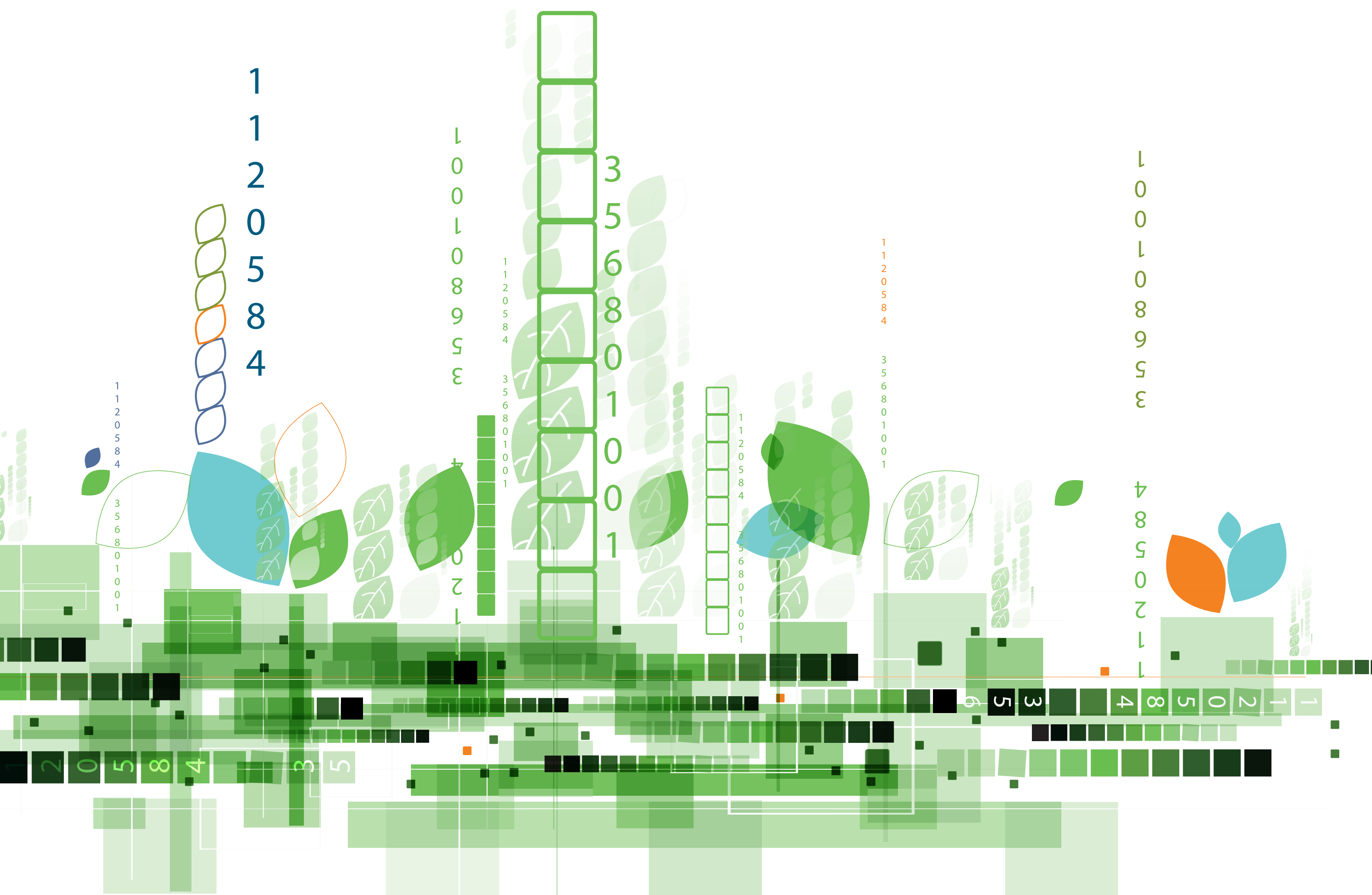
Annual report 2018

HighEFF

Centre for an Energy Efficient and Competitive Industry for the Future



Selected highlights from 2018

JANUARY


Petter E. Røkke
@proekke
«Our cities are hidden power stations» - Development of smart thermal grids for #energyefficiency in urban areas. Worth reading! :-) #fme #higheff @SINTEF @Statkraft @RCN_Norway

MARCH


NTNU Energy
@EnergyNTNU
Rundt dette bordet er ledere fra mange FMEer, @NTNU OG @SINTEFenergy samlet for å finne ut hvordan vi kan få enda mer #innovasjon ut av forskningssentrene for #miljøvennlig #energi (#FME). Vi kaller det Innovation Task Force

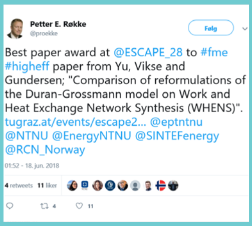
APRIL


Petter E. Røkke
@proekke
Attending @EASACnews meeting on Energy & environment today, giving advice on SET plan priorities within #energyefficiency and discussing policy advice for EU strategies within this topic.
#fme #higheff @EERA_SET @EU_ScienceHub @EU_H2020 @RCN_Norway @stracma

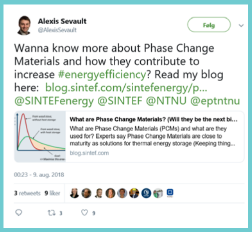
MAY


#SINTEFblog
HighEFF Annual Meeting – Picture Blogg

JUNE


Petter E. Røkke
@proekke
Best paper award at @ESCAPE_28 to #fme #higheff paper from Yu, Vikse and Gundersen; "Comparison of reformulations of the Duran-Grossmann model on Work and Heat Exchange Network Synthesis (WHENS)". tugraz.at/events/escape2... @eptntnu @NTNU @EnergyNTNU @SINTEFenergy @RCN_Norway

JULY


Alexis Sevault
@AlexisSevault
Wanna know more about Phase Change Materials and how they contribute to increase #energyefficiency? Read my blog here: blog.sintef.com/sintefenergy/p... @SINTEFenergy @SINTEF @NTNU @eptntnu

AUGUST


Horisont 2020
@Horisont2020
Kunnskapen fremskaffet i Prosjektet SuperSmart etterspørres nå fra resten av Europa. @SINTEFenergy i førersetet for å spare energi i supermarkeder. #arendalsuka2018 #horisont2020


SINTEF Energy
@SINTEFenergy
Vår forsker Camilla Claussen bidrar til at du (og europeere) kan spise is med god klimasamvittighet
gemini.no/2018/08/norske... #arendalsuka @forskningsradet @EU_Commission @proekke @Nils_Rokke @eptntnu

Ingrid C. Claussen from HighEFF at Arendalsuka

÷10 %
Greenhouse gas emission

÷30 %
Specific energy consumption

Increased value creation

Follow our new account **@HighEFF_FME**

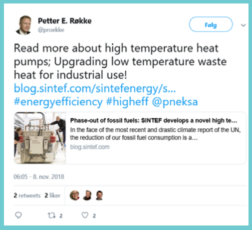
SEPTEMBER

HighEFF presentation at the Research Council of Norway contact meeting

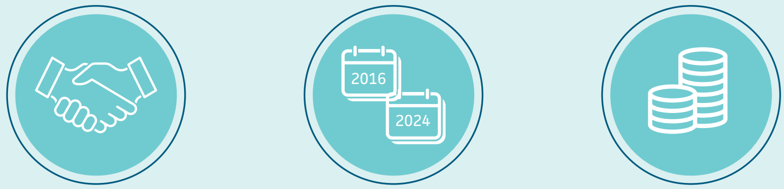
OCTOBER

HighEFF Cross-sector workshop

DECEMBER

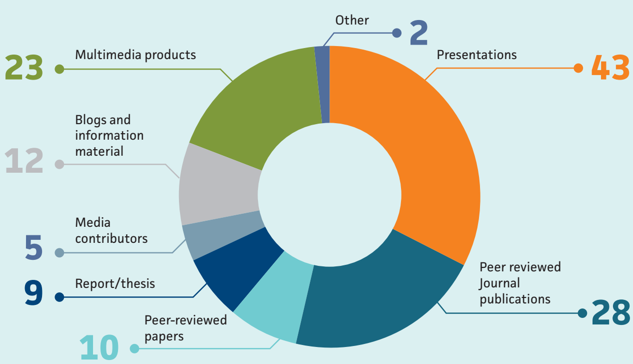


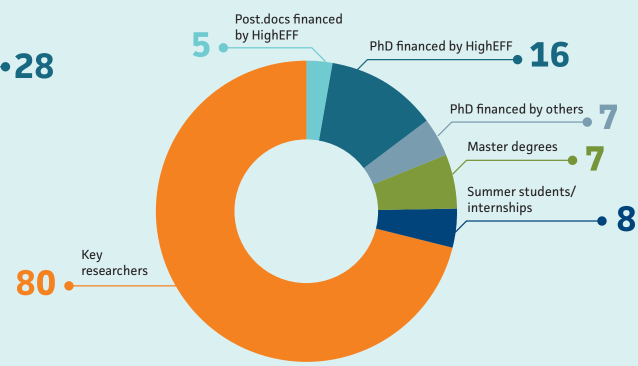
Selected highlights from 2018 – find more videos and stories on
www.higheff.no -> Annual report 2018



43 PARTNERS **8** YEARS **400** MNOK

2018 by the numbers





There might be some discrepancies between the numbers in figure and numbers registered in Cristin, mainly due to FME partners that do not have a university or research institute affiliation or because the FME projectcode has not yet been registered in the post.

