
LOWEMISSION
2020 ANNUAL REPORT

Contents

By numbers

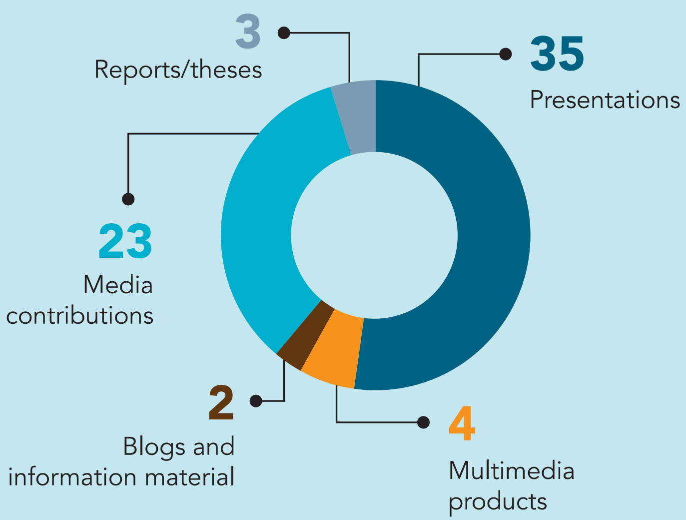
30
INDUSTRY PARTNERS

2
RESEARCH PARTNERS

316
MNOK

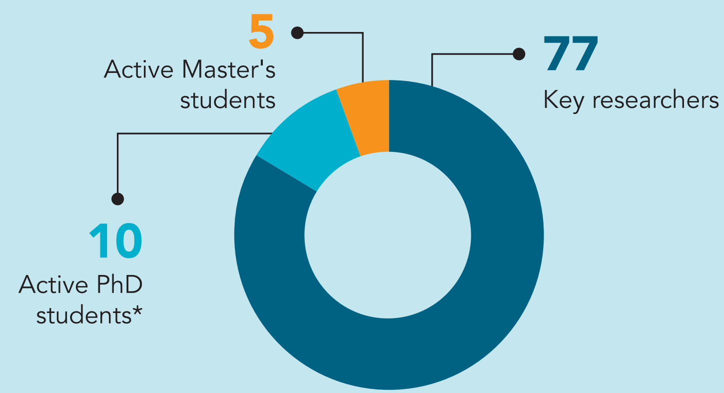
8
YEARS

Visibility*



*numbers for 2019-2020

Personnel

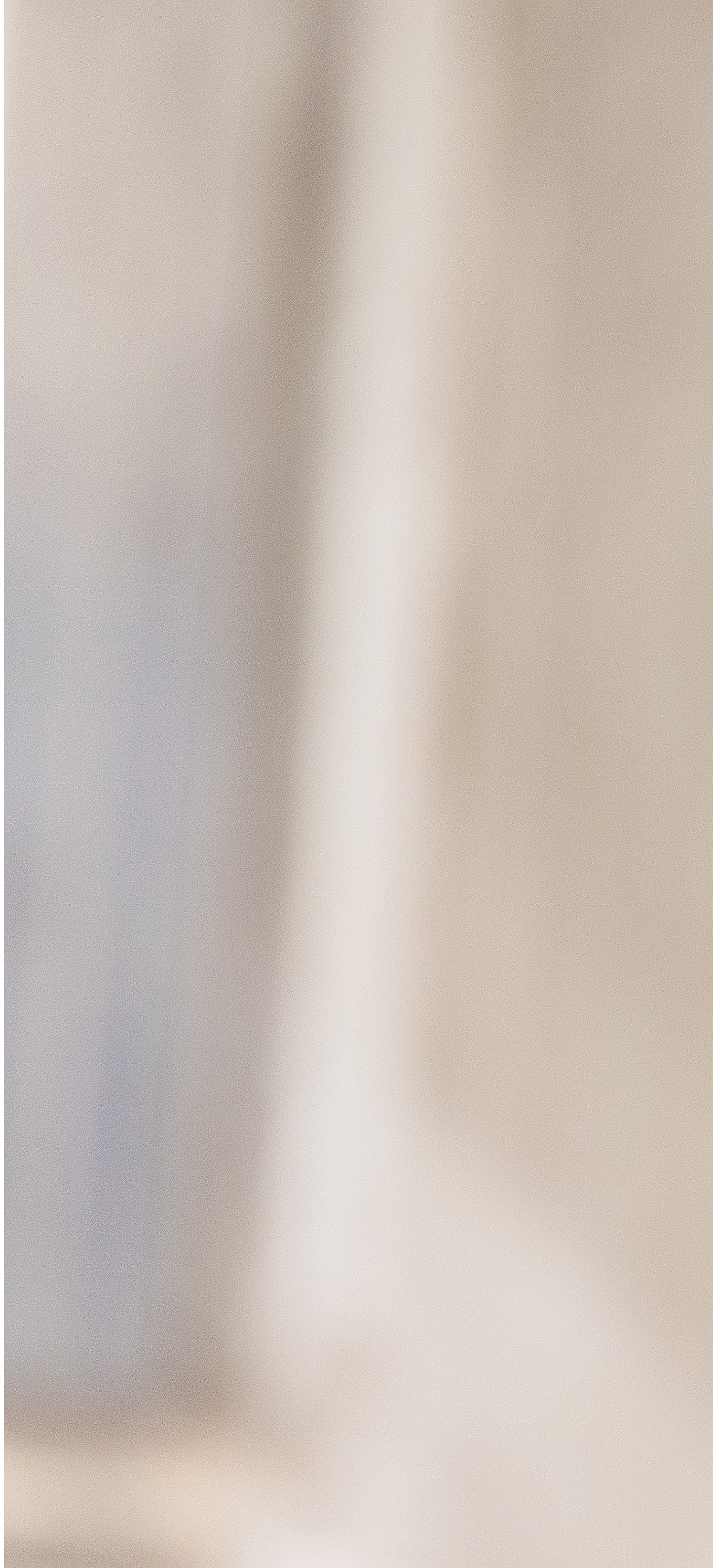


*with financial support from the Centre budget

About *LowEmission*

LowEmission is a research centre for low emission technology for petroleum activities on the Norwegian continental shelf (NCS). World-leading Norwegian and international industrial entities including vendors, operators and energy companies join forces with globally recognized research groups at SINTEF and NTNU, and other top-rated universities and research institutes. The mission is to pave the road towards zero-emission production of oil and gas from the NCS.

LowEmission develops new technology solutions and concepts for offshore energy systems and integration with renewable power production technologies. This will accelerate development and implementation of low-emission offshore technologies on the NCS. It will help Norwegian industry meet its 2030 goal of 50% reduction in greenhouse gas emissions – and move towards the 2050 goal of zero emissions from new facilities. *LowEmission* is a platform for innovation, and strong interaction within the Centre will generate spin-off projects and technology transfer possibilities for the industry.



SINTEF's high pressure combustion facility is used in the LowEmission Centre to investigate the characteristics of ammonia and hydrogen combustion from real gas turbine burners. It is important to measure how the flames behave in pressurised environments (like the inside of gas turbines) by studying their structure, stability and pollutant emissions. Here, Chief Scientist Mario Ditaranto adjusts the optical instrumentation to capture the flame emission spectrum from hydrogen – ammonia – nitrogen mixture flames.

2020 achievements

We have now been operating for about a year and a half, and despite 2020 being challenging due to the ongoing Covid-19 pandemic, work has caught up pace throughout the year. There have been no significant effects on deliverables, despite temporary delays in laboratory work in some of the SINTEF/NTNU labs. This was made possible thanks to the fantastic collaborative efforts of the *LowEmission* scientists and industry partners.

In fact, this year has been action-packed for the Centre. An impressive group of 10 PhD candidates started their research projects within *LowEmission* at NTNU, and we look forward to showcasing their research activities at future Centre meetings.

Another example is the well-received webinar series that ran last autumn, showcasing some of the work done in the Centre during the year, and the *LowEmission* Innovation Challenge, where industry partners are invited to present low emission-related challenges of specific interest to the scientists and the whole Consortium. Our hope is that the Innovation challenges will spur new ideas, inspire new activities within the Centre and even result in new spin-off projects outside the Centre. Furthermore, the Centre Management Team had several meetings with associated agencies, such as the Norwegian Oil and Gas Association, the Norwegian Petroleum Directorate and the Ministry of Petroleum and Energy, all of whom wish to follow up on the Centre's activities and engage in a continuous dialogue on technology development and the outlook for emissions reductions in the petroleum sector.

The Technical Committee of Innovation and Commercialisation is also up and running, consisting of 13 technical experts from operators and vendors in the Centre. This year, the Committee contributed heavily to evaluating case study suggestions and annual work plans.

The *LowEmission* subproject 6 – Case studies and Innovation, has a budget to be allocated every year to case studies, where for example technology solutions developed in the other subprojects can be implemented on specific platforms, fields or other real-life scenarios. The Technical Committee of Innovation and Commercialisation selected 5 case studies out of 19 suggestions to receive funds in 2020. The results from the case studies are being disseminated through webinars and blogs, in addition to being summarized in a deliverable found on the Research Council of Norway's project bank.

LowEmission aims to generate 26 spin-off research projects during its lifetime, and in 2020, *LowEmission* generated spin-off activities in the form of 5 applications for Competence-building projects (KSPs), of which 2 received funding. All the 5 submitted applications can be found in the *LowEmission* eRoom, and we would once again congratulate the teams behind DIGITAL TWIN and OFFLEX on their winning proposals!

We have seen a great interest in the *LowEmission* Centre since its establishment and warmly welcomed seven new industry partners to the Consortium:

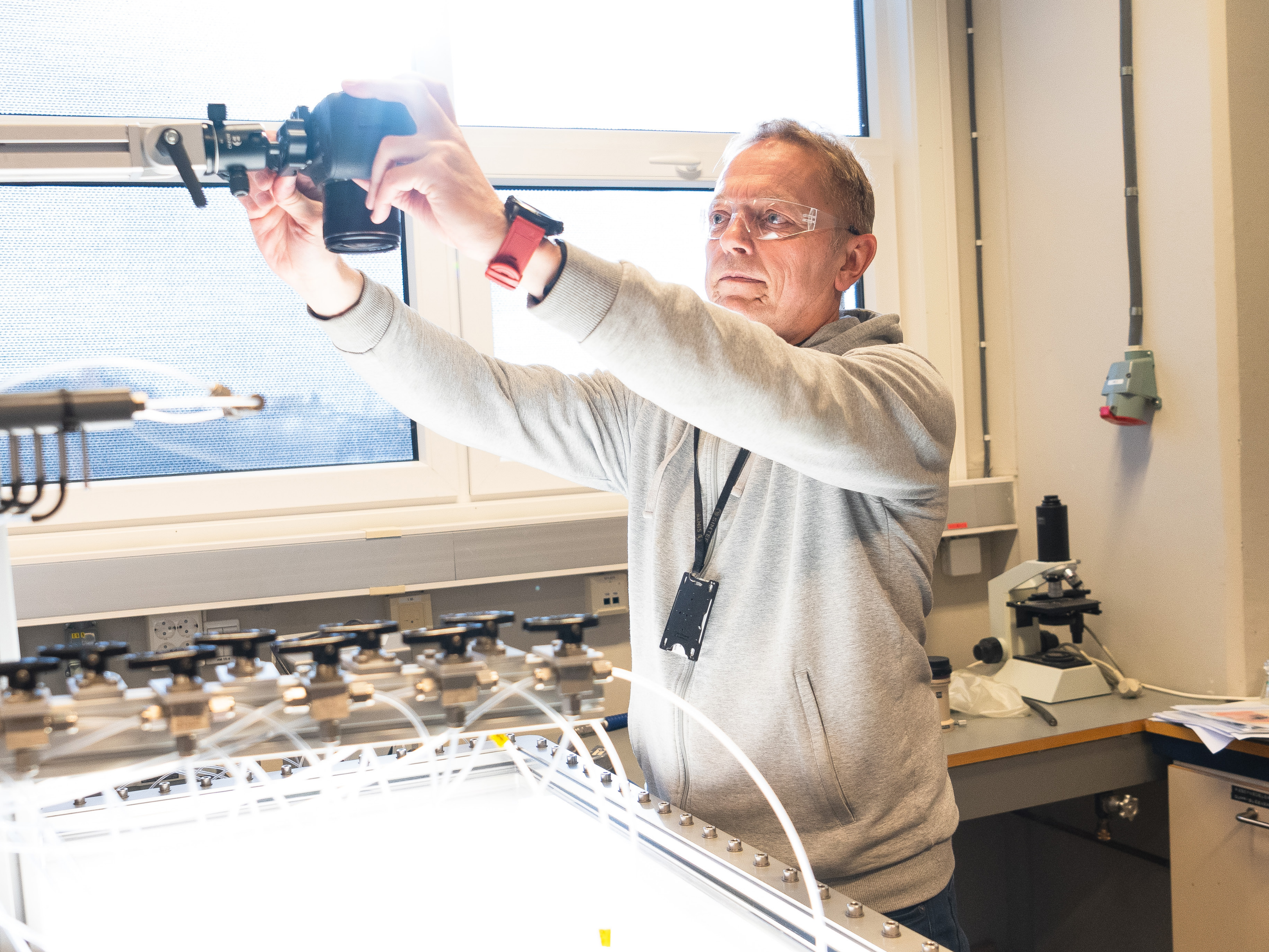
- ConocoPhillips
- Total E&P Norge
- Altera Infrastructure Production
- Borealis

- Nedstack Fuel Cell Technology
- Nexans Norway
- Odfjell Drilling

The new partners have brought significant added value to the Consortium, in form of technology expertise and support to specific subproject activities, participation in the Technical Committee, stimulating discussions and generating new ideas for research and spin-off activities.

The Consortium Day 2020 was a true highlight for the Centre and was held as an online event with both a morning and afternoon session on October 28th. Around 100 participants from research institutes as well as industry partners attended. A big *thank you!* to all who participated.

A good understanding of subsurface processes is required to find energy-efficient drainage strategies for oil and gas production, without jeopardizing the recovery. The Petroleum Department at SINTEF Industry has an advanced Reservoir Flow Laboratory for this purpose. In this picture, Per Bergmo (SP7-leader) is adjusting the camera of the Hele-Shaw cell made for studying multiphase flow in fractured rocks. The camera fixed above the cell takes a series of pictures during the experiment, which are later analysed using a specially developed image-processing software. The images are then used to quantify the speed of fluid displacement and the flow patterns developing underway. The fully transparent cell built at SINTEF is one of very few in the world of its size and capabilities, and gives important insights for production of oil and gas in naturally fractured reservoirs and for fluid flow in near-well regions where induced fractures may occur.



Renewed ambitions

2020 was a special year for everyone. For the *LowEmission* research centre, it meant making rapid adjustments to ensure continued progress despite a disruptive pandemic. Not only did the Centre manage this task, but it comes out of 2020 with even stronger ambitions than before. We sat down with Centre Chair Hege Rognø and Centre Director Malin Torsæter to get a fresh status update.

Nobody knew at the beginning of 2020 how different the year would turn out to be. "We were a bit worried about what the pandemic restrictions would mean for our research, particularly access to labs and such, says Centre director Malin Torsæter. But we're coming through it really well." She adds that though human contact is sorely missed in certain situations, digital solutions mean busy people can get through a lot quite quickly.

New goals

A major development in 2020 was the announcement by the Norwegian government that it would strengthen its emissions reduction target set under the Paris agreement. The target now calls for a 50% reduction in emissions by 2030 compared to 1990 levels – it was initially set at 40%. "This makes emissions from offshore activities an even more relevant topic to address", says Chair Hege Rognø.

The reinforced targets come together with a suggested raise in the carbon tax to 2000 NOK per tonne of CO_2 (from 590 NOK).

"These are positive developments, says Malin Torsæter. It makes our research all the more important and renders emissions reduction innovations even more attractive to use for the industry." She adds that she has seen a steady stream of new operators showing interest in joining the centre.

Innovation challenge

A popular new activity this past year was the Innovation challenge: a webinar in which certain industry partners were invited to challenge scientists with their real world problems. "This was an exciting and important activity for our partners", says Hege Rognø. The event was a success and will be repeated with other partners.

"The climate challenge we face is global and calls for cooperation. Open and transparent discussion is required. We need many tools, many solutions to reduce emissions", she adds.

Applied research

Among the many challenges faced by *LowEmission* scientists is not only finding solutions to reduce emissions, but bringing as many of them to a level of readiness where they can actually be used by the industry. "We're challenged from two sides, says Malin Torsæter. On the one hand is the government, setting new, more ambitious targets and consulting us about what's feasible. On the other hand is the industry – represented in our Technical Committee – always making sure the research is drawn in a direction that will be useful for them, resulting in practical and useable solutions. It's all very positive for our scientists."

"Emissions reduction is important for everyone, adds Hege Rognø. The EU. The whole world. The political pressure and the weight of public opinion in these matters are very present. And that's not just a positive thing; it's the way it should be."

