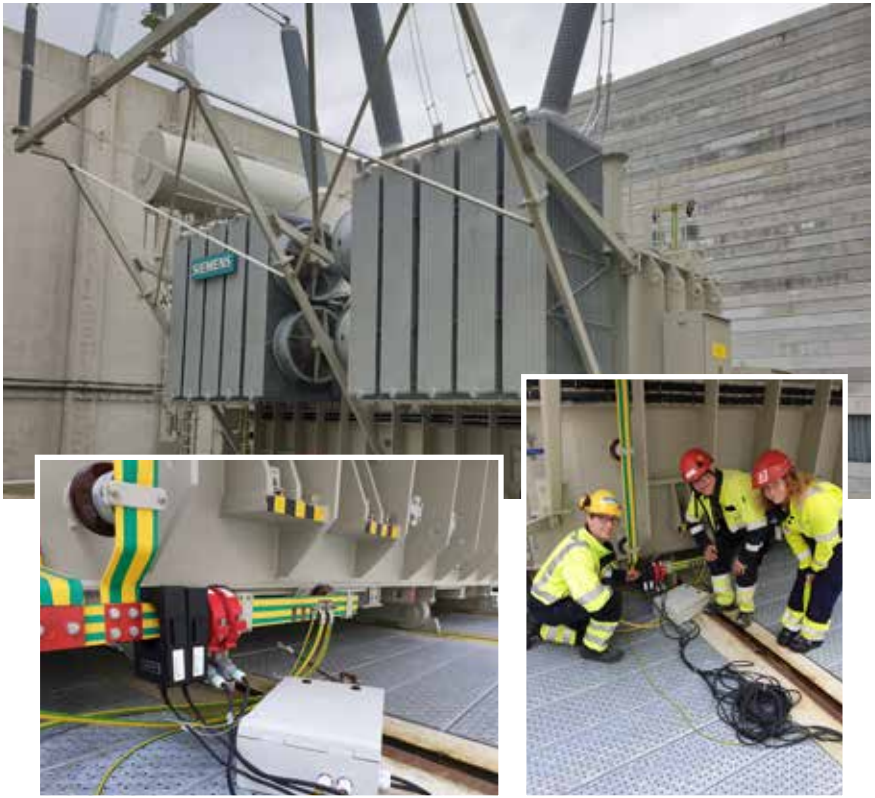
During the annual Arendal Political and Business Forum (*Arendalsuka*), SINTEF and NTNU held a presentation on sustainable wind power development in Norway. The talk drew a lot of attention, resulting in a 10-minute feature on the *Dagsrevyen* TV news programme on 13 August.

The TV studio introduced the message behind the presentation, and reporter Jon Gelius read out our three pieces of advice. Senior Research Scientist John Olav Tande answered a question about why Norway should be investing in wind power now, and how it should be developed in a way that safeguards the natural world and other interests. Kjell Børge Freiberg, the Minister for Petroleum and Energy, then explained how Norway will invest in offshore wind while at the same time safeguarding nature as part of its wind farm developments.

Images taken on 13 August from the TV news programme Dagsrevyen 21. »

September 2019

Kristian Thinn Solheim is coordinating an exciting project in which he, in collaboration with Statnett and the Norwegian Water Resources and Energy Directorate (NVE), aims to find out how it may be possible to prevent solar storms from interfering with electricity supplies. In autumn 2019, five different types of sensors were installed on a 420 kV transformer owned by Statnett. The sensors will serve to identify the links between the magnetic field created by solar storms and the influence it has on the electricity grid.



Pictures from the project. Picture below right: Thinn Solheim (SINTEF), Trondh Ohnstad (Statnett) and Astri Gillund (NVE).

October 2019

The ElPowerLab has acquired a new camera with the following features:

- one billion images per second
- a 3-nanosecond exposure time
- 12-bit resolution

SINTEF will use it to film ultra-fast phenomena such as arc flashes. The camera, which will be used for research into the reliability of electrical power components, has now been installed and is available to researchers working on relevant projects. The camera is funded by the Research Council of Norway's INFRASTRUKTUR fund, which focuses on investments in research infrastructure.

November 2019

SINTEF's Executive Vice-President for Sustainability Nils Røkke is a highly regarded commentator on the global stage in the field of energy research issues such as hydrogen and CCS.

Facsimile from www.euractiv.com og www.rechargenews.com.

December 2019

The Hyper project was designed to investigate the potential of producing large volumes of hydrogen in Norway for export to markets in Europe and Japan. Results showed that there is massive potential in the low-emissions production of hydrogen in Norway, both from natural gas using CCS technology and from renewable energy sources. A conference was held in Brussels in December to mark the conclusion of the project, which was funded by the Research Council of Norway and private sector partners Equinor, Gassco, Shell, Linde Kryotechnik, Kawasaki Heavy Industries, Mitsubishi Corporation and Nel.

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