TABLE OF CONTENT

MESSAGE FROM **THE DIRECTOR**

PETTER E. RØKKE is the Centre Director of HighEFF.

His current position is Research Director for the Thermal Energy department in SINTEF Energy Research.

Petter earned a PhD in Mechanical Engineering from NTNU in 2006.

During his career in SINTEF, he has been active within the fields of CCS (CO2 capture and storage), Bioenergy and Industrial Energy Efficiency. Since 2011 he has been within the management group of SINTEF Energy Research, first as Research director for the Electric Power Technology department and since November 2012 for the Thermal energy department. He was chairman of the board for FME CenBio, is currently member of the board for FME Bio4Fuel and member of the EnergiX program board in the Research Council of Norway. Internationally, he is coordinator of the Joint Programme «Energy Efficiency in Industrial Processes» within the European Energy Research Alliance.

Welcome to the 2018 annual report for FME HighEFF!

Following the ”start up years” 2016-2017, we are now reporting from a very productive year. Our vision *”Joint effort for creating a competitive, energy efficient and environmental friendly industry for the future”* is still well in progress and we see specific results contributing towards fulfilling this vision.

From the management side we have had a strong focus on increasing the interaction between academia, R&D and industrial partners, both vendors and end users. Particularly in the planning of 2019 there have been several bilateral meetings with industry as well as a successful ”cross-sector workshop” in October 2018.

In this report you will find information about selected highlights from FME HighEFF, description of activities within the six research areas and will get to know more about educational activities.

Innovation is an important aspect for the FMEs. Early 2018, NTNU and SINTEF established an ”Innovation task force” with the intention to formulate a set of advices for the FMEs to ensure that innovation is high enough on our agenda. This resulted in a report giving five specific recommendations for the FMEs, that we will follow up in FME HighEFF.

22 PhDs and Postdocs have already been employed within the Centre and all are well in progress with their research. We have seen presentations from these both in technical meetings and in discussions with the consortium.

During 2018 we arranged two workshops for the consortium, and we will do the same in 2019. The next workshop is planned for 8th and 9th May 2019, in Trondheim. The first day will be a conference open for the public hoping to attract participants also outside of FME HighEFF, to inform about Centre activities.

I hope you find this annual report interesting and share it internally in your company!

MESSAGE FROM
THE CHAIRMAN OF THE BOARD

ARNE ULRIK BINDINGSBØ is Chairman of the HighEFF Board.

His current position is Leading Researcher, Energy efficiency and CO_2 reducing technologies, Research & Technology, in Equinor.

Arne Ulrik Bindingsbø earned a PhD in Materials Science from NTH in 1992.

He has more than 25 years of R&D experience from the Oil & Gas sector. His focus area is to develop and execute R&D projects within the field of Operations & Maintenance. As the field of O&M consists of many technical disciplines, Bindingsbø is very focused on collaborative innovation to obtain R&D projects that result in industrial implementation.

Since 2014 he has held a position as Adjunct Professor, Department of Marine Technology, NTNU.

Vast amount of waste heat is unused in the industry. Improved energy efficiency and reduction of emissions plays a crucial role in protecting the global environment. Significant changes in both production and consumption of energy are needed to avoid a global temperature rise of more than two degrees.

The Norwegian land-based industry and offshore oil & gas production are already among the world leaders in energy efficiency compared to similar industries in other countries. Nevertheless, the greenhouse gas emissions from these operations account for a large part of Norway's total emissions. There is a need for technology development and subsequent implementation to further increase the energy efficiency and reduce the greenhouse gas emissions.

During the first years of operation HighEFF together with our partners, more than 50 universities, research institutions and industrial partners, have been working together towards achieving the vision of creating a competitive, energy efficient and environmentally friendly industry for the future. Our strength is in the cross industrial collaboration with all the largest industry sectors in Norway: material and metal producing industries, oil, gas and energy industry, food and chemical industry as well as industry clusters with different sectors.

We have progressed well with both our academic and industrial ambitions and have already identified significant energy efficiency potentials through the completed case studies and will pursue these and others further by developing and implementing knowledge, technology and solutions developed within HighEFF.


บริษัท พีทีที ฟีนอล จำกัด
20
ปลอดภัยไว้ก่อน SAFETY FIRST

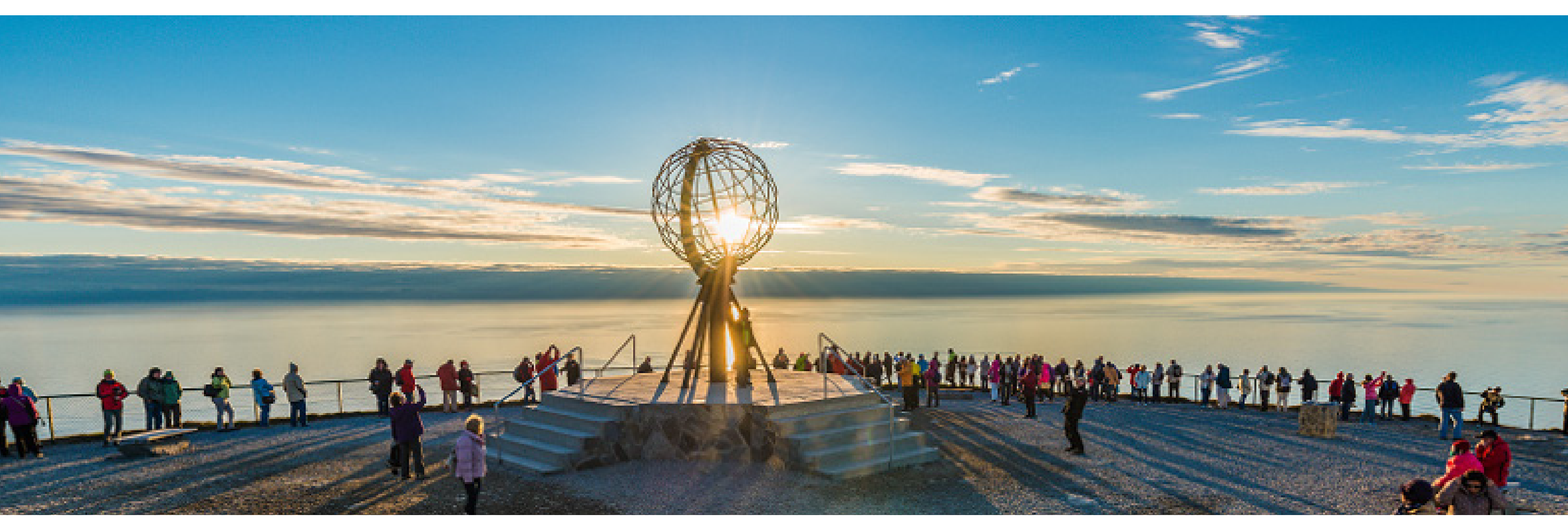
VISION

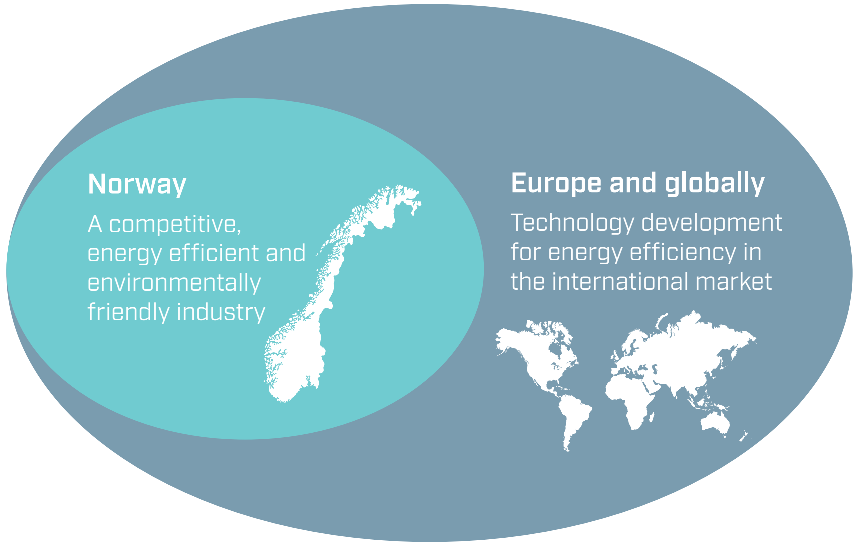
Joint effort for creating a competitive, energy efficient and environmental friendly industry for the future

Energy preservation and security is a global challenge. There is a global energy shortage, and the way we use and produce energy today is causing greenhouse gas emissions contributing to climate changes.