Hege Rognø, Centre Chair

Hege Rognø has more than 30 years of experience in the oil industry, both from field operations, business development and technology development. She has international experience (UK, Australia) and from 2009 to 2012 she headed Equinor's East Coast Canada office in St. John's. Since 2016, she has been heading Equinor's technology development within Low Carbon Oil&Gas Technologies including Low Carbon Power&Heat solutions for offshore/onshore applications.

Malin Torsæter, Centre Director

Dr Malin Torsæter has over 10 years' experience as a scientist, senior scientist and research manager at SINTEF. She has managed several large national and international research projects with a high number of industry partners involved. Malin is the Manager of a group of 20 scientists and was elected Norwegian "Leader talent of the year" in 2017.

Vision and goals

Goals

LowEmission aims to develop technologies and solutions needed to reduce offshore greenhouse gas emissions on the Norwegian continental shelf by 50% within 2030 and to move towards zero emissions in 2050.

Subobjectives of *LowEmission* are to:

- Develop solutions for co-optimising power supply and demand in the offshore energy system
- Reduce cost of low emission oil and gas technologies by 5-50 %
- Develop a digital energy management tool for planning energy use of fields and the CO_2 footprint of operational choices over the life of the field including short- and long-term uncertainty
- Provide 10-15 innovative solutions for offshore emission reductions
- Generate 8 KPN, 10 IPN, 4 DEMO and 4 EU spin-off projects
- Educate 19 PhD/Postdocs, 30 MSc candidates, and train/recruit 20 experts in offshore low-emission technologies
- Disseminate and communicate project results in 70 journal and conference papers, present in O&G specific workshops and meetings such as ONS and OTC, and disseminate news articles
- Perform brown- and green-field case studies to demonstrate actual emissions reductions

The successful outcome of *LowEmission* will enable the industry partners to:

- Facilitate rapid deployment of low-emission technologies and system solutions that reduce offshore O&G-related GHG emissions
- Increase value creation in the Norwegian O&G industry
- Commercialise products based on *LowEmission* results in the international market
- Create new digitalised decision-support and planning tools for operators and vendors
- Perform relevant case studies with emphasis on the system perspective

Gender equality

All partners of *LowEmission* recognise the importance of gender aspects, and this focus is emphasised at all levels of the Consortium. The Centre encourages all partners to collectively achieve the EU target of recruiting at least 40% female staff in scientific positions.

The academic partners encourage female applicants through open announcements, striving for gender balance when employing PhD candidates and Postdocs. NTNU developed a plan for equal opportunities and recruitment of women to the university and encourages female professorships through mentor programmes and skill development.

Urgent innovation

The fastest way is to cooperate

In 2020, the Norwegian government announced that it would strengthen its commitment under the Paris agreement to reduce greenhouse gas emissions by 50-55 percent, by 2030.

- There is no way we can reach these goals unless we cut emissions on the Norwegian Continental Shelf (NCS), says William Christensen, Head of the Research and Technology Section in the Ministry of Petroleum and Energy (OED).

- And to develop the necessary technologies to cut the NCS' emissions, big, long term research and innovation centres like *LowEmission* are crucial, he adds.

How is *LowEmission* different from regular R&D projects?

- Everyone operating on the NCS shares a common goal: to significantly reduce their emissions by 2030s and to be as close as possible to zero emissions by 2050. And the fastest way to do that is for the industry to cooperate instead of everybody trying to figure out the best solutions on their own. That is why financing research centers like *LowEmission* through the Research Council of Norway is so important, says Christensen.

Gathering the whole industry under one roof has considerable advantages and should speed-up innovation according to Christensen.

- First of all, the scientists in *LowEmission* are very closely connected to the whole industry, not just one or two companies. This ensures that the work *LowEmission* does has the highest possible industry relevance. Secondly, *LowEmission* ensures an economy of scale, where each partner gets more out of every NOK invested in research than they would if everybody had to finance individual projects. Thirdly, I would like to point out the longevity of *LowEmission*. The long timeframe of the Centre opens research and innovation opportunities that shorter, smaller projects just cannot.

How do you expect research will contribute to realising the 2030 and 2050 goals?

- Research and innovation will be very important for both goals, but in different ways. We have to work on several fronts at the same time. In my experience, 10 years is rarely enough time to innovate, test, validate and implement new technologies, though it does happen. So, to reach the 2030 goals, implementing and improving existing technologies will be crucial, Christensen explains.

- But looking beyond 2030, we are heading towards zero emissions. And to get to zero emission we also have to come up with new, innovative solutions. I believe that the full potential and impact of *LowEmission*'s work will be seen in a 2040 perspective.

Kjell-Børge Freiberg, minister of Petroleum and Energy at the time, officially opens the LowEmission research centre in 2019 in front of a crowd of enthusiastic SINTEF and NTNU employees.

Jan Petter Pettersen, leader of the Technical Committee of Innovation & Commercialisation.

Photo: Geir Hole photography

Connecting industry and scientists

***LowEmission*'s Technical Committee of Innovation & Commercialisation managed just one in-person meeting before society largely shut down because of the Covid-19 pandemic. Nevertheless, the Committee's activities are well under way. We had a chat with the Committee's leader, Jan Petter Pettersen (Repsol).**

The Technical Committee is formed by members of the industry, and its purpose is to evaluate commercial potential and evaluate spin-off projects. As such, it serves as a link between the industry, with their needs and expectations, and the scientists, with their ideas for improving processes and technology. Making sure both sides understand each other becomes a natural part of the Committee's work.

"Industry people like to work with clear plans and have the details in place from the get go, says Pettersen. It makes sense from a financial point of view. But from a scientist's point of view, you can't bet all your coins on the same horse. Then you might end up in a dead end. You have to start wide and then, as things start to crystallise, you can direct your focus to the most promising avenues. So it's very much a learning process for both sides."

A learning curve

A research centre is a big ship to set into motion, and for some industry representatives, there is a learning curve. "Not everyone has been involved in such a large research venture before, and sometimes expectations need to be adjusted slightly, says Pettersen. Of course, scientists from the different subprojects have to listen to the industry, but it also goes the other way around. The industry has to find out what role it can play in the centre and work to ensure an optimal collaboration. This is what we're spending our energy on; to make sure we're on the right track."

The Committee already set up a schedule for the case studies, and is in the process of defining the criteria they will be evaluated on. There is also a meeting scheduled with the Norwegian CCS Research Centre's Technical Committee, to see if the *LowEmission* centre can learn from the carbon-capture centre's experience.

A delicate balance

One of the balances to strike is between improving existing installations and designing better ones for the future. "Coming from an offshore operator background, I'm very interested in how we can improve existing infrastructure – for example make the gas turbines less polluting. Of course if we want to reach the 2050 targets, we also have to think about future installations. The need to walk that line is why it's good for us, the industry, to be involved in establishing the strategy for the Centre."

Looking forward, Pettersen hopes to see a few exciting results and spin-off in the next couple of years. "It would be great to have a couple of success stories within that time frame. The 2030 and 2050 goals are long-term objectives, but seeing a spin-off take off with good involvement from the industry would be really motivating – like a sign that we're on the right track."

Our contribution to a more sustainable world

LowEmission's research in cleaner offshore energy systems and integration with renewable power production technologies contributes to reaching the UN's Sustainable Development Goals. The following three are the ones we deem most relevant to our areas of research, and for which we hope to achieve significant impact.

Fuel cells for reducing emissions from the oil and gas industry

By Belma Talic

Operation of an oil platform requires huge amounts of energy. Today, most of this energy is generated using natural gas-fired turbines, leading to large emissions of CO_2. Fuel cells are among the possible solutions examined to replace the gas turbines and reduce emissions.

Reducing emissions from the oil and gas industry

The *LowEmission* centre is developing new technologies and concepts for decreasing the emissions from the international oil and gas industry. In addition to working on making the gas turbines more efficient and compatible with carbon-free fuels such as hydrogen or ammonia, the centre is looking into alternative technologies for generating the needed electricity.

A possible solution: fuel cells

Fuel cells are among the promising zero-emission technologies we examine as they convert hydrogen into electrical power and heat, emitting only pure water in the process. This technology has been around for decades and is currently being used everywhere from hydrogen-fuelled trucks to domestic combined heat and power units across Japan.

There are several reasons why fuel cells are attractive for offshore applications:

- Fuel cells are inherently modular and can be distributed across the platform or supply vessel, thereby making the most of the limited space available.
- Fuel cells can respond rapidly to load changes and are also efficient at low loads. This makes them ideal for balancing out the intermittent power generated by offshore wind turbines.
- Fuel cells are more efficient than gas turbines. Whereas the average gas turbine installed offshore today only can convert of 1/3 of the energy contained in natural gas to electricity, a fuel cell can convert nearly 2/3.

Obstacles to overcome

So why are there no fuel cells on offshore platforms yet? One concern is that the offshore conditions present some unique challenges such as low temperature, varying slopes (due to platform/vessel movement caused by waves or wind), and low maintenance frequency, for which the technology needs to be qualified. As part of the work on fuel cells in *LowEmission*, a review has been conducted on the status of commercial fuel cells and their suitability for offshore applications.

There are several types of fuel cells available, utilizing different material systems and operating at different temperatures. The review was focused on the two technologies considered to have the greatest potential for offshore application, namely the Polymer Electrolyte Membrane Fuel Cell (PEMFC) and the Solid Oxide Fuel Cell (SOFC).

Polymer Electrolyte Membrane Fuel Cell

PEMFC offer a high power density and are therefore attractive for applications where space is limited. The cells are operated below 100°C and are currently cheaper and more suitable for operation under highly dynamic conditions (fast start/stop and load changes). This is the fuel cell technology that is implemented in fuel cell vehicles designed by Toyota and Hyundai, for example. PEMFC are increasingly being considered also for maritime (ships) and stationary applications with several commercial manufacturers able to supply systems up to the MW scale.

Solid Oxide Fuel Cell

SOFC are operated above 500°C and generally bulkier and require longer start-up and shut down times. On the other hand, while PEMFC are limited to operation on pure H_2, SOFCs can operate directly on a wide range of different fuels, including natural gas and ammonia.

The high operating temperature means that the SOFC generates a high quality heat, which can be utilized for example in a gas turbine or steam bottoming cycle to produce additional electricity. The technology is currently primarily used for stationary power (and heat) applications but has been demonstrated also for mobile applications.

Testing and development

Both PEMFC and SOFC have already been tested onboard various types of vessels, demonstrating that the technologies can handle the special conditions that the systems may experience offshore. Several PEMFC stack and system manufacturers have in the recent years developed systems specifically engineered for maritime applications, for example Ballard, Nedstack and PowerCell. For SOFC, there are currently no commercial suppliers of a dedicated maritime system, but several manufacturers are involved in projects working to realise this.

The review found that both SOFC and PEMFC technologies have to a large degree been qualified for offshore operations, but that some uncertainties remain to be resolved. On the technical side, the uncertainties are primarily related to the system surrounding the fuel cell (balance-of-plant components such as compressors and gas recirculators) and how this will handle operation under highly dynamic conditions. A much greater barrier is the lack of regulations and infrastructure for distribution and storage of hydrogen.

In the coming year, the work in *LowEmission* will be focused more on the system aspects of fuel cell and their integration on offshore platforms. The *LowEmission* centre is also involved in testing and characterizing both PEMFC and SOFC.

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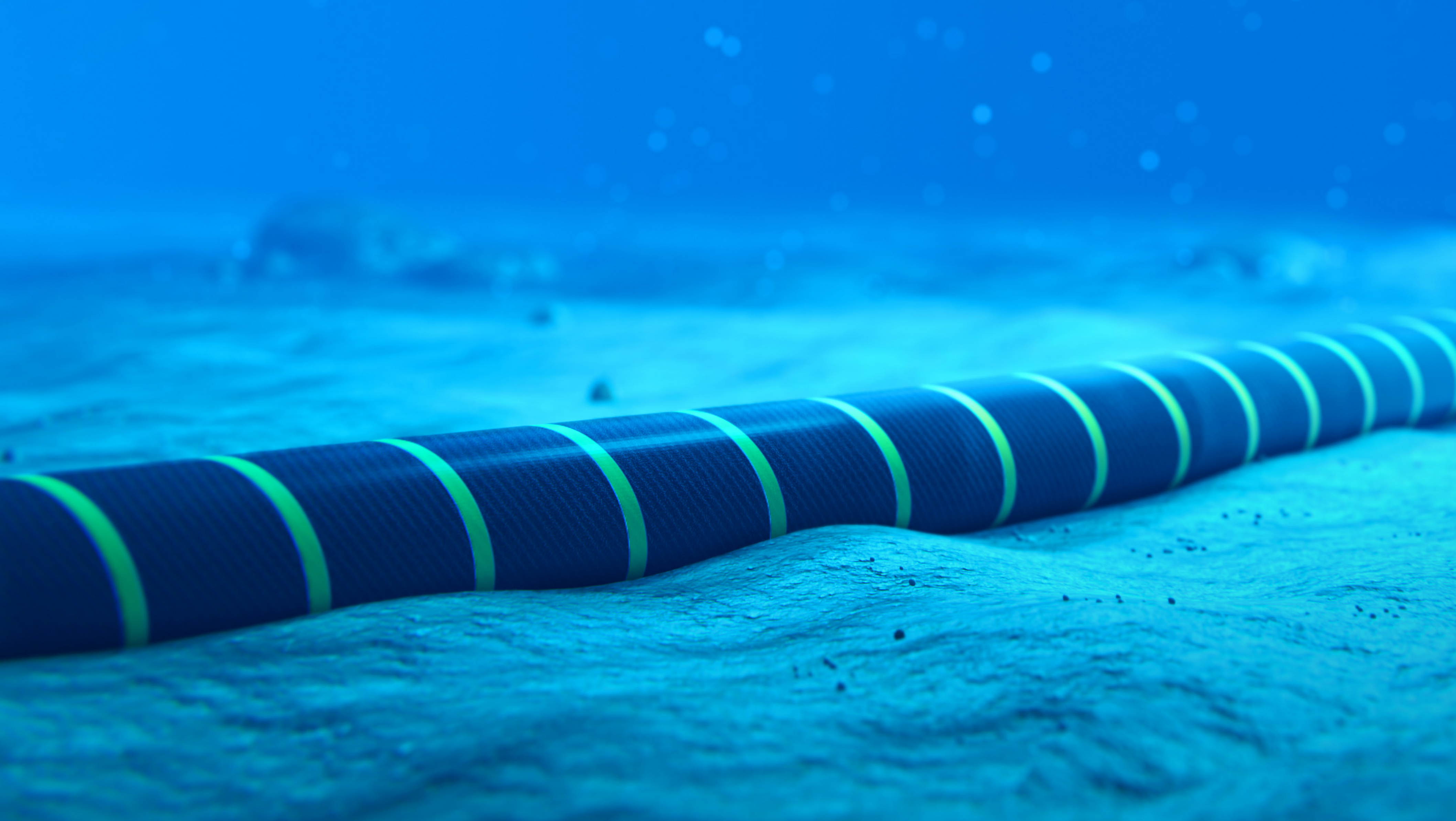
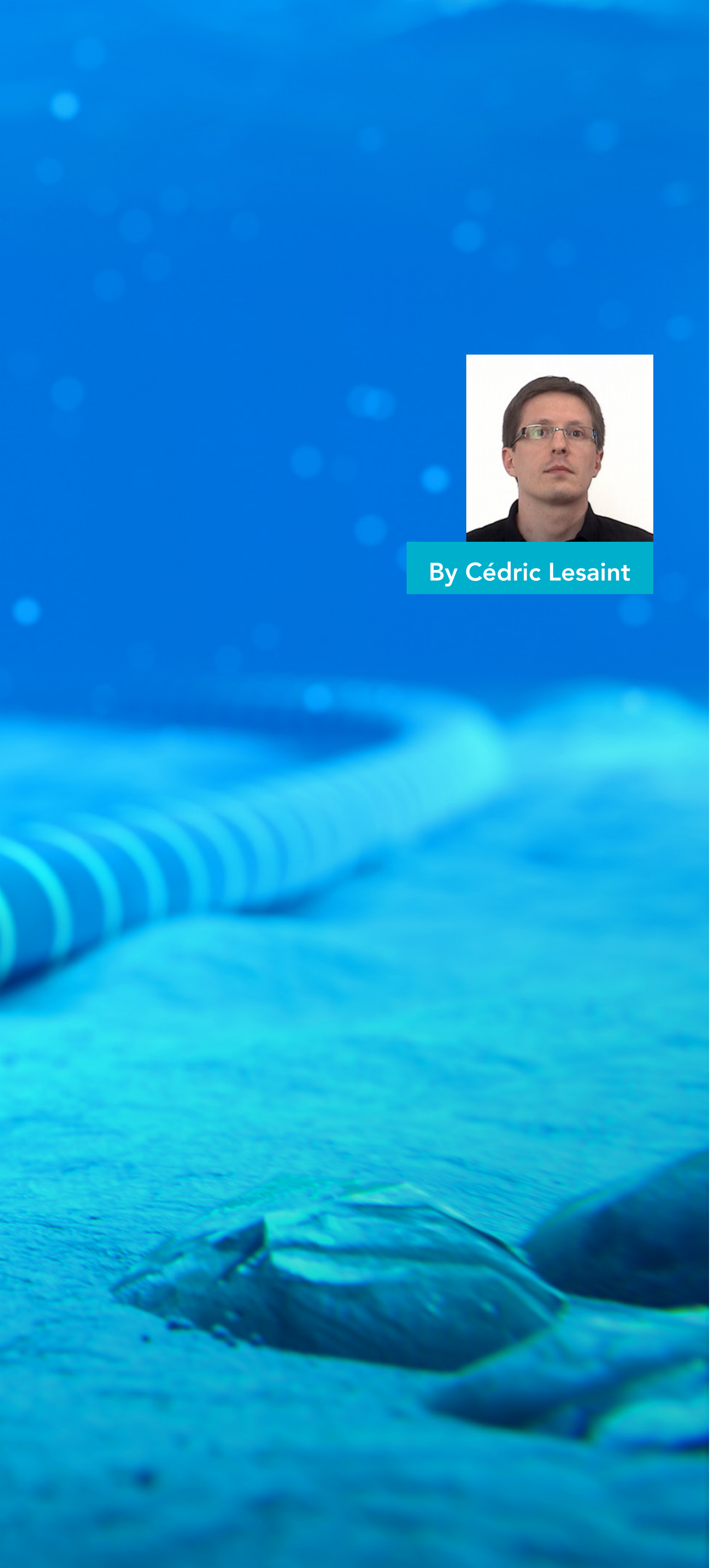
High voltage subsea cables: reducing costs by simplifying design





By Cédric Lesaint

High voltage subsea cables are crucial to electrify oil platforms – and for many other uses such as connecting floating wind farms. Currently, they are quite expensive. *LowEmission* is trying to find new designs to reduce their costs.