The EU has energy and climate targets of 40 % reduction in greenhouse gas emissions and 27 % increase in energy efficiency by 2030. At the same time, there will be an increased demand for energy in the years to come. There is a clear need for reduction in industrial emissions and more effective industrial energy systems. For instance, if one industrial plant can be more energy efficient, there will be more available energy for other purposes. Also, Norway depends on being more energy efficient to maintain a competitive industry in the future, both nationally and internationally. As part of solving this problem, FME HighEFF was established in 2016.

HighEFF will build an internationally leading Centre for strategic research within industrial energy efficiency. For one thing, HighEFF will enable a 20-30 % reduction in specific energy use and 10 % in emissions, hence, supporting the EU energy targets. HighEFF will also allow value creation for the Norwegian industry by developing 15-20 new innovative solutions for energy and cost-efficient plants, energy recovery and utilization of surplus heat, and develop methods and tools for analysis, design and optimization of energy efficient systems.





GOALS

HighEFF will spearhead the development and commissioning of emerging, energy efficient and cross-sectorial technologies for the industry, and:

- Enable 20-30 % reduction in specific energy use and 10 % in emissions through implementation of the developed technologies and solutions, hence support the EU target of 40% reduction in greenhouse gas emissions and 27 % increase in energy efficiency by 2030.
- Allow value creation for the Norwegian industry by developing 15-20 new innovative solutions for energy and cost-efficient plants, energy recovery and utilization of surplus heat.
- Develop methods and tools for analysis, design and optimization of energy efficient systems.
- Build an internationally leading Centre for strategic research within industrial energy efficiency.
- Generate 6 KPN, 8 IPN, 6 DEMOS and 4 EU spin-off projects
- Enable competence building by educating 22 PhD/ Post.doc candidates, 50 MSc candidates, and training/recruitment of 30 experts in industrial energy efficiency.
- Disseminate and communicate project results; 150 journal articles and conference papers.

	The three first overall goals are illustrated by three different symbols in this document:
	Enable 20-30% reduction in specific energy use and 10% in emissions through implementation of the developed technologies and solutions, hence support the EU target of 40 % reduction in greenhouse gas emissions and 27 % increase in energy efficiency by 2030.
	Allow value creation for the Norwegian industry by developing 15-20 new innovative solutions for energy and cost-efficient plants, energy recovery and utilization of surplus heat.
	Develop methods and tools for analysis, design and optimization of energy efficient systems.

RESEARCH PLAN
AND STRATEGY

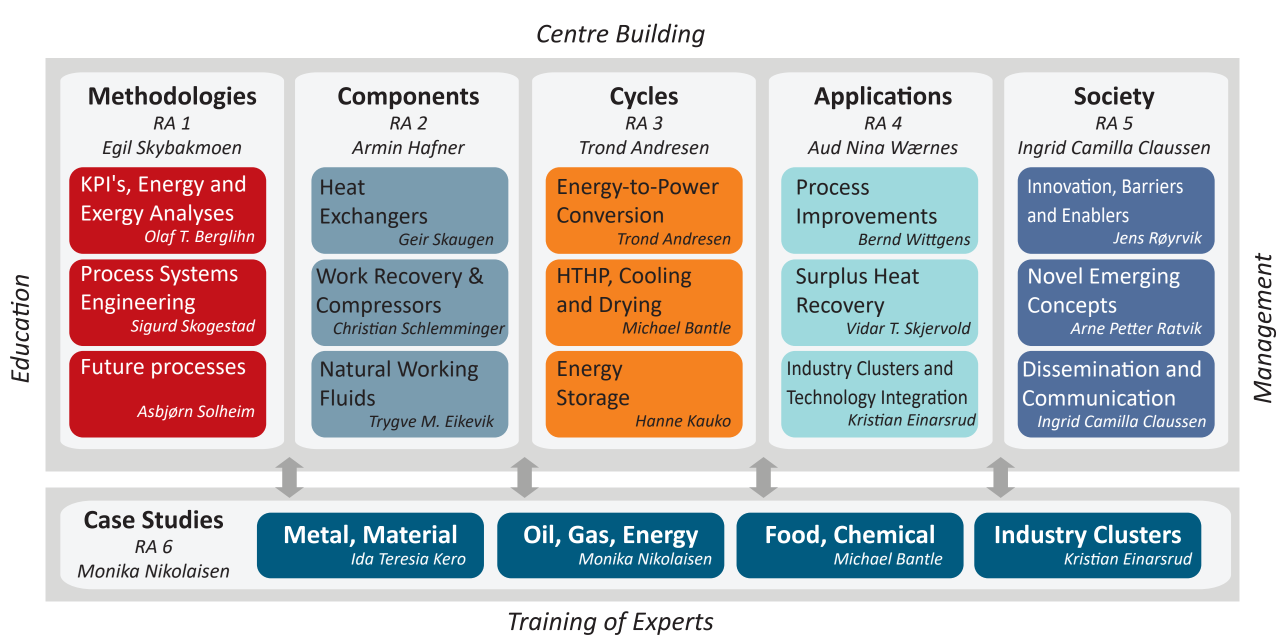
RESEARCH PLAN

The research topics covered by HighEFF require in-depth studies of fundamental aspects related to research on thermodynamic systems and operation, heat and mass transfer processes and fluid dynamics, in addition to social science. The fundamental knowledge is implemented in development of components, cycles and applications.

HighEFF addresses the research and development areas in 6 Research Areas (RA), with a special focus on industry related case studies in RA6 where measurable results from the implementation of HighEFF technologies in the different industry sectors are obtained. Sector-based workshops are arranged to identify the path for concept development and the key areas where undertaking energy efficiency measures is likely to give the most significant impact. The KPIs and energy and exergy analyses from RA1 will be utilized in making these decisions. The case studies give input to the innovation strategies and roadmaps in RA5 as well as to the concepts studied in RAs 2-4.

To ensure collaboration and exchange of results across the RAs and WPs, researchers from academia and research institutes are working closely with industrial experts. The research methods include lab experiments, industrial measurements and pilot plants, as well as modelling efforts at different levels for simulation and optimization. Fundamental technological R&D involving thermodynamics, kinetics and transport phenomena are conducted for increased insight and competence building that could act as a catalyst to innovation. The international partners participate in research and education activities.

Education on PhD and Post-doc level, as well as on a Master level, is an important part of the centre activity.



INNOVATION STRATEGY

Tweets from the Innovation Task Force report launch.

FME Innovation Task Force

"FME Innovation Task Force" was an expert hub of people appointed by SINTEF Energy and NTNU Energy in 2018. The aim was to make recommendations on how innovation and new ideas are best created within the FME communities. In November 2018, the final report of FME Innovation Task Force was presented, giving five recommendations;

1. A high level of management commitment is essential, and all FME Managers must assume the role of a committed promoter of innovation.
2. It is essential to have a plan in place at each FME for the development of an innovation culture, and the FME should assign a dedicated person (Innovation Manager) to follow up this plan.
3. The Innovation Manager shall supervise all aspects of innovation within the FME and maintain contact with the other FMEs, perhaps by means of an innovation forum.
4. The task force recommends the use of tools to facilitate the systemisation and valuation of concepts and technical innovations.
5. The task force recommends that a systematic project be conducted to highlight the technical innovations generated by the FMEs. This project should be linked to the FMEs' ongoing dissemination work.

Some of these activities are already covered in the HighEFF Centre activities, but these recommendations will be followed up closely by the HighEFF team in 2019 to ensure further development on innovation strategies.

Novel Emerging Concepts

To further emphasize innovation in HighEFF, and make room for new ideas, the yearly funding of Novel Emerging Concepts (NEC) will continue. In 2018 HighEFF funded the NEC project *Organizing shared resources and alternative business models* with the aim to provide the HighEFF partners with a handbook/report for use when assessing new possibilities for resource- and energy exchange and collaborations, including decision support models and tools. Having the 2018 NEC proposals in mind, the expectation for the 2019 calls are high!