A little background first

A subsea HVDC power cable is a transmission cable carrying Electric power at high voltage over long distances below water. The cables are made of a conductor, which is usually copper or aluminum, the insulation, which is XLPE and some protective screens around the insulation. Cables that withstand a voltage higher than 52 kV are usually equipped with an extruded lead sheath to prevent water ingress inside the insulation. This is a well-proven design but it has some limitations, mostly because of the lead sheath which is costly to apply and reduces the flexibility of the cable. Moreover, the European Union is likely to ban the use of lead in the near future. This means other solutions need to be considered.

To suggest new designs and therefore reduce the cost of subsea cables, it is vital to understand the effect of different material properties on the long-term ageing of the cables. The use of **wet-design** high voltage AC power cables (see Figure 1) – meaning with no metallic protective barrier, where water can enter in the cable – is an interesting alternative. These cables are easier to implement and to install than traditional heavier cables. Since they are lighter, longer sections can be transported at once, reducing the overall costs. To sum up, they are cheaper and easier to make.

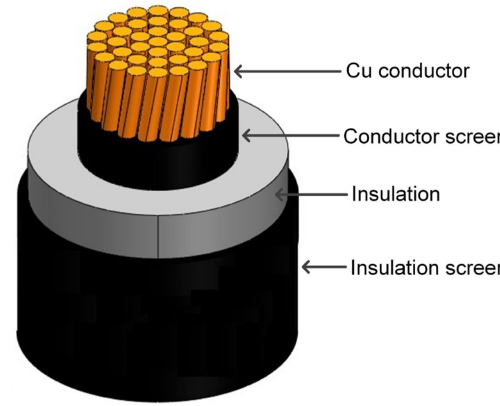


Figure 1: "Wet design" XLPE Submarine Cable (courtesy of Kristian Solheim Thinn, SINTEF). The black conductor and insulation screens are also called semiconductor.

XLPE or **cross-linked polyethylene** is a medium- to high-density polyethylene (long carbon chain) containing cross-link bonds introduced into the polymer structure, changing the thermoplastic into a thermoset. The high-temperature properties of the polymer are improved, its flow is reduced, and its chemical resistance is enhanced. It is used predominantly in building services pipework systems, hydronic radiant heating and cooling systems, domestic water piping, and insulation for high tension (high voltage) electrical cable.

However, over time, water will enter the cable and cause a degradation of the cable insulation which will result in a reduction of its service lifetime. When water can enter the insulation system, several ageing mechanisms can cause a decreased lifetime. The combination of electrical stress, water soluble contaminants and a humidity level above 70% can result in growth of so-called water trees.

What is a water tree?

A water tree is a diffuse, partially conductive 3D plume-like structure, or in other words a dense network of extremely small water-filled channels.

For water treeing to appear at the interface between the semi-conductive layers and the insulation, a contamination by ions is necessary. Since the 1980s, a lot of effort has been made to reduce the concentration of critical ions in the semi-conductive screens by improving the materials that are used and how they are manufactured and handled. Nevertheless, despite the continuous technological progress, water trees still grow in new and modern insulation and the semi-conducting layers can play an important part in the treeing process when ions are present.

What is the purpose of this study?

In Figure 2 we show an example of a vented water tree observed with an optical microscope, growing from the screen inside the insulation. The surface is very smooth and does not seem to be contaminated. There is no apparent anomaly, such as a void for example. So, what caused the growth of this tree at this spot? This is what we are trying to figure out.

The aim of this study is to examine different methodologies to detect the ions responsible for the initiation and growth of water trees in a modern subsea cable insulation by determining the chemical composition in very localized spots near the root of the water tree. If the overall concentration of ions inside the material is close to zero, we want to prove that a high localized

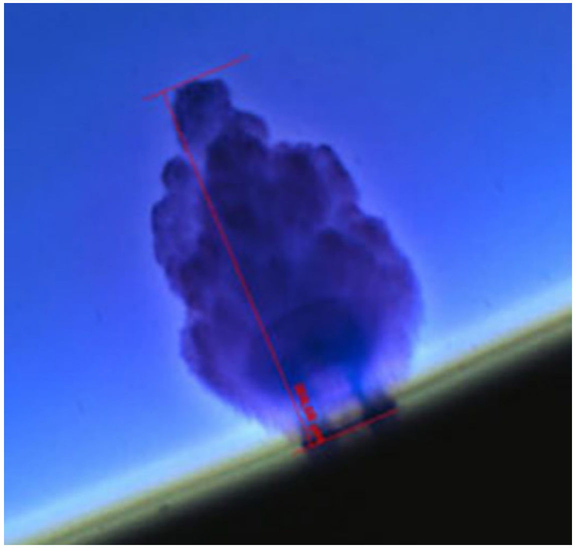


Figure 2: Typical water tree growing from the insulation screen

concentration can result in the growth of the water trees.

The results

Scanning Electron Microscopy (SEM) analysis was used to examine the interface between the semi-conductive screens and the XLPE insulation in the vicinity of a water tree (Figure 3). However, the trees become indiscernible through SEM as the tree structure dries out during the vacuum process, making it difficult to find specific spots where water trees are located.

A **scanning electron microscope (SEM)** is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons.

It operates in a vacuum to prevent electrical discharge in the gun assembly (arcing), and to allow the electrons to travel within the instrument unimpeded. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample.

Energy Dispersive X-Ray analysis (EDX) is used to determine the chemical composition of the area investigated by SEM (figure 3). The y-axis depicts the number of counts and the x-axis represents the energy of the X-rays. The position of the peaks is used for the identification of the elements and the peak height results in the quantification of each element's concentration in the sample.

It was found that the concentration in sodium and chlorine observed near the position of a water tree was two times higher than elsewhere, revealing a potential localized higher concentration of salt, leading to the growth of the water trees.

In order to investigate if what was observed with the combination of SEM and EDX was relevant or only a surface (contamination) effect, a focused ion beam (FIB) was used. Gallium ions are bombarded at the surface of the sample in order to mill in depth (ca 50 µm deep), as observed in Figure 4. FIB-milling is an inherently destructive process, as the bombardment of a surface with ions causes atomic sputtering from the surface. The sample is then tilted and the chemical composition of the surface between the insulation and the semiconductor can be investigated by EDX along a straight line as observed in Figure 4. Very simply put, we dug a hole inside our sample to check the composition below the surface.

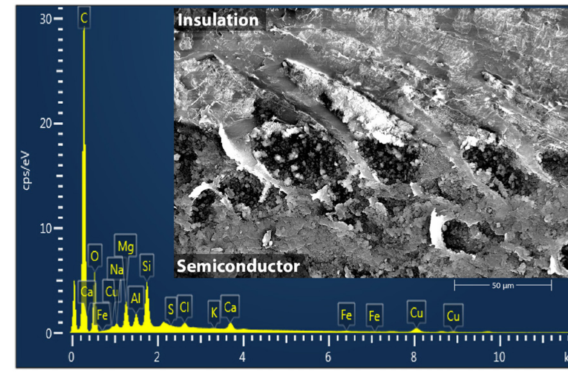


Figure 3: EDX spectrum of a specific spot near a water tree at the interface between the insulation and the semiconductor.

The EDX spectrum along the line under the surface revealed only carbon and oxygen. No

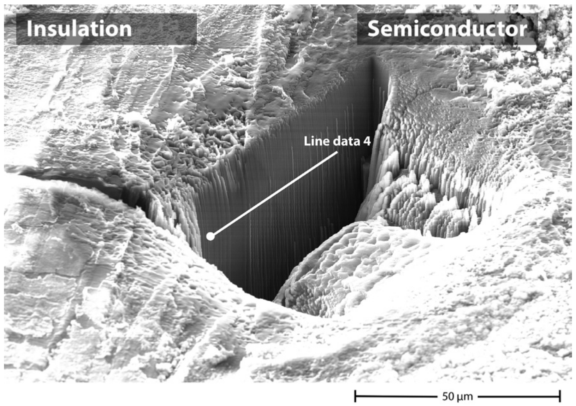


Figure 4: SEM picture of a section located at the interface between the insulation and the semiconductor after some FIB-milling (ca 50 µm depth). The line drawn inside the crevasse was investigated by EDX.

other elements were found. The concentration differences in elements observed at the surface can vary within just a few microns. It is therefore quite possible that the investigated area was too far from the water tree. However, no other element than carbon and oxygen were observed at all under the surface. It is a possibility that the bombarding with gallium has wiped out completely the surface of the other elements and this requires a further investigation.

To conclude

Water trees can grow even in modern HV XLPE cable insulation with significant lengths. Moreover, even though no apparent contaminations are present at the interface, if the contaminant ions responsible for inception of the water trees at the screens are available at the surface, they can be revealed by a simple methodology consisting of examining the surface by SEM combined with EDX.

The results displayed here show that any surface contaminations could dilute the results, making this approach challenging. To overcome this, FIB-milling can be used to exclude contaminations at the surface, detecting ions tens of microns into the sample.

To be continued …

Detail of the Scanning electron microscope's sample holder.

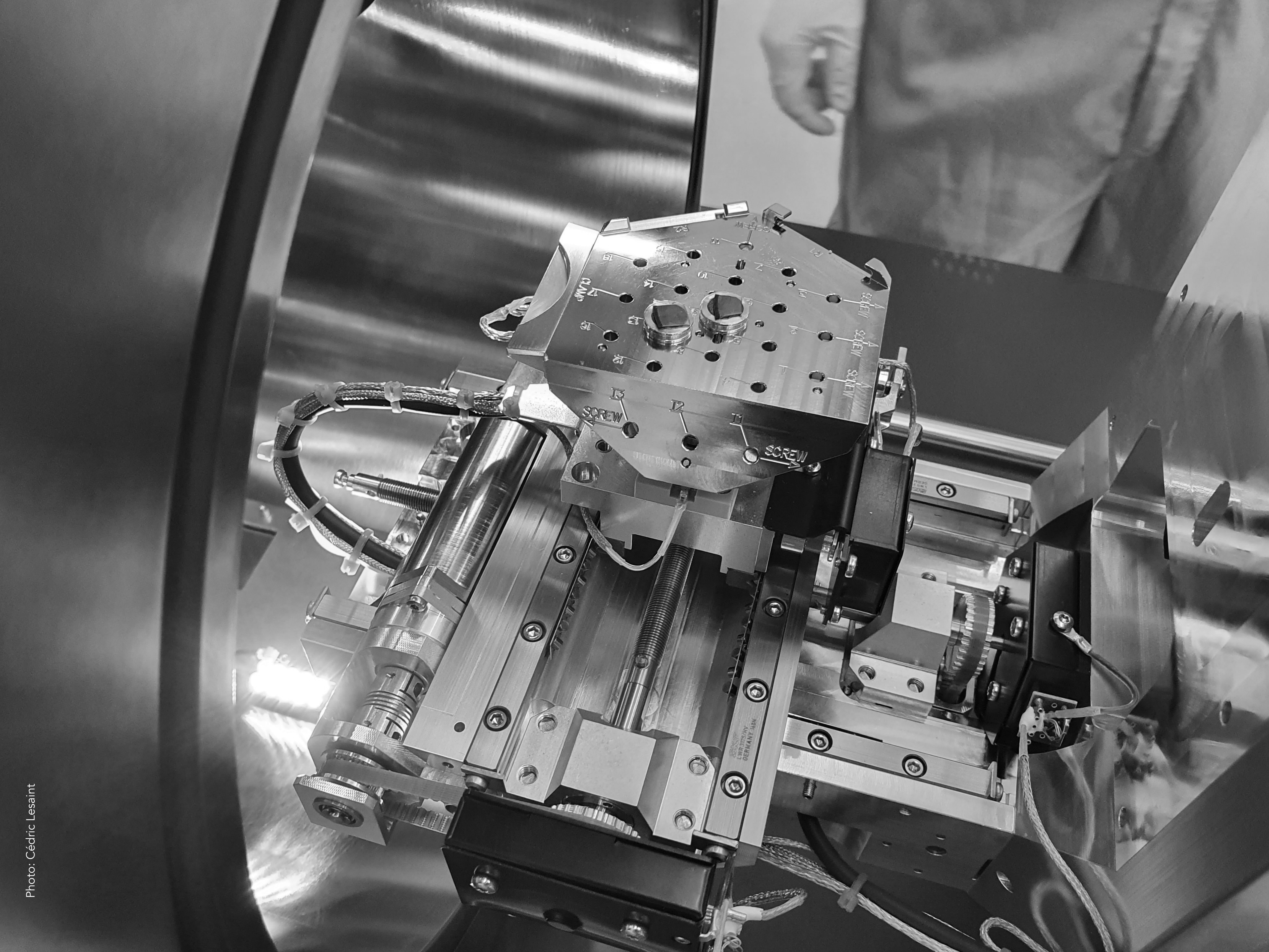


Photo: Cédric Lesaint


ONLY

Offshore supply with emission-free fuels

By Victoria Gribkovskaia

Co-authors Tina Andersen, Truls Flatberg, Elin Espeland Halvorsen-Weare, Patrik Kjærran, Lars Magne Nonås, Endre Sandvik

A cross-disciplinary feasibility study

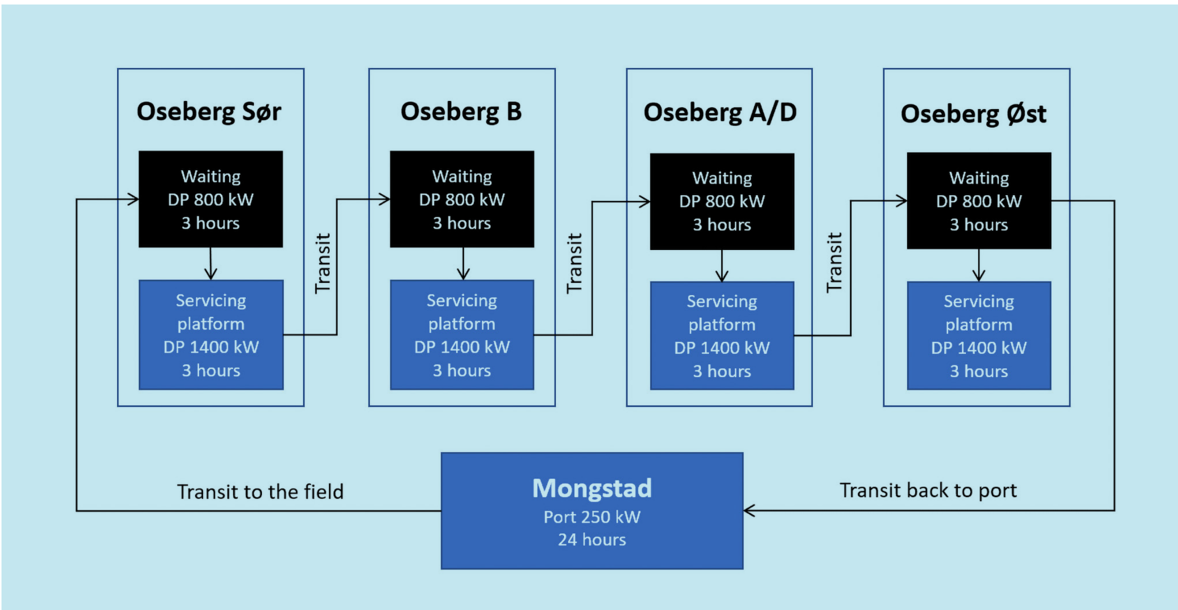
The focus on greenhouse gas emissions from ships is stronger than ever before. Consequently, the demand for low-emission or zero-emission propulsion systems is expected to increase even further. Battery and fuel cell technology have improved over the last couple of years, both in terms of technological maturity and costs for large-scale applications. Under the umbrella of the Low Emission research center[1] a group of scientists from SINTEF Industry and SINTEF Ocean investigated the costs associated with different degrees of emission reductions for supply vessels with hybrid energy solutions – all within a realistic operational setting.

The cross-disciplinary approach in the feasibility study was fulfilled using three decision-support tools.

How was the study performed?

The cross-disciplinary approach in the feasibility study was fulfilled using three decision-support tools: Gymir[2], HyOpt[3] and MOLO[4]. GYMIR is a simulation tool for testing vessels in various voyage settings, HyOpt is for the dimensioning and design of hybrid energy systems and MOLO is for determining optimal weekly supply vessel routes and schedules.

The study was run on a representative scenario covering a month of supply vessel operations in the North Sea, based on data verified by the industry. Propulsion was represented by a hybrid system using marine gasoil MGO for the internal combustion engine and hydrogen for the fuel cell in combination with batteries.



This figure illustrates the test scenario used for the simulation. It shows a supply vessel leaving base to service four platforms and then returning to base before repeating the cycle. The amount of power expended for dynamic positioning (DP) during the various stages of the operation (waiting time and servicing time) is also specified.

Results

The test scenario was constructed to represent a typical offshore supply operation in the North Sea. It constitutes repeated round trips from the base visiting four offshore locations with lay time at the base in between. Simulations in GYMIR are performed for four different vessel speeds between 8kn and 11 kn to quantify the required power for operating a supply ship in realistic sea and weather conditions.

The HyOpt tool is used to find the optimal energy system designs for a supply vessel with a hybrid propulsion system including hydrogen (fuel cells), battery and a diesel engine, for various scenarios. Different system variants result in 48 test instances that have been assessed for required emission reduction levels varying between 0% and 100%.

In contrast to the vessel scale analyses by GYMIR and HyOpt, the MOLO tool is used to study the fleet perspective. It helps determine whether the total number and combination of vessels is sufficient to cover cargo demand and satisfy all service requirements offshore. The analysis is set up to study the transfer from MGO to hydrogen as the preferred fuel type.

Conclusions and emissions reduction potential

The abatement cost for a 50% emission reduction level will be around 6080 - 6125 NOK per tonne of CO_2, depending on test instance setting and load profile. If hydrogen becomes available at all destination platforms, the onboard storage requirements for hydrogen can be reduced by around 80%, while the optimal fuel cell size will be approximately the same as for the scenario configuration with hydrogen supply only on the onshore quay.

Substantial costs are involved in upgrading vessel fleets with new or retrofitted hybrid propulsion systems, but these upgrades have the potential to provide major emissions reductions.

Adding an additional battery pack of either 600 kWh or 1200 kWh will increase the total system costs compared to the optimal hydrogen-diesel hybrid system enabling a 50% emission reduction. This is mainly due to the extra investment costs and to the fact that the battery will have a low utilization degree. However, there might be other major benefits from having an extra battery onboard, as the battery can be used as backup power reserves during dynamic operations or to operate the internal engine more efficiently, which in turn will lead to fuel savings.

Operating speed	Hydrogen supply	Extra Battery Size	Battery and Fuel Cell price level
8 knots 9 knots 10 knots 11 knots	Onshore Onshore and offshore	No battery 600 kWh 1200 kWh	Current price level Lower price level

Different system variants result in 48 test instances that have been assessed.

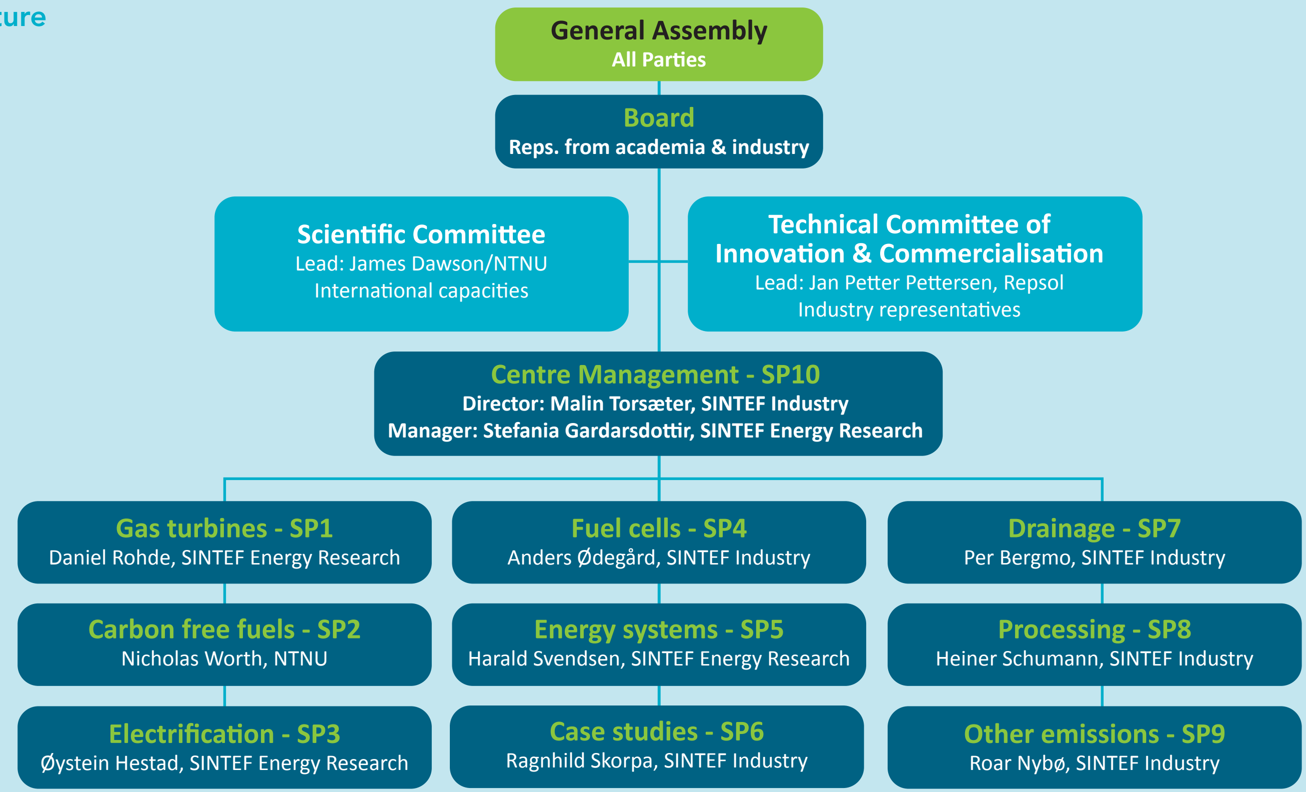
Analysis of the effects of a given technology on a single vessel operation should by combined with a vessel fleet analysis to fully understand the effects of your chosen total vessel fleet

For the case scenario, a vessel fleet of 4 hydrogen vessels is required to replace a fleet of 3 MGO vessels (422t CO_2 emissions) to satisfy all the logistics requirements of the offshore supply operations. From a mixed fleet perspective, the same service level can be achieved by a combination of 2 hydrogen and 1 MGO vessel (173t CO_2 emissions).

1 https://www.sintef.no/projectweb/lowemission/
2 http://www.smartmaritime.no/sub-projects/
3 sub-project-3-simulation-of-long-term-ship-performance-virtual-testing-phase-1/
4 https://www.sintef.no/publikasjoner/publikasjon/?-pubid=1769018
5 https://www.sintef.no/projectweb/molo/

Organisation

Governance structure



Centre Management Team

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Research Manager
SINTEF Industry

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Research Manager
SINTEF Energy Research

Jon Magne Johansen
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Senior Project Manager
SINTEF Industry

Lars Magne Nonås
Centre Operations
Research Manager
SINTEF Ocean

James Dawson
Lead for Scientific Committee
Professor
NTNU

Jan Petter Pettersen
Technical Committee of Innovation & Commercialisation
Asset Manager Blane
Repsol Norge AS

Board

The board of *LowEmission* is the operative decision-making body of the Centre, and is accountable to the General Assembly which consists of all partners in *LowEmission*. The Board is led by industry with representatives from SINTEF, NTNU and industry.

ABB	Tor-Christian Ystgaard
Aker Solutions	Ragnhild Stokholm
ConocoPhillips	Ole Klingsheim
Equinor	Hege Rognø
Lundin	Charlotte Berge
NTNU	Olav Bolland
NTNU	Ole-Morten Midtgård
Repsol	Espen Enge
Siemens	Jenny Larfeldt
SINTEF Energy Research	Mona J. Mølnvik
SINTEF Foundation	Rune Bredesen
TechnipFMC	Marc Cahay
Vår Energi	Oddvar Ims
Wintershall Dea	Michael Charles
Research Council of Norway (observer)	Ingrid Anne Munz

Partners

Operators:

equinor
Lundin Energy Norway
vår energi
REPSOL
TOTAL
wintershall dea
ExxonMobil (outgoing)
ConocoPhillips

Service & vendors:

KONGSBERG
SIEMENS
aibel
COGNITE
CoorsTek Amazing Solutions
Schlumberger
Nexans
Nedstack PEM FUEL CELLS
CYBERNETICA
KONGSTEIN
REINERTSEN NEW ENERGY
SERAM COATINGS
TechnipFMC
ABB
altera INFRASTRUCTURE
RYSTAD ENERGY
AkerSolutions
ANSALDO ENERGIA
CURISTEC
ReStone AS
ScanWell
ODFJELL DRILLING
BOREALIS

Research & development:

SINTEF

NTNU

Public financing:

The Research Council of Norway

Associated Research Entities:

University of Strathclyde Glasgow

Carnegie Mellon University

TNO innovation for life

The Oil & Gas Technology Centre

Lund University

Sandia National Laboratories

DTU Technical University of Denmark

University of Cambridge

Cranfield University

Associated agencies:

Norsk Industri

Norsk olje&gass

Petroleumstilsynet

Norwegian Energy Partners

Oljedirektoratet

Scientific committee

International academic collaboration is of the highest importance to the excellence and success of *LowEmission*. The Scientific Committee's purpose will be to support this, by providing strategic advice on scientific focus and priorities. It will be led by NTNU, through Professor James Dawson. Discussions are ongoing, and it is expected that the committee will become operative during the course of 2021.

Technical Committee of Innovation & Commercialisation

LowEmission strives to be a dynamic centre, targeting challenges of high relevance to industry. To continuously focus on industry-relevant challenges, a Technical Committee of Innovation and Commercialisation (TCIC) was established in 2019. The TCIC consists of and is led by industry, and its purpose is to evaluate commercial potential and identify spin-off projects. This includes reviewing Annual Working Plans and evaluating progress in subprojects as well as advising the Board on new research directions. Mr Jan Petter Petterson (Repsol) is the leader of the TCIC.

Cooperation between partners

The subproject (SP) families have proven to be an integral part of stimulating collaboration between industry and R&D partners. The SP families consist of technical representatives from the industry partners, as well as researchers and PhD candidates working within the different SPs. The SP families discuss matters such as strategies, operational plans for the coming year, communication and dissemination activities and research results, as well as performing quality assurance of results and publications.

The *LowEmission* autumn webinar series was kicked off on the 24th of September and continued through the rest of 2020. The webinars showcased some of the work done in the Centre this year and stimulated discussions and exchange of ideas between the scientists and industry partners in the Centre. The webinars were well received, with 30-100 participants for each!

The annual Consortium Day continues to be an important arena for showcasing the newest research results and collaborative efforts between the *LowEmission* partners. Despite being an online event, the 2020 Consortium Day on the 28th of October was very successful, attended by around 100 participants from research institutes as well as industry partners. The morning session contained keynotes from both industry partners and affiliated agencies along with an update about the ongoing research in the Centre. After lunch, a short overview of the education program in the *LowEmission* Centre was presented. It was followed by a presentation of several of the new PhD candidates in the Centre, and their thoughts about working closely with the industry in a dynamic research centre. The main focus of the afternoon session was "the way ahead towards implementability", dedicated to success stories from ongoing research and industry collaboration for advancing low emission technology. Highlights from collaborative research and technology development from selected research areas in the Centre were given which led to good discussions afterwards.

The *LowEmission* Centre has the ambition to establish a program for mobility and researcher exchange between partners. PhD and Postdoc candidates are encouraged to spend time at other academic institutions, and partner researchers

are encouraged to visit consortium partners – for shorter or longer periods. Such as program was scheduled to start up in 2020 but had to be put on hold due to the ongoing Covid-19 pandemic. Planning for the mobility program will resume once traveling becomes easier.

RESEARCH AND RESULTS

Efficiency enhancement of gas turbines

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This subproject focuses on the design of Combined Cycles Gas Turbines (CCGTs) where the exhaust heat runs a Steam Bottoming Cycle (SBC) for additional power generation and increased efficiency. For this, we need new, compact, and efficient SBC heat exchangers. Design of efficient CCGTs includes development of effective control strategies for gas turbine and CCGT operation.

Main objective

The main objective of SP1 is to reduce the emissions related to offshore gas turbine operation. The measure with the highest emission reduction potential is to recover heat from the exhaust gas to produce electricity and/or heat in a bottoming cycle. This concept has been implemented before, but the large weight and footprint impede widespread implementation. Our focus is therefore on developing more compact and lightweight designs, possibly using other working fluids than steam.

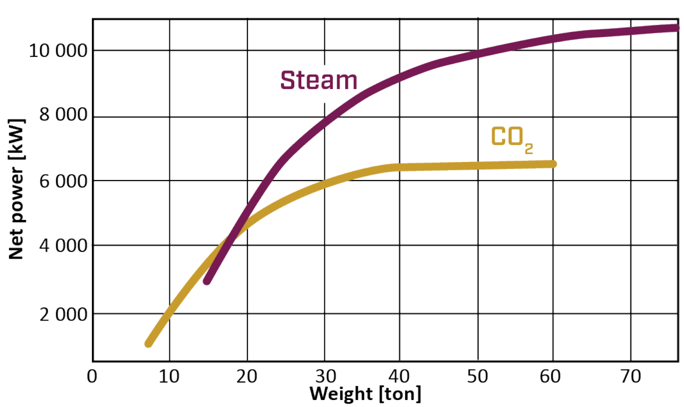
Main results 2020

- Further development of framework for simultaneous optimisation of component design and process parameters by
  - Including full geometry description of plate heat exchangers and finned tube heat recovery heat exchangers.
  - Adding a recuperator to the cycle for improved efficiency.
- The heat recovery heat exchanger is a key component of a bottoming cycle, but most simulation models are 1D-models. A dynamic 2D-model was developed in 2020 to enable more detailed simulations.

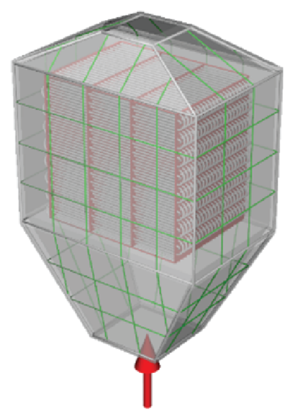
- PhD student Mohammad Ali Motamed started working in the summer. Tentative title for his thesis is "Assessment of alternative concepts for combined cycle gas turbine operation under varying loads".
- Summer researcher Knut Andre Grytting Prestsveen successfully developed a web interface to the process optimisation model. This will be launched 2021.

Impact and innovations

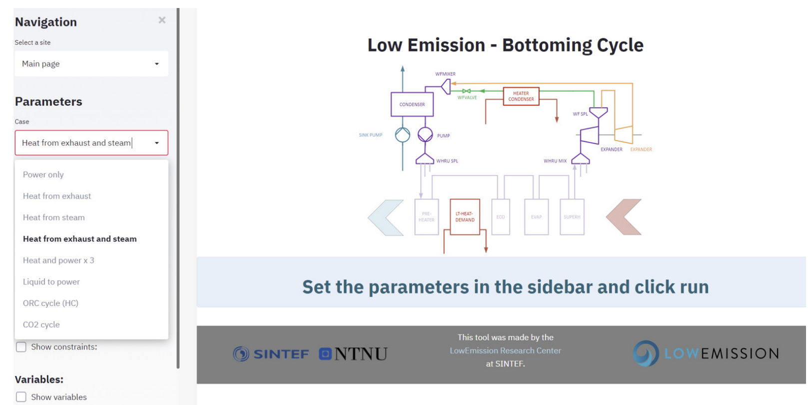
- Compact bottoming cycle designs, possibly with new working fluids, which could enable widespread implementation.
- New methodology for simultaneous optimisation of component specifications and process parameters.