Effects of energy research: Energy efficiency in the industry

Another spin-out-study in 2018 was called "Effekter av Energiforskningen" (The effects of energy research). The study was financed by the Research Council of Norway.

The study was conducted by Impello Management and Menon Economics in cooperation with all eight FME Centers. Each FME reported on different sections of the study. HighEFF was responsible for reporting on the section covering *energy efficiency in industry*.

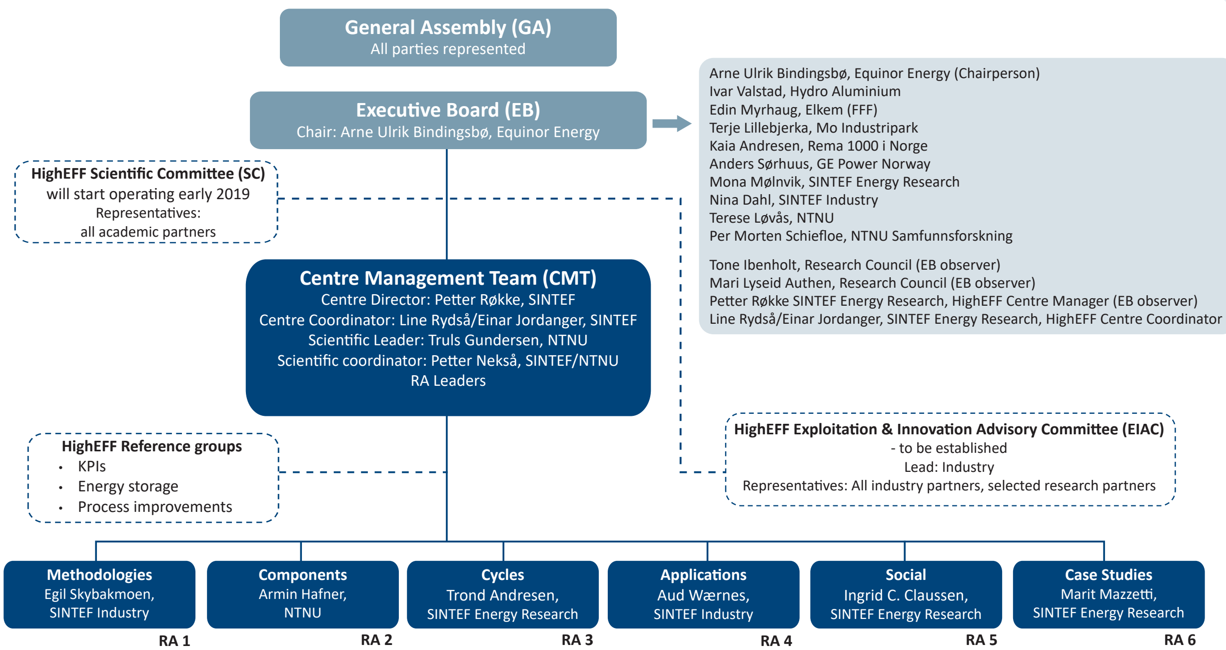
Within the topic industrial energy efficiency, six case areas were chosen in total (as shown below), covering a broad range of Norwegian industry. The effects of the research are based on projects financed through the EnergiX, RENERGI and Climit programs during the last 10 years (2008-2018).

C1: Energy efficient and eco-friendly refrigeration and HP systems for supermarkets with CO_2 as working fluid
C2: Reduced emission from off-shore gas-turbines by heat recovery
C3: Increased utilisation of low temperature surplus heat
C4: Reduced energy use and greenhouse gas emissions in the aluminium industry
C4: Energy efficient and environmentally friendly production of copper
C5: Integrated energy systems for the industry

The results showed a high potential for reduction in energy costs. Estimates shows a potential of 30 to 40 billion NOK based on an energy efficiency potential of 10 TWh/year documented by two of the selected cases. The realization is naturally depended on a stepping up and implementation in the industry.

Kjell-Børge Freiberg, Minister of Petroleum and Energy who commissioned the effect study, with Petter Røkke, Centre Manager in HighEFF.

ORGANIZATIONAL **STRUCTURE**



FME HighEFF is hosted by SINTEF Energy Research and the Centre Director is Petter E. Røkke. The General Assembly (GA) where all partners (30 industry partners and 13 research partners) and the Executive Board Chair are represented, makes decision that involve major changes to the consortium. Nancy Jorunn Holt (Hydro Aluminium) was appointed as the GA Chair at the first GA meeting in June 2017. The GA meets at least once a year.

The GA approved the members of the Executive Board (EB) and Arne Ulrik Bindingsbø (Statoil Petroleum) was appointed Chair of the EB at the first GA meeting in June 2017, and the members have not changed since then. In addition to Arne Ulrik Bindingsbø, the other members of the EB are Ivar Valstad (Hydro Aluminium), Edin Myrhaug (Elkem/FFF), Terje Lillebjerka (Mo Industripark), Kaia Andresen (REMA 1000 Norge), Anders Sørhuus (GE Power Norway), Mona Mølnvik (SINTEF Energy Research), Nina Dahl (SINTEF Industry), Terese Løvås (NTNU), and Per Morten Schiefloe (NTNU Samfunnsforskning). The EB usually holds four meetings a year.

The work with finding the Scientific Committee representatives was started in 2018 and will be completed and start operating early in 2019.

The Centre Management Team (CMT) consists of the Centre Director Petter E. Røkke (SINTEF Energy Research), Centre coordinator Line Rydså (Einar Jordanger, deputy), the Scientific Leader Truls Gundersen (NTNU), Scientific Coordinator Petter Nekså (SINTEF Energy Research), and the six RA leaders. The RA leaders are Egil Skybakmoen (SINTEF Industry), Armin Hafner (NTNU), Trond Andresen (SINTEF Energy Research), Aud N. Wærnes (SINTEF Industry), Ingrid Camilla Claussen (SINTEF Energy Research) and Marit Mazzetti (SINTEF Energy Research). The CMT is responsible for the strategic and executive centre management, including issues relating to coordination between work packages, and centre performance. CMT arrange regular meetings as required for coordinating the activities in the Centre. The Centre management reports on scientific, technical and financial matters as well as actual progress relating to EB.

METHODOLOGIES RA1
Egil Skybakmoen
SINTEF Industry

COMPONENTS RA2
Armin Hafner
NTNU

CYCLES RA3
Trond Andresen
SINTEF Energy Research

APPLICATIONS RA4
Aud N. Wærnes
SINTEF Industry

SOCIETY RA5
Ingrid Camilla Claussen
SINTEF Energy Research

CASE STUDIES RA6
Marit Mazzetti
SINTEF Energy Research

SCIENTIFIC COORDINATOR
Petter Nekså
SINTEF Energy Research

SCIENTIFIC LEADER
Truls Gundersen
NTNU

FME HighEFF Centre management is located at NTNU Gløshaugen in Trondheim.

In addition to the above-mentioned structure, HighEFF also has a Core Team (CT) consisting of the Centre Director, Centre Coordinator, Scientific Leader and the Scientific Coordinator, discussing matters concerning budget, educational activities and other scientific topics.