Example result: Net power given a total weight budget for Steam and CO_2 Cycle



Heat recovery heat exchanger with casing and structures



Web-interface to optimization model

SP2

Carbon-free firing of gas turbines

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This subproject conducts research and development of gas turbine combustion concepts for hydrogen and ammonia firing, with the aim of achieving a 100% reduction in CO_2 emissions from gas turbines. The potential use of these fuels will be investigated through targeted improvements to current combustion technology and the development of new combustion technology.

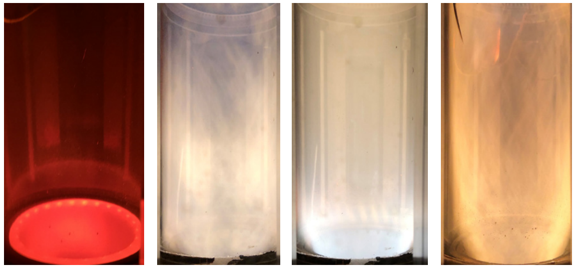
Main objective

SP2 aims to advance capabilities for carbon-free firing of gas turbines (GTs) and internal combustion engines (ICEs), to reduce emissions on the Norwegian Continental Shelf. The research methodology in SP2 follows three main tracks:

1) In collaboration with Siemens and TU Darmstadt, investigate how to optimize NH3/H2/N2 blends in order to *reduce hydrogen reactivity* and provide a potential step-in fuel for natural gas.
2) In collaboration with Ansaldo, investigate the GT combustion system *handling of hydrogen reactivity* preferably without dilution, in order to offer robust aerodynamics that are flashback resistant.
3) Investigate the *use of ammonia* as a hydrogen vector to fuel internal combustion engines (ICEs), by examining injection strategies, ignition, and hydrogen piloting.

Main results in 2020

- A PhD candidate was hired (NTNU/TU Darmstadt), and an experimental plan was produced for measuring the structure of $NH_3/H_2/N_2$ flames using Raman/Rayleigh laser diagnostics.



Ammonia blended flame structure in the HIPROX scaled SGT-750 burner

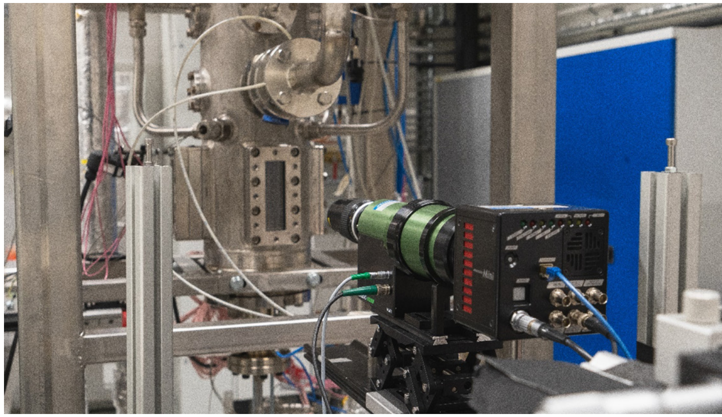
A series of experimental tests have been completed in a scaled SGT750 burner up to 2.5 bar. Key findings included: the stabilisation behaviour of the burner; a favourable emissions performance resulting from different main/pilot splits; and importantly for ammonia blends, a favourable emission trend with pressure was observed.

- Setup and preliminary design and testing work has been completed for the Direct Numerical Simulation (DNS) of the Flamesheet combustor concept, which is a design potentially capable of extreme reactivity of hydrogen blended fuels. Testing confirmed the feasibility of the approach, allowing detailed simulations to be initiated in 2021.
- A series of tests have been completed to prepare for the manufacture of a scaled Flamesheet combustor. These test results will inform the engineering design of the combustor in 2021, allowing this concept to be tested experimentally.
- A PhD student was hired to conduct numerical modelling of ammonia combustion at ICE conditions. Engine mapping based on a stochastic reactor approach is underway, to address the effect of ammonia fuelling on performance and emissions for off shore marine engines applications.

Impact and innovations

The favourable emission trends mentioned above represent a very important result with significant impact for the near-term deployment gas turbines based on ammonia as energy carrier. Inspired by these initial findings, further work is underway to determine if the favourable emission trend continues at even higher (and therefore more engine-relevant) pressures.

Furthermore, the preliminary assessment and application of the DNS methodology to the Flamesheet combustor represents a significant innovation. Such advanced numerical tools, which provide a high formal order of accuracy and fidelity in the representation of the reactive flow, have never been applied before to a geometrically complex configuration such as the Flamesheet combustor concept.



Advanced measurement techniques are used to study the effect of ammonia on the stability of high-pressure flames as can be found in gas turbine combustors. Here, a high-speed intensified camera is used to image the flame by its UV emission – which is invisible to the eye or normal cameras, but which reveals the highest temperature flame zones.

SP3

Reduced cost of electrification

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This subproject develops new technology for electrifying offshore installations. We are investigating a novel approach using wet design of high-voltage offshore cables in combination with subsea compensation units to enable long distance AC power transmission. This gives lighter cables without the need for a metallic barrier to prevent water ingress, and reduced costs for production and installation of the cable.

Main objective

The gas turbines used for offshore power production today emit large quantities of greenhouse gases (GHG). Electrification from shore may drastically reduce these emissions. While the technology for electrification is already available, it is not often used as the price of electrification is high. The emphasis of SP3 is on reducing costs without sacrificing system reliability for the energy system and key components. The main objectives are to:

1. Identify/develop cost-efficient reliable power components for offshore/subsea power distribution
2. Test components/insulation systems based on models of typical load patterns
3. Develop models for estimation of global GHG emission reduction due to electrification

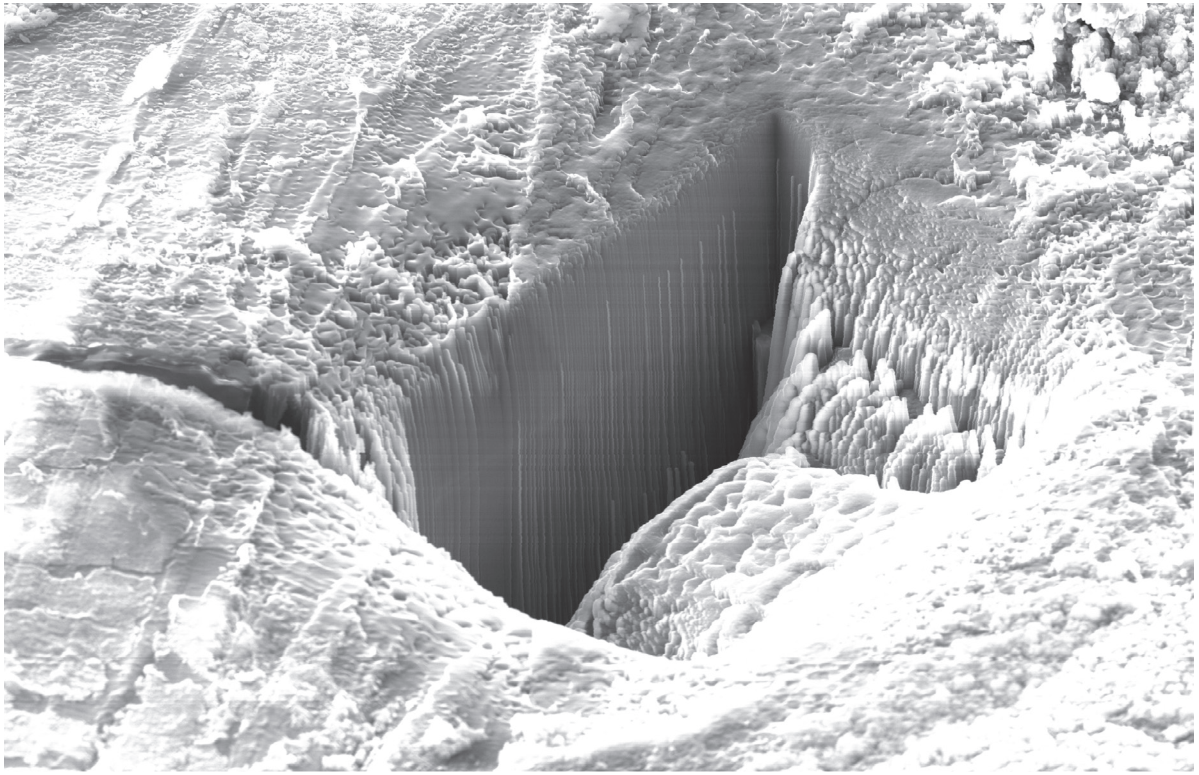
Main results in 2020

- Improved and documented the offshore grid layout optimisation model (PowerGIM) and completed preliminary analyses with the European power system expansion optimisation model EMPIRE.
- A new methodology for water tree analysis was established based on Scanning electron

Microscopy (SEM) coupled with energy dispersive X-ray analysis (EDX). In addition, FIB-milling was used to exclude contaminations at the surface, detecting ions tens of microns into the sample. This will be an important tool in future research on water tree inception and growth, which is central in future development of wet-design cables.
- Performed and reported a review of tools to simulate energy systems and of approaches to quantify the GHG emissions associated with the utilisation of power from shore. Carried out a preliminary identification of relevant scenarios to assess offshore electrification on the Norwegian Continental Shelf.

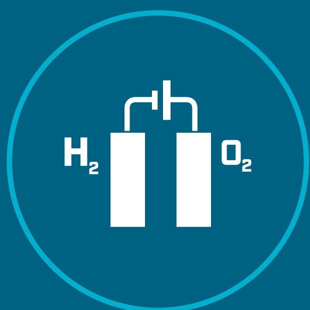
Impact and innovations

- The main goal of the material characterisation of aged wet-design cables (ongoing in 2021) is to link chemical and mechanical properties of the XLPE cable insulation with inception and growth of water trees. A methodology including examinations of the surface of the spiralized slices soaked in de-ionized water by SEM combined with EDX has been established and is promising for the identification of impurities in the vicinity of vented water trees.
- The analyses of tools and methods to quantify GHG emissions gives a sound basis to measure the actual environmental impact of electrification.



SEM picture (x1500) of a section located at the interface between the insulation and the semiconductor after FIB-milling (ca 50 µm depth).

SP4



Fuel cells for zero emission heat and power

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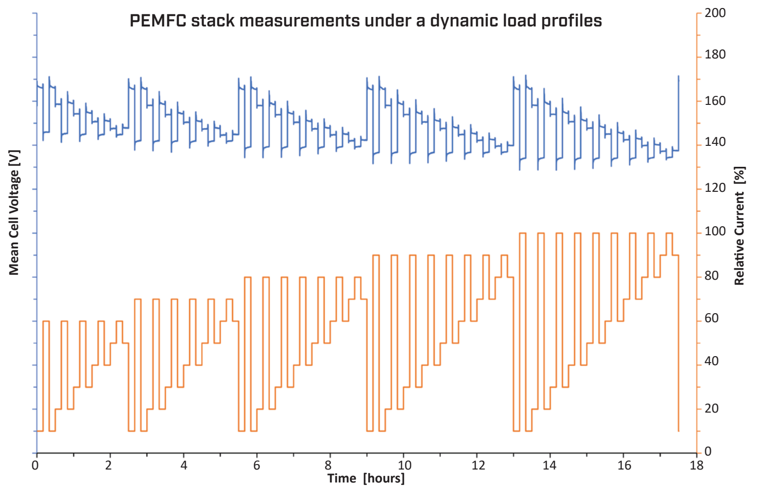
This subproject investigates the use of fuel cell technology, considering the varying requirements of heat and power, hydrogen management and integration into the offshore energy system. Specific research includes high-efficiency, compact and robust systems fueled with hydrogen and/or ammonia. The development of reversible fuel cell technology for production of electricity and pressurisation of dry hydrogen is planned.

Main objective

The overall objective of SP4 is to investigate the use of fuel cell technologies on offshore installations, either to replace or hybridise with gas turbines for heat and power supply. The research covers both low and high temperature technologies, respectively PEMFC and SOFC.

Main results 2020

- Survey of available fuel cell technologies and suppliers of systems for offshore use completed and disseminated to the Low Emission partners through a report and a webinar.
- Procedure for testing PEMFC stacks established and measurements under a dynamic load profile completed, demonstrating good response to sudden changes in current density.
- Completed a risk assessment and lab upgrade to enable reversible SOFC tests.
- Reversible SOFC test performed at 600°C, showing performance improvement in fuel cell mode during long-term aging for 375h but significant degradation when operated in reverse mode (switching from fuel cell to electrolysis operation every 2h).



PEMFC stack measurements under a dynamic load profile

Part of Øyvind Lindgård's work is testing fuel cells in SINTEF's labs, where new technologies are being researched for the production and use of hydrogen for mobile and stationary applications.

Impact and innovations

The work in 2020 has mainly focused on establishing the basis for further work and development in the Centre (identified key features fuel cells must cover and the current status in relevant technologies). In itself, the work has not yet contributed to major overall impact and innovations.

SP5

Energy systems – digital solutions

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This subproject develops generic methods, models and digital tools for analysis and optimisation of offshore energy systems with renewable energy supply, to enable cost-effective, reliable and stable design and operations of hybrid offshore energy systems with low or zero CO_2 emissions. The focus is on power systems, but heat supply is also considered. A key output will be digital solutions that leverage computing power, digital ecosystems, and the huge amount of data among operators.

Main objective

Consider the integration of low-emission technologies into offshore energy systems and develop methods, models and tools to support design and analysis.

- Optimal design and operation of hybrid energy systems with renewable energy integration
- Models and methods for detailed analyses of electrical stability of proposed solutions
- Integrated energy tools and data-driven methods supporting industry digitalisation

Main results 2020

Created an open specification and energy and power system models of an oil and gas reference platform ("LEOGO") for research purposes.

- Added operational uncertainty to the HyOpt investment planning model.
- Improved the *Offshore Oil and Gas Energy System Operation* (Oogeso) tool.
- Estimated impact on CO_2 emissions and other key indicators for a platform partially supplied with wind energy, using a power management simulator (PPSim) and the Oogeso tool.
- Investigated inertial and primary frequency

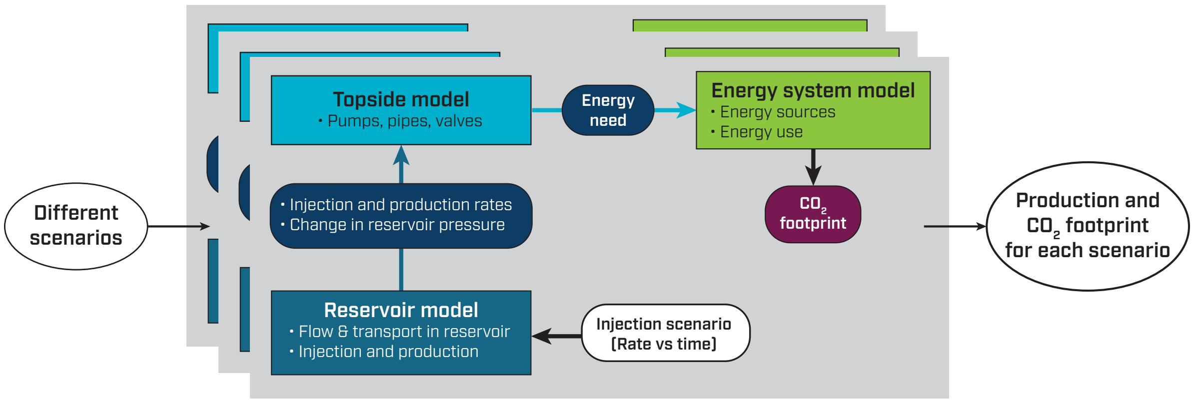
support by an energy storage system for an oil and gas platform with wind power supply (submitted for journal publication).

- Preliminary integration of topside, reservoir and energy system models and analysis of water injection scenarios and impact on CO_2 emissions

Impact and innovations

- New (Oogeso) and improved (HyOpt) software models for energy system optimisation in operation and investment planning

https://www.sintef.no/en/software/offshore-oil-and-gas-energy-system-operational-optimisation-tool-oogeso/



SP6

Case studies & innovation

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This subproject performs industry-driven case studies over a one-year period to show emissions reductions from the implementation of technologies on the Norwegian Continental Shelf fields. Studies on the economic aspects of technology development through advanced techno-economic analyses will also be performed.

Main objective

The goal of *LowEmission* case studies is to develop technology concepts that can lead to a minimum 5% reduction in offshore energy consumption and/or CO_2 emissions. The industry-driven case studies will be conducted over a one-year period to show emissions reductions from implementing technologies on the Norwegian Continental Shelf (NCS). Studies will depend on industry partners making available data necessary to evaluate emission, weight and cost reductions.

Main results 2020

- Summary of Consortium Day 2019 highlights and breakout sessions
- *LowEmission* autumn technical webinar series
- 5 case studies investigating the possibility of new technology on emissions reduction

Impact and innovations

Initiated 5 case studies

Heat & power generation

- Partial decarbonisation of Equinor's Johan Castberg FPSO by ammonia injection in natural gas

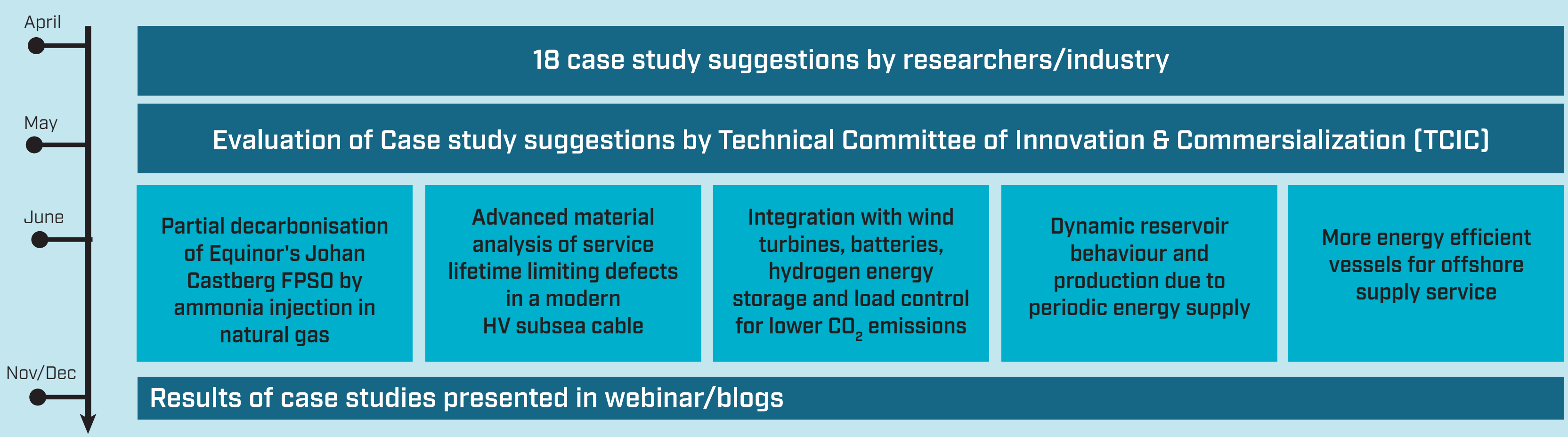
- Advanced material analysis of service-lifetime-limiting defects in a modern HV subsea cable

System integration
- Integration with wind turbines, batteries, hydrogen energy storage and load control for lower CO_2 emissions

Reduced offshore energy consumption
- Dynamic reservoir behaviour and production due to periodic energy supply
- More energy efficient vessels for offshore supply service

Initiated "*LowEmission* Innovation Challenge" with first industrial challenge from Vår Energi and Equinor to get the industry perspective.

Case study selection process 2020



SP7

Energy efficient drainage

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This subproject analyses the energy use for different reservoir drainage strategies. Potential reductions in energy use will be identified, both for implementation on short time scales in mature fields, and on longer time scales for new field developments. The work is performed in close cooperation with industry partners.

Main objective

Assess and quantify energy use coupled to subsurface flow processes for relevant drainage strategies and identify potential for energy reduction while maintaining focus on maximising oil and gas recovery. Focus in 2020 has been on:

- identifying potential technologies and strategies for reduced energy production
- screening and preparing models for evaluating drainage strategies to quantify energy use and reduction potential
- developing an optimisation framework to enable maximised oil and gas recovery combined with reduced energy needs and costs.

Main results 2020

- Presented an overview of candidate technologies for reduced energy use related to drainage.
- Created models for simulating effect of inflow devices in wells for reduced energy use associated with water production.
- Prepared modified subsurface models of the Norne field and the Norne E-segment. The models will be used for studying water-based

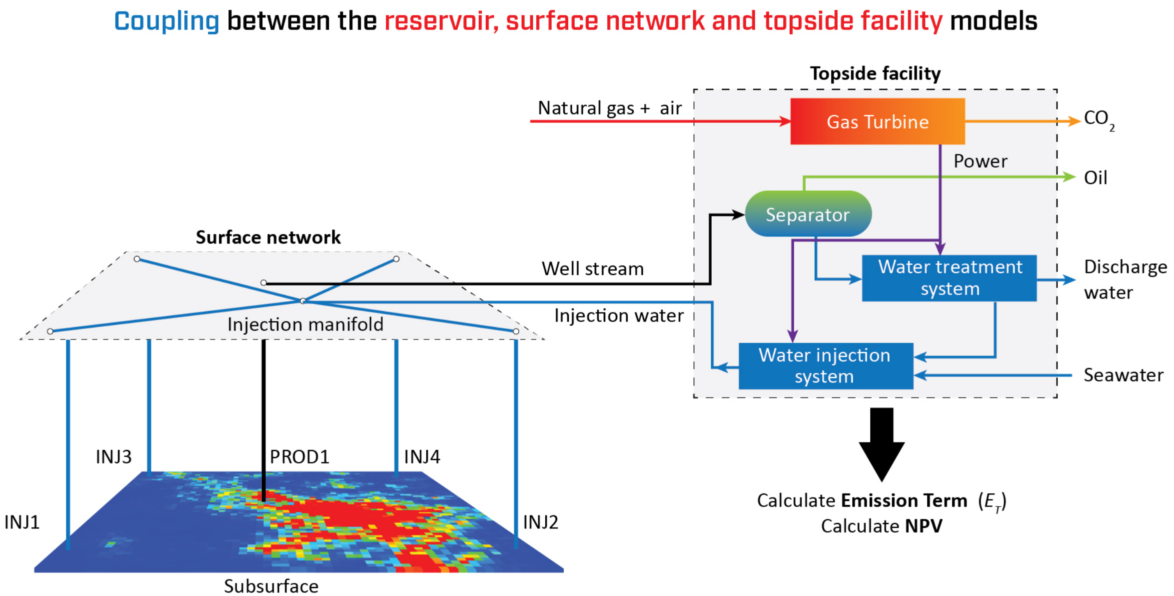
drainage strategies. The simulation models were tested in commercial and open-source simulators, and the modified Norne model was used in a case study for SP6.

- A methodology for joint optimisation of oil and gas production and CO_2 emissions has been developed through coupling of reservoir, subsurface and topside models. Optimisation is implemented in the open-source software FieldOpt (NTNU).
- A prototype for visualisation of energy dissipation in the reservoir has been developed.

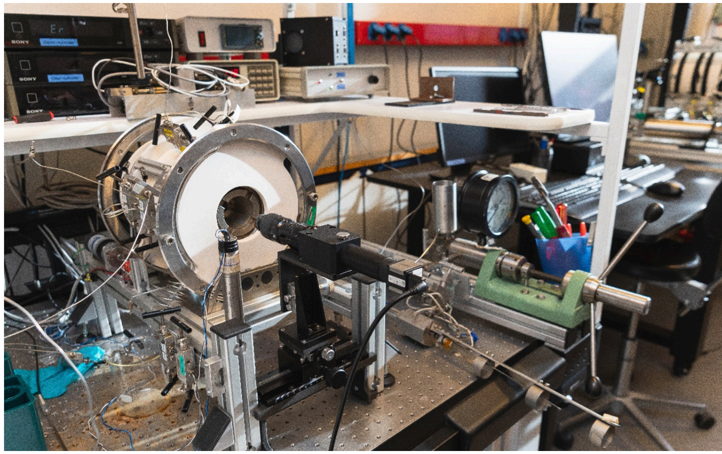
Impact and innovations

Expected innovations are:

- Assessment methodology for energy consumption for relevant drainage strategies
- Methodology for co-optimisation of oil and gas production, energy use and costs
- Guidelines for selecting energy efficient drainage strategies.



Schematic of model used in joint optimisation with topside and subsea facilities, wells and the subsurface reservoir.



Capillary pressure, caused by interfacial tension (IFT) between reservoir fluids is the most basic rock-fluid property in multiphase flow. Image of high pressure, high temperature, pendant drop IFT measurement cell.

SP8

Energy-efficient processing

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This subproject develops new technologies (and improves existing ones) for subsea, in-well and topside processing with minimal energy use.

Main objective

The main objective of SP8 is twofold: to demonstrate and optimise the use of new technologies for subsea, in-well and topside processing with minimal energy consumption in brownfields and greenfields on the NCS; and: to support industrial uptake of the innovations. This will be achieved by:

- Demonstrating energy wastage and identifying the potential for efficiency improvements.
- Testing new technologies and concepts to accelerate their implementation.
- Demonstrating "non-intrusive" process-optimisation solutions for existing fields.
- Studying measures necessary to meet challenges arising from future energy supply solutions (examples of such challenges: unsteady energy supply, little excess heat).

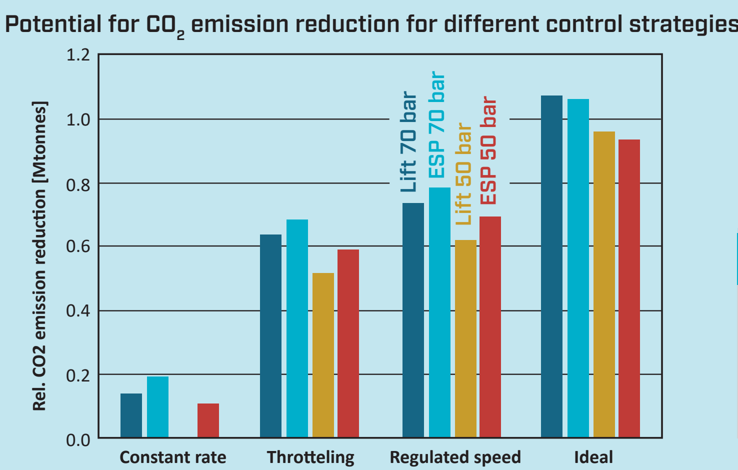
Main results 2020

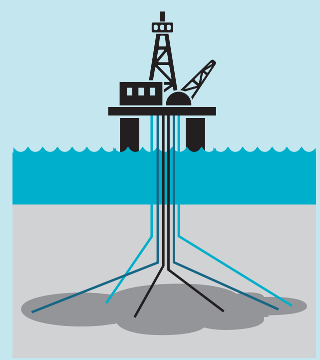
- Created process models for the subsea transport system and topside processing part.
- Initiated a study mapping energy consumption, losses and dissipation in the production system and analysed the first generic production scenario. Further relevant scenarios will follow.

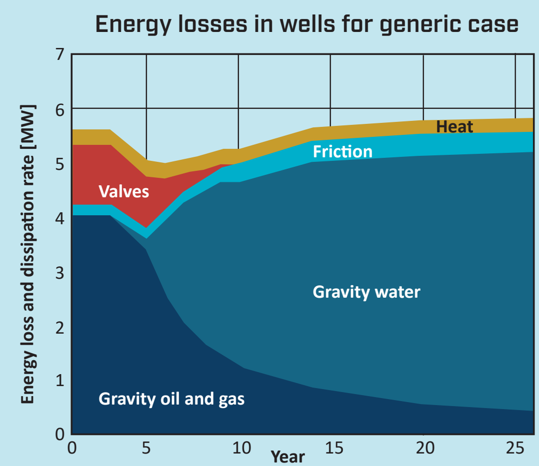
Results will be used to identify measures with high potential for reducing energy consumption and emissions and by this define further work in the SP.
- A PhD candidate was recruited and started in the position. Title of the project is "Decision support methods to design and operate hydro-carbon production systems considering energy efficiency and environmental performance using numerical modelling and optimisation"
- A case study was successfully performed together with SP7. Title: "Dynamic reservoir behaviour and production due to periodic energy supply"

Impact and innovations

- Guidelines and decision help for new design and improvements of existing production systems.
- Example studies comparing and showing the potential of new technologies will simplify and accelerate implementation of such solutions.
- Solutions for overcoming problems related to implementation of renewable energy supply solutions will be investigated
- Inputs to other SPs (for example covering reservoir & energy system) will be provided by defining boundary conditions and predicting feedback and limitations of the processing system.







SP9

Other emissions

Roar Nybø
Senior Business Developer,
SINTEF Industry
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This subproject seeks to reduce emissions from mobile units through logistics optimisation and zero-emission vessels, and to reduce methane and other emissions.

Main objective

The overall objective of SP9 is twofold: to reduce emissions from offshore mobile units by optimising logistics and ensuring the use of low-emission vessels; and: to reduce methane and non-methane volatile organic compounds (NMVOC) emissions from crude oil tankers and installations.

Main results 2020

- Development of a state-of-the-art decision support tool for planning of efficient and environmentally-friendly usage of offshore supply vessels is ongoing, with more functionality added based on the feedback from potential users and more complex and efficient solution algorithms implemented
- Dialogue meetings with industry representatives – mainly logistics planners and marine supervisors from the partner operator companies – have resulted in a memo summarising common logistical challenges and areas of interest for future research. These among others include the use of advanced decision-support tools in resource planning; more strategically-oriented cooperation on resource sharing between the operators and

potentially also vessel owners; and the effects and infrastructure availability of alternative low-carbon fuels for vessel propulsion.
- The requirements for use of fuel cells in offshore vessels was revised.
- The economic optimisation model for the design and dimensioning of hybrid energy system has improved support for setting up cases involving vessels with fuel cells in combination with batteries and internal combustion engines. The model was used as part of a case study on offshore supply vessels with hydrogen-powered fuel cells in SP6.
- Studied cost-effective ways to make platform-specific methane measurements.
- Computational Fluid Dynamics simulation of the filling of oil tanks on ships.

Impact and innovations

The software in development in SP9 lays a foundation for more cooperation between actors in the offshore supply chains and will help make informed investment decisions when seeking to minimize emissions from the supply vessel fleet.

The Low Emission Centre studies fuel cells in the SINTEF Low Temperature Electrolysis and fuel cell laboratory.

Innovations

LowEmission aims to be a platform for competence building, and the sharing and promotion of innovation and value creation for industry. The partnerships between industry end-users, vendors and research institutions are a driving force, stimulating the innovation process and shortening the path from research to commercial products.

LowEmission promotes open innovation to optimise technology output across company borders and increase the gain for each company involved. The pool of ideas will be greater than that of each company, and partners can commercialise ideas and technologies created outside company borders. By facilitating opportunities for industry to collaborate and bring technologies to the market, the Centre can make a major impact in terms of value creation both on the NCS and around the world.

Industry-driven case studies are conducted through subproject 6 – Case Studies & Innovation, focusing on 1-2 year periods, to show emission reductions from technology implementation on NCS fields. Studies depend on industry partners making the necessary data available to evaluate emission, weight- and cost reduction. Industry plays a vital role in ensuring implementation through in-kind contributions/ expertise. The output will be emission reduction potential and weight/cost data for implementing technologies providing a foundation for spin-offs or demonstration projects.

LowEmission Innovation Challenge

The *LowEmission* Innovation Challenge was kicked off on the 15th of October. The Innovation Challenge provides a platform for the industry partners to shine a light on specific challenges they deem of particular importance. The aim of this initiative is to further stimulate innovation, idea generation and spin-off activities from the Centre. The first Innovation Challenge was presented by Vår Energi in October 2020 and was well received with 75 registered participants. The second Innovation Challenge was presented by Equinor in December 2020 with 62 registered participants.

"What we are addressing using the OOGESO tool is the challenges and strategies for the operation of low or zero emission offshore energy systems."

- Harald Svendsen,
main developer for OOGESO

INNOVATION

Offshore oil and gas energy system operational optimisation (OOGESO) tool

The energy supply and energy balancing on platforms today is provided by gas turbine generators, with high CO_2 emissions from the combustion of natural gas. Low emission alternatives such as wind are needed. However, without the flexibility of gas turbines, the balancing of energy supply and demand is a challenging task that must be achieved by other solutions.

The Oogeso tool is open-source Python based software for simulating the operation of offshore oil and gas platform energy systems. It is intended for analysing systems with variability and flexibility associated with the integration of low-emission technologies such as wind power supply, batteries, other energy storage, and flexible energy demand.

It may be used to compute and compare key performance indicators such as greenhouse gas emissions, gas turbine starts and stops, etc, with different system configurations and operating strategies. For example, the performance with different sizes of wind turbines and batteries, different amounts of online reserve power required, or different amounts of allowed variation in petroleum production.

The simulator is based on a rolling horizon mixed-integer linear optimisation. The system modelling is simplified and linear, but includes energy and mass flows, with the basic links between oil/gas/water flows and energy demand by pumps and compressors, as well as gas turbine efficiency curves.

https://www.sintef.no/en/software/offshore-oil-and-gas-energy-system-operational-optimisation-tool-oogeso/

OOGESO is being developed as a Python package by SINTEF researchers within the *LowEmission* Centre. It is intended for research purposes and is still under development. Since it is open source with a permissive licence, modelling concepts and system operating strategies implemented in the tool may be ported to commercial products for deployment.