CENTRE DIRECTOR
Petter E. Røkke
SINTEF Energy Research

CENTRE COORDINATOR
Line Rydså
SINTEF Energy Research

CENTRE COORDINATOR (DEPUTY)
Einar Jordanger
SINTEF Energy Research

PARTNERS

RESEARCH & EDUCATION INSTITUTES

VENDORS & TECHNOLOGY PROVIDERS

USER INDUSTRY

equinor

AkerBP

GASSCO

FINNFJORD

Hydro

eramet

Alcoa

Elkem
A Bluestar Company

NIKKELVERK
A GLENCORE COMPANY

Ferroglobe

MOWI®

Mo Industripark as

bulk
infrastructure

WACKER

Borregaard

REMA 1000

TINE®

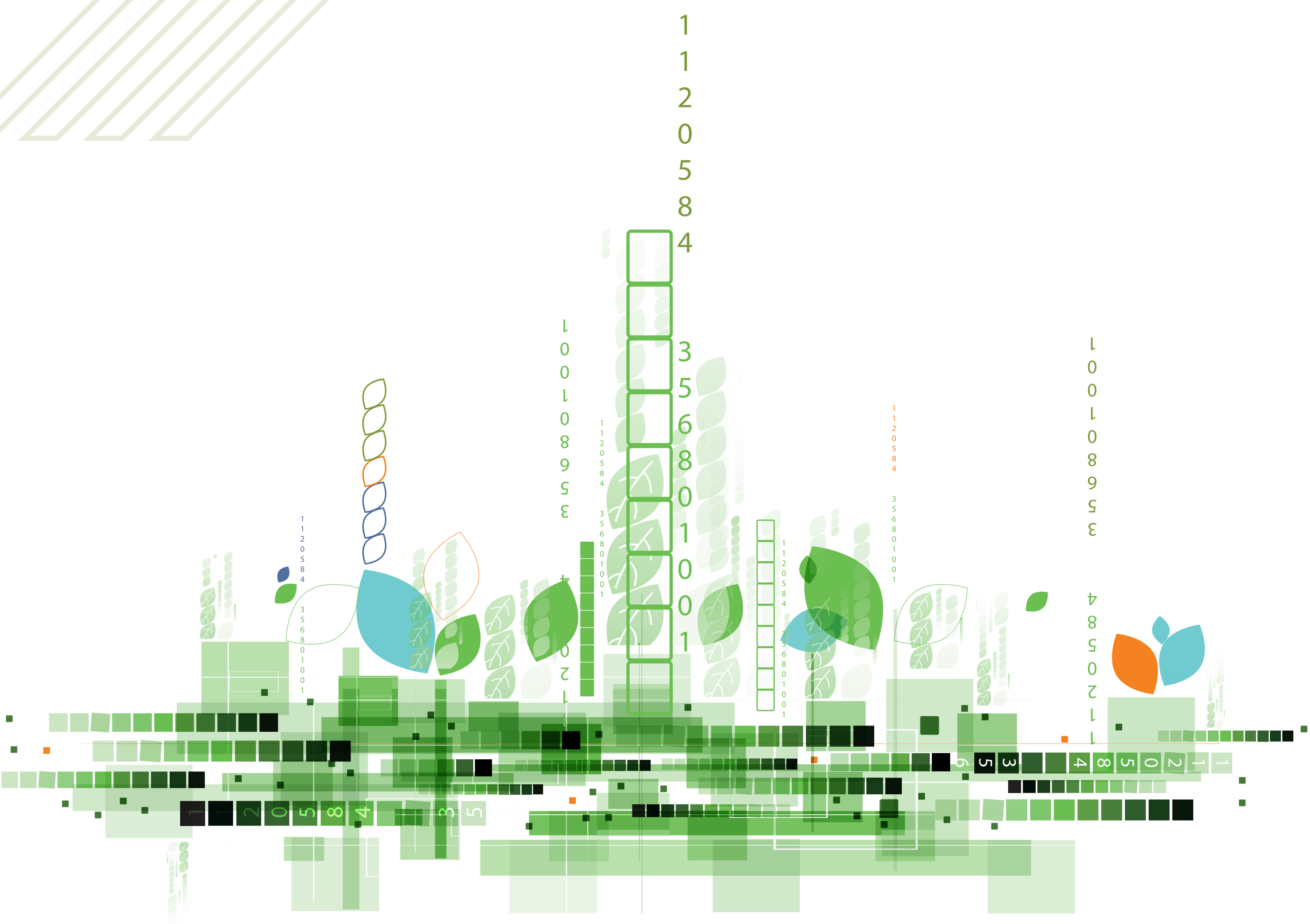
Orkla

VEDDE
FISHMEAL FISHOIL

ENABLERS

ENOVA

Innovasjon
Norge



How we work together

The vision of HighEFF strongly rely on creating good arenas for cooperation between industry, academia and research partners. Our vision is founded on the words of Professor Arne Bredesen, stating that excellent research best can be produced through three means: Knowledge-Friendship-Teamwork. HighEFF will build upon and bridge the good means through common goals, joint research and teamwork.

All partners are able to contribute to the technical discussions and take part in research activities and affect the direction and ambitions for the next year's work plan. There are many arenas for technical discussions and initiating new activities.

In addition to all the meetings for specific sectors, research areas, topics, activities or tasks, 2018 saw the following larger meeting places and workshop open for all partners:

- Cross-sector Workshop, highlighting both the sector-specific and the wide-relevance technology development, barriers and enablers (held on 24-25 October)
- Annual Consortium meeting held in Trondheim on 2 and 3 May

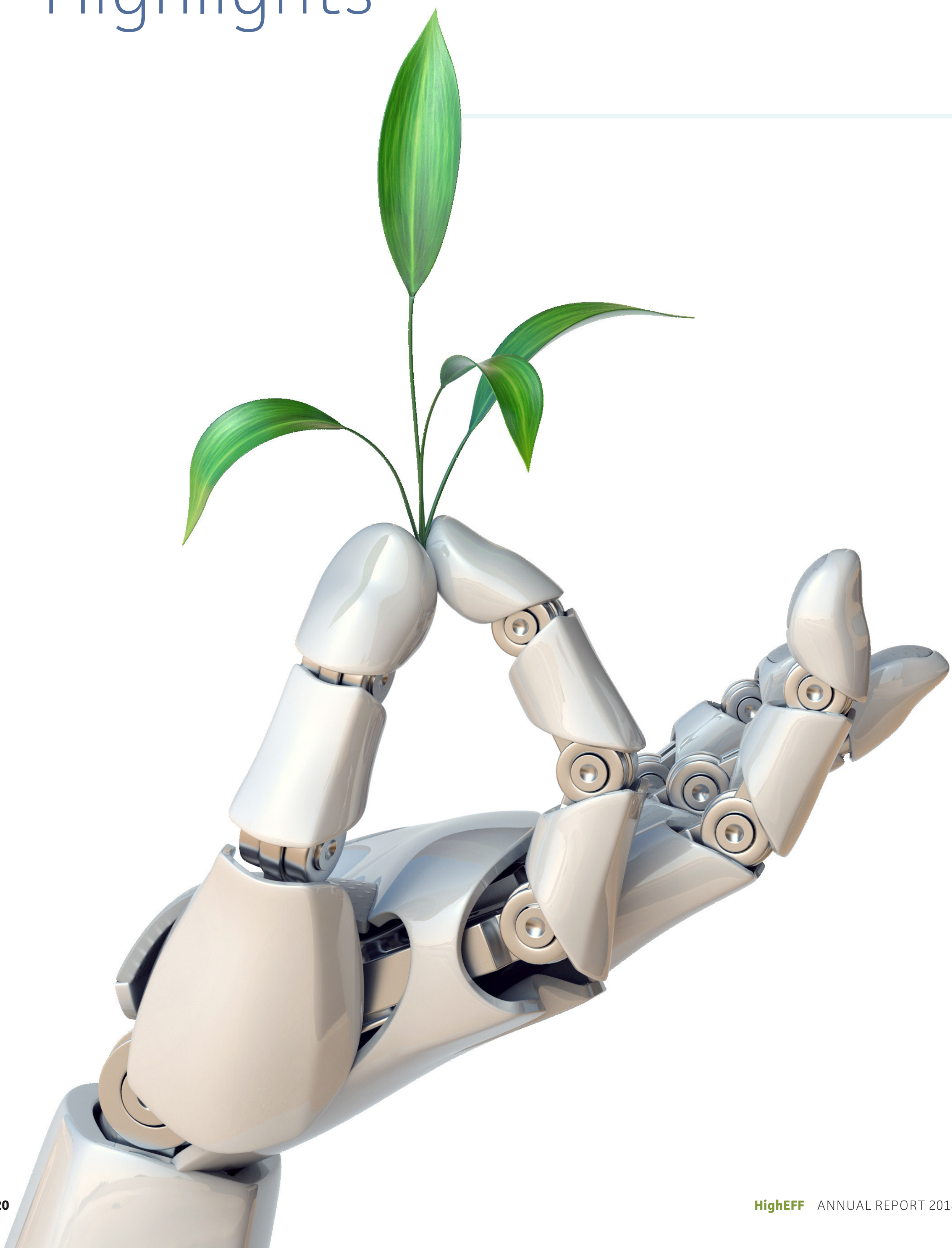
To ensure that all suggestions and input to research tasks are taken into consideration, the Scientific Coordinator will have the overall overview of the process.

The first annual internal PD and PhD workshop for the entire center was held at 7 March 2018, and the second workshop centre is planned for 25 February 2019.

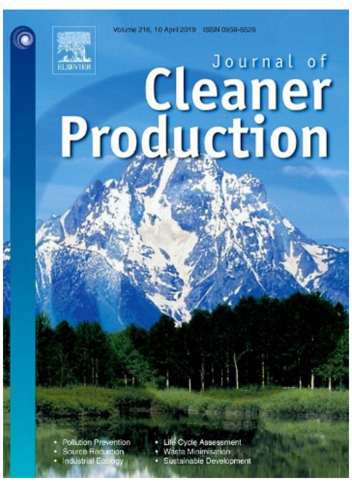
Centre management and the decision-making groups have consistent meeting frequencies:

- Executive Board (EB)- 4 meetings in 2018
- A site-visit from the Research Council was combined with the first EB-meeting (February)
- General Assembly (GA) – 1 meeting in 2018
- Centre Management Team (CMT) - every 3rd week
- RA Work meetings

Highlights



Highlight #1



Collaborative dynamics in environmental R&D alliances

Siri Jakobsen, Thomas André Lauvås, Marianne Steinmo, Nord University

The use of environmental policies to facilitate research and development (R&D) collaborations that generate environmental innovations (EI) is increasingly important for sustainable development. However, few studies have examined how the collaborative dynamics between R&D partners influence how they respond to environmental objectives.