Spin-off projects

Two Knowledge-building spin-off projects from *LowEmission* were granted funding in December 2020 and will start in 2021:

Digital Twin - Digital Twin for Optimal Design and Operation of Compact Combined Cycles in Offshore Oil and Gas Installations

Objective: The main objective of DIGITAL TWIN is to develop modelling software necessary to design a digital twin for an offshore bottoming cycle with respect to optimizing its operational efficiency and reliability
Project partners: SINTEF Energy, NTNU, University of Oslo, *LowEmission* industry partners
Funding: Petromaks2 (Research Council of Norway), *LowEmission* industry partners
Duration: 2021-2024
Project manager:
Marit J. Mazzetti, SINTEF Energy

OffFlex - Offshore energy system optimisation considering load and storage flexibility

Objective: Identify the potential, barriers, and benefits of using energy demand flexibility for energy balancing in oil and gas platforms with up to 100% wind energy supply
Project partners: SINTEF Industry, SINTEF Energy, University of Oslo, *LowEmission* industry partners
Funding: Petromaks2 (Research Council of Norway), *LowEmission* industry partners
Duration: 2021-2023
Project manager:
Harald G. Svendsen, SINTEF Energy

Education and recruitment

After a successful advertisement campaign in 2019, ten highly qualified and motivated PhD candidates were recruited in 2020. With this, more than half of the planned candidate work force (19 PhDs/Postdocs total) is already hired. We are proud to present our candidates in this chapter.

During 2020, we made efforts to ensure that the PhD candidates were effectively integrated in the daily life and activities of the Centre. The candidates are all included in the so-called SP (subproject) families. This means that they take part in relevant meeting activities within the SP and with the industrial partners. They were also active in the webinar series during the fall, both as presenters and in the audience. In 2021, we plan a separate session at the *LowEmission* Consortium Day dedicated to the candidates for presentations and pitches. Based on the research needs of the Centre, individual research plans were developed for each candidate.

Several of the SPs have already connected with Master's students, who have taken on projects relevant to the research plan of the Centre. This has proven successful in terms og generation of ideas for new activities, such as case studies.

Name: Amar Abideen
Affiliation: NTNU
Nationality: Saudi Arabian
Supervisor: Associate Prof. Frank Mauseth (NTNU) and Dr Øystein Hestad (SINTEF)
Period: 2020-2024
Thesis: Wet cable design for subsea applications

This work concerns transmission technologies in subsea. The aim of this project is to examine and determine the critical aging mechanisms for wet design AC power cables with an emphasis on water treeing (WT) in XLPE cables. Results from this work can contribute to facilitating the electrification of offshore installations, which can lead to more efficient transmission and indirectly reduce the CO_2 emissions. The work started in 2020 with an initial experiment on aged cables to investigate WT structures and inception locations to identify factors that influence the inception of WTs.

Name: Leila Eyni
Affiliation: NTNU
Nationality: Iranian
Supervisors: Associate Prof. Milan Stanko (NTNU) and Dr. Heiner Schümann (SINTEF)
Period: 2020-2023
Thesis: Energy-efficient processing

My project's main objective is to study, develop, evaluate and validate modeling approaches to compute energy efficiency and environmental performance of hydrocarbon production systems (subsea and in-well components), including guidelines and recommendations for implementation and operation of the technology in the Norwegian Continental Shelf. For this purpose, I shall determine and evaluate modeling approaches to compute and assess key performance indicators such as energy efficiency, greenhouse gas emissions, CO_2 footprint, energy usage, thermodynamic properties (e.g. exergy), and economic indicators.

Name: Andreas Breivik Ormevik
Affiliation: NTNU
Nationality: Norwegian
Supervisor: Prof. Kjetil Fagerholt (NTNU) and Prof. Frank Meisel (Kiel Univ.)
Period: 2020-2024
Thesis: Emission reduction in the upstream offshore supply chain on the Norwegian Continental Shelf

In my project, I will develop decision support models for optimising the performance of the upstream supply chain on the Norwegian Continental Shelf, aiming to evaluate the potential for reductions in greenhouse gas emissions from different supply chain stages. Large reductions both in terms of costs and emissions from the daily operations can be obtained through alternative policies for offshore logistics planning. My research work will start by investigating the impact of weather conditions on planning problems for platform supply vessels (through 2021), and I will continue by looking at the effects of restructuring the supply chain.

Name: Martin Löw
Affiliation: NTNU
Nationality: German
Supervisor: Prof. James R. Dawson (NTNU), Andreas Dreizler (TU Darmstadt), and Prof. Dirk Geyer (TU Darmstadt)
Period: 2020-2023
Thesis: Investigation of the flame structure of ammonia-hydrogen-nitrogen flames

The main objective of my project is to provide experimental insights to the combustion of ammonia-hydrogen-nitrogen fuel blends by using advanced laser diagnostics. These blends can be obtained by partial cracking of ammonia into hydrogen and nitrogen. During combustion of ammonia-hydrogen-nitrogen blends, no carbon dioxide is formed and in the right blend composition, the combustion properties are close to those of natural gas, which makes these blends applicable in gas turbines. Besides a variety of laser diagnostics, we will apply the combined Raman/Rayleigh-spectroscopy to get deeper insights into the reaction processes in ammonia-hydrogen-nitrogen flames.

Name: Kiet Tuan Hoang
Affiliation: NTNU
Nationality: Norwegian
Supervisor: Prof. Lars Struen Imsland (NTNU)
Period: 2020-2024
Thesis: Stochastic nonlinear model predictive control of offshore hybrid power systems

I will establish the foundation for integrating alternative renewable offshore power systems such as offshore wind into existing offshore power systems using control and systems theory. This is important, because the total emission offshore accounts for approximately 25% of the total Norwegian greenhouse gas emissions. The vision is that the technology from this project will lay the foundation and facilitate increased share of renewable energy in offshore energy systems and reduce total greenhouse gas emissions. The focus of my work will be on stochastic model predictive control, a technique that can be used to control the interactions between the different power systems in an optimal manner, even in the presence of uncertainties in for example weather predictions.

Name: Jessica Gaucherand
Affiliation: NTNU
Nationality: French
Supervisor: Prof. Terese Løvås (NTNU)
Period: 2020-2023
Thesis: Detailed experimental and numerical study of zero carbon fuel in combustion engines

In my project, I will be studying the potential of using ammonia as a fuel for internal combustion engines. Ammonia is a carbon free fuel that is of interest to decarbonise engines. The goal of my project is to investigate burning ammonia with hydrogen and air in a compression ignition engine. I will be using experiments and numerical tools to investigate ammonia's combustion properties. This will allow an efficient combustion in the engine with the lowest amount of emissions such as nitrogen oxides.

Name: Hongyu Zhang
Affiliation: NTNU
Nationality: Chinese
Supervisor: Prof. Asgeir Tomasgard (NTNU), Prof. Ignacio Grossmann (Carnegie Mellon Univ.) and Dr Brage Rugstad Knudsen (SINTEF)
Period: 2020-2023
Thesis: Norwegian offshore energy system decarbonisation

My project is about the optimisation of Norwegian low-emission hybrid offshore energy systems investment planning and operation. Approximately a quarter of the current total Norwegian greenhouse gases is emitted from the Norwegian continental shelf, 84.6% of which is caused by platform located gas-fired generation. Therefore, it is of great importance to integrate more renewable technologies (e.g. offshore wind) to supply clean power to platforms to achieve low-emission offshore energy systems. I will develop a large-scale stochastic optimisation model and corresponding computational methods that provide cost-optimal, reliable, and secure low-emission hybrid offshore energy systems design and operational strategies.

Name: I Gusti Agung Gede Angga
Affiliation: NTNU
Nationality: Indonesian
Supervisor: Associate Prof. Carl Fredrik Berg (NTNU)
Period: 2020-2023
Thesis: Reduction of emissions from hydrocarbon production through alternative and energy-efficient drainage strategies

My project aims to develop or improve methodologies for reducing CO_2 emissions associated with reservoir recovery techniques. It is important because the subsurface fluid flow processes have great influences on energy use in petroleum production. The main challenge is how to ensure high recovery while keeping emissions low. At first, I will develop models for accounting for energy use, emissions, and costs in offshore hydrocarbon production. After that, I will perform optimisations of the drainage strategy considering both economic and CO_2 emission aspects.

Name: Daniel dos Santos Mota
Affiliation: NTNU
Nationality: Brazilian-Norwegian
Supervisor: Prof. Elisabetta Tedeschi (NTNU)
Period: 2020-2023
Thesis: Control strategies for stability guarantee in oil and gas platforms with significant renewable energy integration

I will propose control strategies for guaranteeing the stability of the electrical grid of oil and gas platforms with significant renewable energy integration. Gas turbines on the Norwegian Continental Shelf, usually running at low efficiency levels with spare capacity, account for roughly 20% of the total greenhouse gas emissions of Norway. Offshore wind represents an opportunity for reducing such emissions. In the next two years, I will investigate and propose strategies for overcoming technological challenges ahead of partially replacing gas-powered generators by offshore wind. These strategies are also applicable to island communities relying on fossil fuels as a primary energy source.

Name: Mohammad Ali Motamed
Affiliation: NTNU
Nationality: Iranian
Supervisor: Associate Prof. Lars O. Nord (NTNU)
Period: 2020-2023
Thesis: Lifetime efficiency improvement of gas turbine power generation offshore

I will design a gas turbine power generation system that could handle load changes efficiently offshore. This will reduce CO_2 emission and fuel consumption. This is important because gas turbines are expected to work mostly at inefficient part loads due to availability patterns of renewable energies. The design will be compatible with modern carbon capture and storage systems and hydrogen-base fuels requirements. I will develop a design methodology for future intermittent load gas turbines offshore. Then I will develop an inhouse modelling software for power generation offshore and assess the potential solutions through it.

International cooperation

International collaboration and dissemination are paramount to the excellence and success of *LowEmission*. The Centre capitalises on contributions both from academic research partners and industry. The communication and impact of the research results benefit greatly from the international collaboration in the Centre. The international penetration of Norwegian industry will also benefit from the adoption of transnational collaboration schemes. Globally leading universities and research centres secure a high academic tenure, while a strong commitment from the industry will ensure the implementation of the Centre objectives.

At the academic level, *LowEmission* collaborates and plans to organize researcher exchanges with top-rated international universities and research institutes such as:

- University of Strathclyde, UK
- Technical University of Denmark
- TNO, the Netherlands,
- Carnegie Mellon University, USA
- Lund University, Sweden
- University of Cambridge, UK
- CERFACS, France
- Imperial College, UK
- Sandia National Laboratories, USA
- Kiel University, Germany

Communication, dissemination and recognition

Communication was an important part of the *LowEmission* work in 2020 and this will continue in the coming years.

From an internal communication perspective, we strive for an active dialogue between the research and industry partners, ensuring that the Centre activities continue to tackle challenges that are highly relevant to the industry.

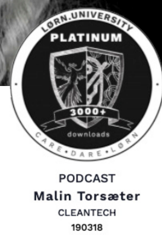
With *LowEmission* being a centre for knowledge transfer between industry, academia, scientists and the broader public, external communication activities are also of great importance. This includes taking part in meetings and workshops with parties from the oil and gas industry as well as taking part in public events and debates. As part of this work, *LowEmission* scientists had 10 scientific conference presentations in 2020.

Popular science communication

A trend in the popular science communication landscape is the multiplication of formats consumed by audiences. Short online videos and in-depth conversations (on podcasts, for example) are increasingly appreciated, in addition to articles and other written materials. We therefore made sure to include those formats in our popular science communication during the past year.

LowEmission was featured in two podcasts in 2020. Subproject 9 Lead Roar Nybø was featured in a new, international podcast called *Deep Tech Musings [AI + Blockchain]*. In the episode he dove into how and why AI and Machine Learning can be (and are) used on the NCS. You can find the episode here: spotify:episode:1bVifJRZ0vDXeM-nlbnmwYW

Centre Director Malin Torsæter was featured in one of Norway's most popular educational podcasts: *LØRN.TECH*. She explained and discussed the heart of *LowEmission*: how technology and science can be used to reduce the carbon footprint of offshore oil and gas production. The episode was downloaded more than 3000 times! You can find it here: https://shows.acast.com/lrntech/episodes/609-energytech-malin-torseter-forskning-for-en-grnnere-oljei



Center Director Malin Torsæter and LØRN.TECH host Silvija Seres.

We also made a video featuring three of our PhD candidates, explaining what their PhD projects are, and how they contribute to realizing *LowEmission*'s goals. You can find the video here: https://youtu.be/REnPy5aHzYw

Gullkronen nomination

For the past 12 years, Rystad Energy has celebrated Gullkronen, recognising companies, teams or people who have shown outstanding achievements on the NCS during the previous year. *LowEmission* was nominated in the *Green Initiator of the Year* category.

LowEmission
@LowEmissionNCS

Lovely start of the weekend for the LowEmission Research Centre! We are honored to receive a nomination for the 'Green Initiator of the Year' prize at this year's Gullkronen. Thank you @RystadEnergy for the recognition!

Oversett tweeten


GULL KRO NEN

Gullkronen - The Nominees 2020

Gullkronen 2020 honours outstanding achievements made by companies involved in the Norwegian energy business during 2019.

E&P Awards of the Year
Explorer: • Aker BP • Equinor • Lime • PGNiG
Business Developer: • DNO • Equinor & Lundin • Neptune Energy • Vår Energi
Project Developer: • Aker BP (Valhall Vestflanke) • Equinor (Johan Sverdrup) • Equinor (Trestakk) • Spirit Energy (Oda)
Field Operator: • Aker BP (Skarv) • Equinor (Gudrun) • Equinor (Heidrun) • Lundin (Edvard Grieg)

OS Awards of the Year
New Venture: • ControlCutter • InflowControl • Kelda Drilling Controls • Visavi Technology
Globetrotter: • Axess • Deepocean • Halfwave • Tomax
Business Success: • CCB • Interwell • Kaefer Energy • Aarbakke

Green Initiator of the Year
• Edvard Grieg full electrification (Lundin) • Hywind Tampen (Equinor) • LowEmission Research Centre (SINTEF and NTNU) • Northern Lights (Equinor, Shell and Total)

RYSTAD ENERGY
www.rystadenergy.com

SINTEF og 9 andre

9:20 a.m. · 25. jan. 2020 · Twitter for Android

4 Retweets 2 sitat-Tweets 6 likerklikk

Appendix

Statement of Accounts

(All figures in 1000 NOK)
As an option the funding and cost for each partner may be presented and also how funding and cost is allocated to the subprojects in the Centre.

Funding	Amount	In-kind	Sum
The Research Council	16 213		**16 213**
The Host Institution (SINTEF Energi)		861	**861**
Research Partners			
NTNU		1 925	**1 925**
SINTEF AS		579	**579**
SINTEF Ocean		254	**254**
Enterprise partners			
Operators	14 403		**14 403**
Vendors		4 816	**4 816**
Public partners			
Sum	**30 616**	**8 435**	**39 051**

Costs			
The Host Institution (SINTEF Energi)	13 854		**13 854**
Research Partners	20 381		**20 381**
Enterprise partners		4 816	**4 816**
Sum			**39 051**

Publications

PRESENTATIONS - 2020

1. **Barnett, Alejandro Oyarce**. *Fuel cells for offshore installations. LowEmission* Consortium Day - Breakout session 1; 2019-12-05
2. **Ditaranto, Mario; Saanum, Inge; Reyes-Lúa, Adriana; Larfeldt, Jenny**. *Partial decarbonization of Johan Castberg by ammonia addition in fuel. Effect of adding ammonia to fuel in an industrial gas turbine. LowEmission* Case study webinar series; 2020-12-02
3. **Gribkovskaia, Victoria; Nonås, Lars Magne; Kisialiou, Yauheni; Halvorsen-Weare, Elin Espeland**. *Decision support for offshore supply planning. LowEmission* Webinar; 2020-09-29
4. **Gruber, Andrea**. *Carbon-free firing of gas turbines for clean and efficient power generation off-shore. LowEmission* Consortium day - Breakout session 1; 2019-12-05
5. **Holdyk, Andrzej**. *Modelling for interaction studies between electrical components. LowEmission* SP5 webinar; 2020-05-14
6. **Kaut, Michal**. *HyOpt - status and plans. LowEmission* SP5 webinar; 2020-04-23

7. **Angga, I Gusti Agung Gede; Kristoffersen, Brage Strand; Bellout, Mathias; Berg, Carl Fredrik; Slotte, Per Arne; Bergmo, Per Eirik Strand**. *Development of low-emission subsurface drainage strategies*. *LowEmission* Webinar; 2020-10-08
8. **Lesaint, Cedric Michel**. *Material characterization of aged wet-design cable*. *LowEmission* Consortium Day - Breakout session 1; 2019-12-05
9. **Mazzetti, Marit Jagtøyen**. *Develop low emission technology to ensure the O&G industry can meet its emission goals*. Industri-topplederkonferansen (vendors); 2019-05-16
10. **Mazzetti, Marit Jagtøyen**. *Develop low emission technology to ensure the O&G industry can meet its emission goals*. Næringslivets klimakonferanse; 2019-06-24
11. **Mazzetti, Marit Jagtøyen**. *Develop low emission technology to ensure the O&G industry can meet its emission goals*. Aker Solutions Low Carbon Seminar, Aker Solutions offices, Trondheim; 2019-10-24
12. **Mazzetti, Marit Jagtøyen**. *Develop low emission technology to ensure the O&G industry can meet its emission goals*. OG21; 2019-06-25
13. **Mazzetti, Marit Jagtøyen**. Develop low emission technology to ensure the O&G industry can meet its emission goals. Petroleumskonferansen, RCN; 2019-06-05
14. **Mazzetti, Marit Jagtøyen**. *LowEmission - Meeting industry´s emission reduction goals*. NOROG Toppledermøte (operators); 2019-05-23
15. **Mazzetti, Marit Jagtøyen**. *LowEmission - Moving towards zero emission oil and gas production*. Energy Change 2019 - Stjørdalen; 2019-10-24
16. **Mazzetti, Marit Jagtøyen**. *LowEmission - Moving towards zero emission oil and gas production*. TNO workshop on the Nexus of Oil and Gas and Renewables; 2019-11-14
17. **Mazzetti, Marit Jagtøyen**. *LowEmission - Moving towards zero emission oil and gas production*. Offshore miljöforum; 2019-11-21
18. **Mota, Daniel dos Santos**. *Geometric representation of three-phase quantities*. NTNU PESC-EME Colloquium; 2020-05-20
19. **Nonås, Lars Magne; Gardarsdottir, Stefania Osk; Skorpa, Ragnhild**. *Developing technologies for low emission petroleum activities on the NCS*. Feltutviklings-konferansen 2020; 2020-02-11
20. **Nonås, Lars Magne; Gribkovskaia, Victoria**. *LowEmission - Offshore logistics*. *LowEmission* Consortium day; 2020-10-28
21. **Nybø, Roar; Skogestad, Jan Ole**. *Low-Emission - Integrated topside - downhole modelling*. *LowEmission* SP5 webinar; 2020-04-30
22. **Reyes-Lúa, Adriana**. *Offshore gas turbines: Operation practice and typical transients*. *LowEmission* Consortium day - Breakout session 1; 2019-12-05
23. **Reyes-Lúa, Adriana; Rohde, Daniel; Mocholí Montañés, Rubén; Skaugen, Geir**. *SP1 2020 Results and plans for 2021*. First *LowEmission* SP1 Family Meeting 2021.; 2021-03-02
24. **Rohde, Daniel; Skaugen, Geir**. *Simulation of heat recovery heat exchangers – why and how?* *LowEmission* webinar series; 2020-10-07
25. **Rohde, Daniel; Skaugen, Geir; Mocholí Montañés, Rubén**. *Industrial vs. academic approach to offshore bottoming cycle design*. Workshop: Industrial vs. Academic Approach to Offshore Bottoming Cycle Design; 2020-10-27
26. **Rohde, Daniel; Skaugen, Geir; Mocholí Montañés, Rubén**. *SP-family meeting*. *LowEmission* SP1 webinar; 2020-05-18

27. **Schümann, Heiner**. *SP8 – Energy efficient processing*, 6min pitch / project status. Low Emission Consortium Day 2020; 2020-10-28
28. **Schümann, Heiner; Holt, Torleif**. *Energy consumption of offshore oil and gas production*. Low Emission webinar series; 2020-10-21
29. **Skorpa, Ragnhild**. *SP6 Case study and innovation*: 6 min pitch and presentation. *LowEmission* Consortium Day; 2020-10-28
30. **Svendsen, Harald Georg**. *LowEmission - Hybrid offshore energy system modelling for operational decision support. LowEmission* SP5 webinar; 2020-04-16
31. **Svendsen, Harald Georg**. *North Sea Offshore Grid – Norwegian perspective and grid optimisation research*. North Sea Offshore Network (Wind Europe Offshore side event); 2019-11-28
32. **Svendsen, Harald Georg; Holdyk, Andrzej; Wiik, Jan; Mosgren, Idun Runde**. *LowEmission - Energy system modelling and simulation of typical platform. LowEmission* webinar; 2020-11-04
33. **Torsæter, Malin**. *LowEmission - Research centre for a low emission petroleum industry on the Norwegian Continental Shelf*. NOROG Steering group visit, Stjørdal; 2019-03-18
34. **Torsæter, Malin**. *LowEmission - Research centre for a low emission petroleum industry on the Norwegian Continental Shelf*. NPF Breakfast meeting; 2019-03-26
35. **Torsæter, Malin**. *LowEmission - Research centre for a low emission petroleum industry on the Norwegian Continental Shelf*. NEIA-NOIA Canada Cleantech Mission to Norway; 2019-03-13

MULTIMEDIA PRODUCTS

36. **Mazzetti, Marit Jagtøyen**. *LowEmission I Forventinger til senteret*. SINTEF Energi 2019
37. **Mazzetti, Marit Jagtøyen**. *LowEmission åpning*. SINTEF Energi 2019
38. **Mazzetti, Marit Jagtøyen**. Nyhetsmorgen. NRK Radio 2019
39. **Mazzetti, Marit Jagtøyen**. *The LowEmission PhD-candidates*. SINTEF Energi AS 2020

BLOGS AND INFORMATION MATERIAL

40. **Mazzetti, Marit Jagtøyen**. www.lowemission.no - nettsiden. 2020
41. **Mazzetti, Marit Jagtøyen; Skorpa, Ragnhild; Gardarsdottir, Stefania Osk**. *Happy occasion at SINTEF & NTNU – Opening of the LowEmission Research Centre*. 2020

MEDIA CONTRIBUTIONS

42. **Freiberg, Kjell-Børge; Dawson, James**. *Kan bli verdensledende med trøndersk teknologi* (Kronikk). Adressa [Avis]; 2019-01-05
43. **Hernes, Sigurd L.; Torsæter, Malin**. *Skal gjøre norsk oljeutvinning mer klimavennlig*. Adressa [Avis]; 2018-12-13
44. **Krekling, David Vojislav; Mazzetti, Marit Jagtøyen**. *Vil kutte alle utslipp på norsk sokkel innen 2035*. NRK.no [Internett]; 2019-11-26
45. **Lorentzen, Marius; Torsæter, Malin**. *SINTEF vant kampen - skal etablere det nye teknologisenteret for utslippskutt i oljenæringen*. e24.no [Avis]; 2018-12-13
46. **Mazzetti, Marit Jagtøyen**. *- Dette blir vårt nye landslag for lavutslippsteknologi i petroleumsindustrien*. enerwe.no [Fagblad]; 2019-06-14
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Personell

MANAGEMENT

Name	Position	Main research area	Institution	SP
James Dawson	Professor	Fluid mechanics and combustion	NTNU	
Stefania Gardarsdottir	Research Manager	Techno-economic process analysis	SINTEF	
Jon Magne Johansen	Senior Business Developer	Business development	SINTEF	
Jan Petter Pettersen	Asset Manager Blane	Field development	Repsol Norge AS	
Ragnhild Skorpa	Research Scientist	Well integrity	SINTEF	
Malin Torsæter	Research Manager	Formation physics	SINTEF	
Anders Ødegård	Senior Project Manager	Fuel cells and hydrogen	SINTEF	
Lars Magne Nonås	Senior Research Scientist	Optimization of offshore logistics	SINTEF	
Ann Karin Jullumstrø Aalberg	Project Coordinator	Accounting and central operations	SINTEF	

SP LEADERS

Last name	Position	Main research area	Institution	SP
Daniel Rohde	Research Scientist	Dynamic simulations	SINTEF	1
Nicholas Worth	Associate Professor	Turbulence, combustion, experimental methods	NTNU	2
Øystein Hestad	Research Manager	Transmission technology	SINTEF	3
Anders Ødegård	Senior Project Manager	Hydrogen, fuel cells	SINTEF	4
Harald Svendsen	Research Scientist	Energy systems, renewable integration	SINTEF	5
Ragnhild Skorpa	Research Scientist	Well integrity	SINTEF	6
Per Eirik Bergmo	Research Scientist	Reservoir technology, drainage	SINTEF	7
Heiner Schümann	Research Scientist	Process modelling and concept testing	SINTEF	8
Roar Nybø	Senior Business Developer	Well drilling, machine learning	SINTEF	9
Malin Torsæter	Research Manager	Formation physics	SINTEF	10

KEY RESEARCHERS

Name	Institution	Main research area	SP
Brede Andre Larsen Hagen	SINTEF / NTNU	Heat exchanger optimization	1
Daniel Rohde	SINTEF	Thermal energy systems	1
Geir Skaugen	SINTEF	Thermal energy systems	1
Han Deng	SINTEF	Heat exchanger optimization	1
Rubén M. Montañés	SINTEF	Thermal energy systems	1
Andrea Gruber	SINTEF	DNS of reacting flows	2
James Dawson	NTNU	Experimental measurement of reacting flows	2
Jonas Moeck	NTNU	Theoretical/low-order numerical modelling	2
Mario Ditaranto	SINTEF	Experimental measurement of reacting flows	2
Nicholas Worth	NTNU	Experimental measurement of reacting flows	2
Rob Barlow	Sandia National Labs	Experimental measurement of reacting flows	2
Terese Løvås	NTNU	Numerical modelling and chemical kinetics	2
Amar Abideen	NTNU	High voltage insulation (PhD)	3
Cedric Lesaint	SINTEF	Transmission technology	3
Emre Kantar	SINTEF	Transmission technology	3
Frank Mauseth	NTNU	High voltage insulation	3
Gerardo A. Perez-Valdes	SINTEF	Operations reaseach, optimisation, economics	3
Gunnar Berg	SINTEF	Transmission technology	3
Hans Helmer Sæternes	SINTEF	Transmission technology	3
Harald Svensen	SINTEF	Grid planning	3
Julian Straus	SINTEF	Optimisation, process, energy system	3
Luca Riboldi	SINTEF	Energy supply, process, energy system	3
Marit Mazzetti	SINTEF	Energy supply, process, energy system	3

Name	Institution	Main research area	SP
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Øystein Hestad	SINTEF	Transmission technology	3
Alejandro Oyarce Barnett	SINTEF	Low temperature fuel cells PEMFC	4
Anders Ødegård	SINTEF	Low temperature fuel cells PEMFC	4
Belma Talic	SINTEF	High temperature fuel cells SOFC	4
Eianr Vøllestad	SINTEF	High temperature fuel cells SOFC	4
Jonathan Polfus	SINTEF	High temperature fuel cells SOFC	4
Magnus Skinlo Thomassen	SINTEF	High temperature fuel cells SOFC	4
Patrick Fortin	SINTEF	Low temperature fuel cells PEMFC	4
Wen Xing	SINTEF	High temperature fuel cells SOFC	4
Øyvind Lindgård	SINTEF	Low temperature fuel cells PEMFC	4
Adriana Reyes Lua	SINTEF	Offshore energy system	5
Andrzej Holdyk	SINTEF	Electrical system modelling and stability	5
Asgeir Tomasgaard	NTNU	Optimisation	5
Brage Knudsen	SINTEF	Control systems, gas	5
Dag Atle Nesheim	SINTEF	Data mangement	5
Daniel Mota	NTNU	Electrical system control and stability	5
Elisabetta	NTNU	Electrical system control and stability	5
Harald Svendsen	SINTEF	Energy systems, renewable integration	5
Hongyu Zhang	NTNU	Optimisation	5
Jan Ole Skogestad	SINTEF	Integrated modelling	5
Kiet Tuan Hoang	NTNU	Controls	5
Lars Tedeschi Imsland	NTNU	Controls	5

Name	Institution	Main research area	SP
Michal Kaut	SINTEF	System optimisation	5
Roar Nybø	SINTEF	Integrated modelling	5
Vibeke Nørstebø	SINTEF	System optimisation	5
Ragnhild Skropa	SINTEF	Well integrity	6
Stefania Gardarsdottir	SINTEF	Techno-economic process analysis	6
Alv-Arne Grimstad	SINTEF	Reservoir technology, drainage, IOR, EOR	7
Arne Marius Raaen	SINTEF	Rock physics, fracturing and inflow performance	7
Bjørnar Lund	SINTEF	Gas lift optimisation	7
Carl Fredrik Berg	NTNU	Reservoir technology, field scale optimisation	7
I Gusti Agung Gede Angga	NTNU	Reservoir and topside, field scale optimisation	7
Jan Ole Skogstad	SINTEF	Reservoir modelling and simulation	7
Per Bergmo	SINTEF	Reservoir technology, drainage, IOR, EOR	7
Albert Barrabino	SINTEF	Oil & gas processing, dynamic modelling	8
Heiner Schümann	SINTEF	Oil & gas processing, multiphase transport and subsea technology	8
Leila Eyni	NTNU	Oil & gas processing, subsea technology	8
Milan Stanko	NTNU	Oil & gas processing, subsea technology	8
Torleif Holt	SINTEF	Oil & gas processing, energy recovery	8
Dag Atle Nesheim	SINTEF	Offshore logistics, optimization, energy and transport	9
Daniel Franklin Krause	SINTEF	Methane emission measurements, energy and transport	9
Elin E. Halvorsen-Weare	SINTEF	Offshore logistics, optimization, energy and transport	9
Endre Sandvik	SINTEF	Offshore logistics, optimization, energy and transport	9
Lars Magne Nonås	SINTEF	Offshore logistics, optimization, energy and transport	9
Maria Føre	SINTEF	Methane emission measurements, energy and transport	9
Morten Hammer	SINTEF	Gas technology	9

Name	Institution	Main research area	SP
Ole Meyer	SINTEF	Gas technology	9
Roar Nybø	SINTEF	Well drilling, modelling, machine learning	9
Thor Anders Aarhaug	SINTEF	Sustainable energy technology	9
Truls Flatberg	SINTEF	Operations research, optimisation, economics	9
Victoria Gribkovskaia	SINTEF	Offshore logistics, optimization, energy and transport	9
Yauheni Kisialiou	SINTEF	Offshore logistics, optimization, energy and transport	9

PHD STUDENTS WITH FINANCIAL SUPPORT FROM THE CENTRE BUDGET

Name	Nationality	Period	Sex M/F	Topic	SP	Completetd (X)
Amar Abideen	Saudi-Arabian	09/2020 - 08/2023	M	Wet Design of AC Power Cables for Future Offshore Power Grids	3	
Mohammad Ali Motamed	Iranian	07/2020 - 06/2023	M	Assessment of alternative concepts for combined cycle gas turbine operation under varying loads	1	
Martin Löw	German	09/2020 - 08/2023	M	The structure of ammonia/hydrogen/nitrogen flames	1	
Jessica Gaucherand	French	10/2020 - 09/2023	F	Ammonia/Hydrogen for internal combustion engines	3	
Leila Eyni	Iranian	08/2020 - 08/2023	F	Methods to Design and Manage Energy-Efficient Offshore Hydrocarbon Production Systems	8	
I Gusti Agung Gede Angga	Indonesian	05/2020 - 04/2023	M	"Reduction of emissions from hydrocarbon production through alternative and energy-efficient drainage strategies"	7	
Daniel Mota	Brazilian-Norwegian	02/2020 - 01/2022	M	Control strategies for stability guarantee in oil and gas platforms with significant renewable energy integration	5	

Name	Nationality	Period	Sex M/F	Topic	SP	Completetd (X)
Hongyu (Richard) Zhang	Chineese	09/2020 - 08/2022	M	Stochastic programming models for planning and design of hybrid offshore energy systems integrating renewables	5	
Kiet Tuan Hoang	Norwegian	11/2020 - 10/2022	M	Model predictive control under uncertainty for offshore power systems integrating renewables	5	
Andreas Ormevik	Norwegian	09/2020 - 08/2022	M	Logistics optimization of low-emission offshore vessels	9	

MASTER'S DEGREES

Name	Sex M/F	Topic	Task	Year
Jens Fredrik Lunde	M	Electric field distribution in layered polymeric HVDC insulation	3.2	2019-2020
Ingrid Wibe	F	Impact of offshore electrification in Norway to greenhouse gas emissions within the European energy system	3.3	2020-2021
Fadhil Berylian	M	Calculation and visualization of energy dissipation and energy balance in reservoir models	7,1	2020
Andreas Bakke Moan	M	A hybrid genetic approach to the operational supply vessel planning problem with speed optimization	9,1	2020
Pål Ødeskaug	M	A hybrid genetic approach to the operational supply vessel planning problem with speed optimization	9,1	2020

2020

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