We address this gap by studying two Norwegian environmental R&D alliances and the development of their collaborative relationships with respect to organizational structures, knowledge bases and dominant logics. We find that R&D partners with similarities in these aspects are more likely to respond coherently to policy objectives, compares to R&D partners with differences.

We also find that partners that are too diverse may experience problems when collaborating, while partners that are too similar may experience problems when developing radical knowledge. Our results have potential implications for policy makers and organizations that engage in R&D collaboration for environmental innovations.

Highlight #2

Propane-butane heat pump development

Christian Schlemminger (PhD), SINTEF Energi

High temperature heat pumps (HTHP)- a technology enabling increase in efficiency and competitiveness, in addition to emission reduction.

Demands for process heat up to 150 °C are estimated to 172 TWh/year on European basis, an equivalent energy consumption of about 8.500.000 Norwegian households. High temperature heat pumps (HTHP) can utilize and upgrade e.g. low temperature waste heat (<50 °C) to valuable process heat (>100 °C) (Concept B in Figure below). An extended working range of the heat source side enables simultaneous ice- water production (<0 °C) while producing process heat (>100 °C) (Concept A in Figure below). Beside some exceptions like the technology from Hybrid Energy, standard heat pump technologies for industrial applications are restricted by simultaneous heat source and heat sink temperatures in the ranges 30 °C to 70 °C and 70 °C to 90 °C.

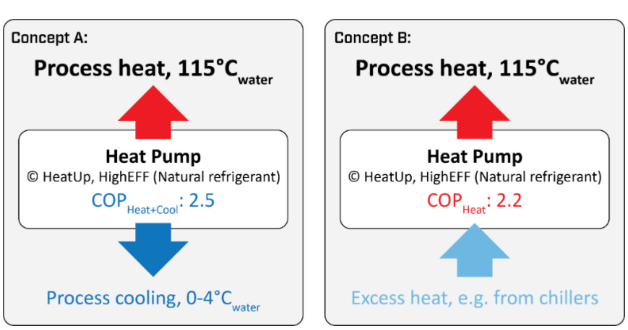
Technology development in HighEFF is focusing on propane butane cascade-HTHP technology where environmentally friendly and non toxic natural working fluids are applied, allowing sustainable systems. The technology is seen as complementary technology to existing HTHPs.

An optimal process integration of HTHP enables the efficient use of renewable electricity as CO_2 lean primary energy source, leading to; a) increased process efficiency, b) reduction in operation costs and c) reduction in CO_2-emissions.

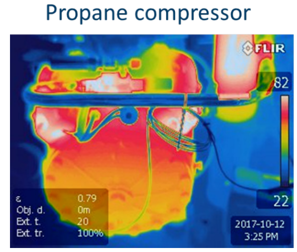
Prototype compressor from Dorin works well under hard conductions with high efficiency

The propane butane cascade-HTHP comprised of on propane compressor (on the shelf) for lifting the heat from e.g. -1 °C to about 65°C and a butane compressor (prototype) lifting from 65°C to 115°C. The compressors are installed in the propane butane cascade-HTHP lab test facility which is part of the HighEFFLab infrastructure.

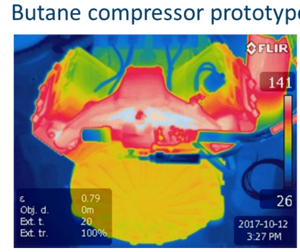
The special design of the prototype compressor allows a better heat management and reduces the thermal stress. The total compressor efficiency of about 0.7 was measured for the butane prototype compared to 0.6 of the on the shelf propane compressor. Oil analysis and a complete compressor maintenance supported the good measurement results.

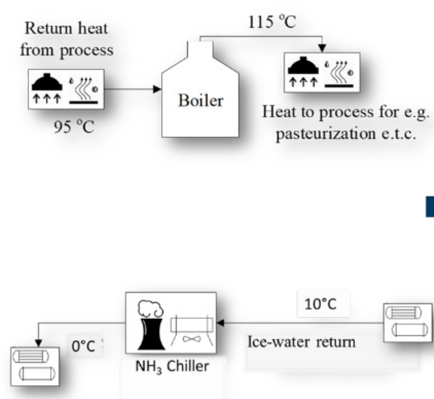


Propane compressor

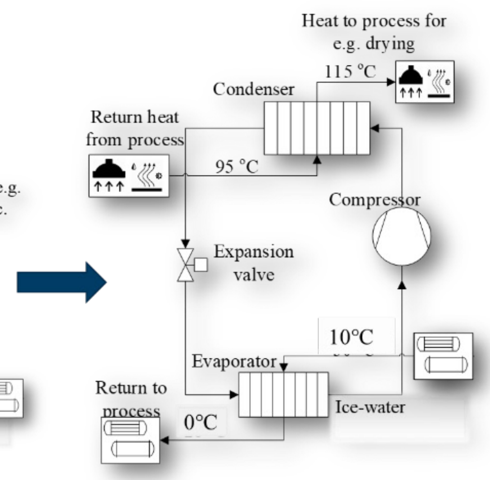


Butane compressor prototype





Separate ice water and process heat production



Integrated HTHP for simultaneous ice-water and process heat production enables:

- Utilization of waste heat → increased efficiency
- Primary energy savings → reduced cost
- CO2 emission reduction → environmental friendly

Successful proof of concept

HighEFF focuses in WP2.2 Work recovery and compressors and WP3.2 HTHP, cooling and drying on component development, cycle improvements and system performance of the novel cascade HTHP. The work carried out supported by HighEFF partner Dorin (Compressor manufacturer), Cadio AS (Heat pump system developer) and in cooperation with KPN-HeatUp. Focus is tuned to extend the working range of HTHP on heat source- and heat sink side temperatures.

In 2018 the focus was set toward simultaneous production of ice-water and process heat. Lab scale cascade heat pump test campaign with a 20 kWth setup were conducted to predict the performance of a 300 kWth pilot plant. The test campaign covers an evaporation temperature range of -1 °C to +1 °C and a condenser temperature range of 113 °C to 118 °C enabling ice-water chilling from 10 °C to 4 °C and a hot-water heating from 85 °C to 116 °C.

A combined heating and cooling $COP_{combined}$ of 2.6 to 2.8 was achieved for a temperature lift of 110 K to 80 K, respectively. In other words, 1 kWh renewable electricity is used to provide 2.8 kWh useful heating and cooling.

HighEFF is paving the way towards industrial pilot installation 300kWth @115°C

The research conducted in HighEFF contributed to the spin-off project SkaleUP where HighEFF partners Tine, Cadio, Dorin and SINTEF together with Skala Fabrikk are aiming to develop an industrial pilot scale HTHP to evaluate the potential of the technology.

Performance estimations predict a primary energy saving potential of 53 % and a potential CO_2-emission reduction of 94 %. The implementation potential is evaluated in RA6 across the industry sectors.

	Concept A	**Concept B**	**Todays system**
Heating capacity	300 kW	300 kW	300 kW
Cooling capacity	125 kW	_	125 kW
Excess heat	0 kW	>125 kW	50 kW (Ammonia HP, COP3)
Oil/gas/district heating	0 kW	0 kW	315 kW
Total energy	170 kW	136 kW	365 kW el fossil
Energy saving	**195 kW / 53 %**	**179 kW / 50 %**	**0 kW / 0 %**
Reduced carbon emission	97 % *based on Norwegian el mix	97 % *based on Norwegian el mix	0 kW

Highlight #3

Pre-Heating of Carbon Anodes for Aluminium Electrolysis

Martin Grimstad, M.Sc. student at NTNU

Internal and external possibilities

In FME HighEFF, a number of case studies are carried out in research area (RA) 6. In 2018, funding from work packages 6.1 and 6.4 were combined to study possible ways to utilise low-temperature waste heat from aluminium electrolysis. A number of options for external use of the excess heat have been collected to be further assessed in 2019. For internal use of the excess heat, two different options for pre-heating of raw materials are evaluated: pre-heating of alumina powder and pre-heating of carbon anodes. So far, the latter option seems very promising.

The pre-heating of anodes has been studied industrially by NTNU-student Martin Grimstad under the supervision of Kristian Etienne Einarsrud, NTNU and Asbjørn Solheim, SINTEF Industry. Grimstad has carried out industrial experiments at Alcoa Mosjøen during the summer of 2018 and more experiments will be performed there during the spring 2019 to confirm and complement the findings.

Anode pre-heating is simple and effective both for energy efficiency and process stability

The energy consumption for a primary aluminium smelter is around 14 kWh/kg Al on average today. The anode replacement procedure has been identified as an activity where energy could potentially be saved. Upon the insertion of a cold anode into the cell, a fraction of the molten cryolite bath will freeze under the anode due to the large temperature difference. This frozen layer can, in addition to delay production, cause process instabilities, thermal disturbances and requires additional energy to re-melt. The old anode extracted from the bath at a temperature of approximately 900°C is an obvious source of potentially useful heat. Our results show that pre-heating the anode was beneficial for energy efficiency and process stability, when compared to previous anode settings. The new anodes could be heated up to 100 °C using the heat from the replaced anode by placing the two in a specially built container.

Kristian Einarsrud far left, Martin Grimsrud number three from the left and Nina Omdahl from Alcoa in the middle.

Highlight #4

New methodology for heat-to-power analysis applied to a surplus heat scenario at Mo Industripark

Joint RA3 and RA6 study, Monika Nikolaisen

A new methodology for design/off-design semi-steady state analysis of power production over variable heat source and -sink conditions was developed and demonstrated in a potential study on utilizing available surplus low-pressure steam at Mo Industripark. In addition to optimizing power output, the new methodology evaluated optimal distribution of heat exchanger sizes in the system using a novel "generic heat exchanger model" (GHX). HighEFF partner Alfa Laval contributed with contributed performance data from their commercial heat exchangers to allow for a validation of the model; and the resulting comparison of heat transfer areas for the same design specifications matched very well.

The potential for power production was found to be up to 8.3 GWhel per year based on available surplus heat in the current boiler system. With new purpose-built boilers for heat-to-power conversion, the realizable potential could be much higher, but the investigated case only considered opportunities using the existing heat recovery infrastructure.

Presentation at the 10th KIFEE symposium – Kyoto international forum for environment and energy
Monika Nikolaisen presented the study at the 10th KIFEE symposium, which took place at the coastal vessel MS Finnmarken (Hurtigruta) 5th - 7th of October. KIFEE is an international forum for exchange of research and education within the fields of environment, energy, and materials, and promotes strategic cooperation towards a sustainable society. Several participants from HighEFF were present at the symposium to share recent advances within energy research.

Monika Nikolaisen (fifth from left) was awarded a prize for her presentation of the study at KIFEE, along with a group of other young researchers

Methodologies RA**1**

The main objective of Methodologies is to improve existing and develop new methodologies for improved energy efficiency in industrial plants. This requires close interaction with industry and the outcome will be disseminated and applied in other Research Areas.

In Methodologies, we believe that technological enhancements are better drivers of innovation than cost reductions. For that reason, solutions that are thermodynamically more efficient will serve as our main driver. Also, changes in the framework conditions related to energy, environment, new technologies and market will be closely considered in our work.

All 6 PhD students are now recruited. One Post Doc (PD) (of two) finished the work from 1.7.2018. International collaboration is established with University of Manchester (UoM) and Massachusetts Institute of Technology (MIT) and one PhD student (Vikse) stays at MIT until summer 2019. 18 journal papers and 16 proceedings/papers for conferences was published and presented in 2018.

KPIs, Energy and Exergy Analyses/ Process Systems Engineering

One important task for RA1 is to use relevant KPIs for energy and resource efficiency. PD Magnanelli fulfilled her work within KPI's and Exergy indicators for industrial practice during 2018. A workshop titled "RA1 + RA4 Workshop on KPIs, process improvements and surplus heat recovery" was arranged in Trondheim June 2018. From industry Elkem, Eramet and Mo Industripark were present together with SINTEF and NTNU researchers. Based on work performed earlier and discussions during this workshop a report "Definition of case studies" was delivered, giving the directions to further work in 2018 and 2019. A case study will be performed at Mo Industripark (MIP).

PhD Vikse and PD Yu are studying Work and Heat Exchange Networks (WHENs), Waste Heat Recovery by using ORCs and various Polygeneration concepts. Together with Prof. Truls Gundersen they received the Best Paper Award at the Escape conference in Graz, titled *"Comparison of reformulations of the Duran-Grossmann model on Work and Heat Exchange Network Synthesis (WHENS)"*. Work and heat integration is established as a new field. Participating with MIT/ Prof. Barton in development of a new paradigm for simulation and optimization is established. The work is non-smooth analysis for (hybrid)modelling and applied to LNG processes.

Future Process Framework

Aluminium electrolysis by the Hall-Héroult process is energy intensive. In Norway, 18 TWh of electric power is consumed (12-13 % of the Norwegian production) for manufacturing about 1.2 Mton aluminium. The process emits around 2.1 Mt CO_2-equivalents. The focus in HighEFF is to evaluate some alternatives to the traditional Hall-Heroult process.

The paper "Inert Anodes – the Blind Alley to Environmental Friendliness?" was presented in a large international conference (TMS) in March 2018 with good feedback and interest. A truly inert anode has not yet been developed, but the foundation of Elysis in Canada (Rio Tinto, Alcoa and Apple) shows willingness to develop a new process. The evaluation of the chloride process with less energy consumption and CO_2-footprint, was finalized early 2018 with the report "Carbochlorination routes in Al production". This route is to be followed up by an industrial partner. New concepts and solutions for use in today's HH- process has also been evaluated, creating a basis for continued research on methods and means for decreased energy consumption and environmental footprint.

Advanced exergy analysis of the oil and gas processing on a North Sea platform is the key activities for a PhD study starting late 2018. This activity will be further planned with industrial partners and ongoing in 2019 with high focus.

Components RA2

The main objective is to develop components required for cost-effective implementation of efficient systems for heat pumping and conversion, with main focus on the categories heat exchangers, compressors and work recovery.

To achieve these goals, we develop methods and tools required for designing components and cycles with natural working fluid mixtures; thermodynamic properties, system optimization, and experimental development. The research area also perform design, support integration and maintain flexible component test facilities for the HighEFFLab infrastructure.

Research Activities and Results

Heat Exchangers

The work related to heat exchanger (HX) for cold thermal energy storage (CTES), applicable for display cabinets in supermarkets continues, with focus on increased performance of display cabinets and power peak shaving. Experience has been gained on how the derivative free optimisation framework NOMAD can be implemented for process and HX optimisation. For simple Rankine cycles the gradient based method was compared to NOMAD in terms of time consumption and robustness.

The work on 3D-printing continues to streamline the process from HX geometry optimisation, on-screen visualization, 3D-editing and finally 3D-printing. The main outcome was a visualization scripting with Python toward Paraview, a well-known visualization toolkit for CFD.

HighEFF Lab – Heat Exchanger Laboratory was designed. The two test rigs cover: HX prototype test rig up to 40 kWth and a small-scale heat transfer coefficient and pressure drop test rig.

Work recovery & Compressors

Design and testing of Multi-ejector expansion modules continue. These devices are substituting standard high-pressure electronic expansion valves in refrigeration systems.

Two expansion devices designed for R744 (CO_2) refrigeration systems (capillary tube and fixed geometry ejector) were experimentally tested to determine performance in different ambient conditions. Tests and numerical investigations concluded that ambient conditions did not significantly affect the operation of the capillary tube and the R744 ejector.

Three approaches to perform modelling of piston compressor processes have been developed: 1D model; 3D CFD model; and 3D FEM impact model. These modelling approached give complementary insights into the piston compressor processes and how to optimize compressors for increased efficiency and reliability. A measurement campaign has been performed with the prototype compressor for butane. The prototype compressor shows high isentropic efficiencies in the order to 0.70 to 0.78, nearly constant over pressure ratio investigated. The volumetric efficiency declined from 0.89 to 0.75 with increasing pressure ratios.

Natural Working fluids

The investigations on hydrocarbon heat transfer and pressured drop in small pipes continues. Calibration was done against correlation for single phase flow in vapor form; a 5.6 % deviation for the pressure drop; 1.6 % for heat transfer coefficient. For fluid visualization, a high-speed camera will be installed in 2019.

A library for general humid gas "hglib" was built based on "hxlib" library. hglib is connected to THERMOPACK, enabling to calculate humid gas as real gas. The EOS, e.g. PR, EOCGC, GERG2008 have been tested with the reference result by hxlib at low pressure, and EOCGC, GERG2008 perform well.

Available methods for calculating the viscosity of a hydrocarbon mixture at high pressures and temperatures were investigated. A sufficiently general correlation is difficult. The TRAPP method is quite accurate but tends to overpredict the viscosity. The CS2 model has a similar accuracy, but underpredicts the results. For both models the density calculations needs to be as accurate as possible. Refprop results are generally better than TRAPP and CS2 with some exceptions.

Cycles RA3

The overall goals are to develop improved cycles and concepts for converting and upgrading energy sources, including surplus-heat-to-power conversion, energy storage systems, and heat upgrade using heat pumps. Technologies and applications where HighEFF research has large impact potential are emphasized.

Energy-to-power conversion
A new methodology for design/off-design semi-steady state analysis of power production over variable heat source and -sink conditions was developed and demonstrated in a potential study on utilizing available surplus low-pressure steam at Mo Industripark. In addition to optimizing power output, the new methodology evaluated optimal distribution of heat exchanger sizes in the system using a novel "generic heat exchanger model" (GHX). HighEFF partner Alfa Laval contributed with performance data from their commercial heat exchangers to allow for a validation of the model; and the resulting comparison of heat transfer areas for the same design specifications matched very well.

Development of thermo-electric generation systems for industrial surplus heat conversion resulted in a preliminary concept design of a redundant 480 W (24 V) TEG system including electrical architecture. Work in 2019 will target source/sink heat exchangers and fouling aspects, as well as evaluating impact potential for a selected industrial application.

High temperature heat pumps, cooling and drying
A heat pump for combined delivery of ice-water (0-4°C) and hot water (100-110 °C) was verified in a 20 kW demo unit in cooperation with HighEFFlab and HeatUp project. The compressor prototypes were delivered by HighEFF partner Dorin Innovations (through RA2).

A concept for a closed loop heat pump system, based on turbo-compressors, was evaluated with focus on more compact de-superheating in order to reduce the system size. This activity will be followed up by experimental investigations in the next years. Additionally, the so-called reversed Brayton Cycle was investigated; which has promising results for heat delivery of up to 500°C.

The advantages of R744 for process chilling was outlined and compared with state of the art freezing/chilling systems. Such systems show high potential for increased productivity due to the increase heat removal.

Energy storage
2018 activities were focused on two tasks:
1 evaluation of thermal energy storage (TES) potential for industry clusters to reduce the use of peak heating; and
2 mapping processes within the industries represented in HighEFF that are suitable for, and that could benefit from, the application of high-temperature TES.

The first task was carried out as a case study towards Mo Industry park, and the work will be continued during 2019. The most promising cases from task (2) will be investigated further with in 2019.

PhD candidate Håkon Selvnes continued his work on a novel cold thermal energy storage (CTES) related to a food processing factory. A pilot CTES unit was delivered to the VATL laboratory at Gløshaugen by the local supplier Skala at the end of 2018, and the unit will be tested during 2019.

Applications RA4

Examination of applications that will integrate basic research and concepts, components, and cycles developed in other RAs into specific industry settings, to generate more energy-efficient processes and improved heat capture and utilisations concepts are targeted.

The exploitable potential in surplus heat found in partner industries, and next generation surplus heat capture and utilization will be investigated. Using industrial examples, the potential of ”green” industry clusters and local thermal grids on a Nordic scale will be developed further. The aim is identification of potential and concepts for possible use of process gas, develop a metal furnace concept with 20% lower total energy use.

Process improvements

Energy consumption and potential energy savings in power intensive industries such as ferro-alloy industries where the prime energy consumer is a sub-merged arc furnace (SAF); potential reduction and/or utilization of energy recovered were main activities in 2018. A literature review on auxiliary systems in ferro-alloy production processes with respect to reduced energy consumption performed. Further a study on improved utilization of the energy streams exiting the SAF through the furnace off-gases has been performed; as an extension concepts for a cascading utilization of the energy in the temperature range from 800oC to approximately 150oC have been presented.

Starting from the energy cascading concept, a new task has been initiated to simultaneously reduce overall energy consumption, NOx-reduction and potentially facilitate CO_2-capture from ferro-silicon furnaces. Currently, furnaces utilize fresh air for temperature control in the furnace hood, during the initial study a concept is developed where cleaned flue gas after energy recovery is recycled to the furnace. The study consist of (i) a CFD-model to evaluate the influence on the temperature profile in the furnace hood and thus NOx-formation and (ii) an evaluation of the potential energy savings and energy recovery through an improved temperature control which allows for higher temperatures into the energy recovery system.

In total three reports/papers on the technical and economic feasibility of simultaneously energy recovery and emission reduction have been presented linking activities within EnergiX-project ”SCORE” to HighEFF. Two papers at Infacon considering the design and experimental verification of the SCORE concept; followed up by a technical and economical evaluation at SPIS/Flogen 2018.

Surplus heat recovery

An energy flow database was completed for Alcoa, Eramet, Hydro and Wacker’s plants in Norway. The data provided by the industry partners has been validated through mass and energy balances both on plant and sub-process level, revealing significant variations in the data quality. Exergy calculations were performed for some plants for additional validation. Process flow diagrams giving an overview of mass and energy flows as well as data validation have been completed for a selection of the plants. The diagrams and the database itself are available on the HighEFF eRoom.

A possible path for improving Al smelter off-gas heat exchanger design has been explored. It was investigated whether changing tube geometry into a wavy cross-section would improve heat exchanger performance. Results were compared against the current state-of-the-art, showing both advantages and disadvantages.

Industry Clusters and Technology Integration

A methodology for modelling and optimization of energy exchange in industrial clusters and dynamic mathematical models for simultaneous exchange of energy and materials were developed. The description of barriers, whether they are physical, conceptual, technical or cultural, and understanding how these can be overcome are crucial in order to identify and implement future cross-industrial synergies and current activities will thus be extended to 2019.

Society
RA**5**

The overall aims are to manage the innovation activities and handle dissemination, communication and general flow of information in the Centre. Additionally, the goals are to form the innovation strategies and technological roadmaps for the industry sectors, and share them among partners, to enhance cooperation and synergies.

Innovation management will include research and internal and external interaction, as well as on the barriers and enablers for innovation and realization of HighEFF technologies and concepts.

Innovation, barriers and enablers

In addition to following up other initiated activities, the main objective of 2018 was to conduct data collections. In order to cover the wide range of topics framed by the label "society", the following collections was conducted:

1 Document studies (in connection to both interviews and case studies), based on available, public documents and mainly used as contextual data for preparation and further analysis.

2 A media discourse analysis on "industrial energy efficiency", an in-depth analysis (both coded and analyzed) covering 310 newspaper articles.

3 A total of 47 interviews, involving both university partners, industry representatives, and other relevant stakeholders.

4 Site visits involving tours of local industry sites and on-site interviews.

5 Two main case studies have been identified and has been followed closely throughout the year.

6 Two workshops within the HighEFF consortium have been conducted each involving 2-3 groups (5-10 participants in each group) of both industry and university partners, and two externally organized industry workshops in connection with one of the case studies.

7 Two HighEFF seminars have been conducted including presentations from university and industry partners as well as plural discussions. On the basis of these data collections, we have increased our knowledge of, and published articles about such topics as,

a) how policies are legitimized and debated in the public, and who are the core actors in the public energy efficiency discourse,

b) new and innovative takes on barriers and drivers of energy efficiency,

c) the potential and challenges related to innovation in FME centers in general,

d) how energy efficiency works in different industrial clusters,

e) how contextual conditions affect business models for industrial clusters and for energy sharing in general, and

f) variability and resilience in industrial symbiosis for energy exchange.

Novel Emerging Concepts (NEC)

The first call for NEC was launched in February 2019. In total 6 applications were received covering a broad part of the scientific challenges in HighEFF. At the end, the project Organizing shared resources and alternative business models was given the opportunity to present the project ambitions and initiate the work. The allocation of funding through NEC will also continue in 2019 with some minor adjustments of the call regarding objectives and guidelines for the funding.

Dissemination and Communication

In 2018, the website was revised to comprise all necessary sections for an efficient communication of project results and the Centre as a whole. A goal was to improve the website to be more attractive for the HighEFF Consortium and the general public, e.g. by giving information on forthcoming workshops, seminars, project content and partners, relevant conferences and news using blogs and newsletters, in addition to actively disseminate all open results from ongoing research.

Dedicated dissemination events arranged by HighEFF was the *Annual Consortium meeting* in May and *The Cross-Sector Workshop* in October.

The Dissemination and Communication plan was updated in accordance with planned activities in 2018. We had 11 blog articles, 4 newsletters and 23 videos. This resulted in higher digital visibility for HighEFF. For more details – see the Communication-chapter in this annual report.

Case Studies
RA**6**

Case Studies will be performed to obtain measurable results from the implementation of HighEFF technologies in the different industrial sectors. The overall goals for the case studies are to develop technology concepts that can lead to a 20-30 % reduction in specific energy use and/or minimum 10 % in CO_2 emissions through implementing technologies and solutions.

The research area shall promote HighEFF innovations, for example through spurring the development of novel concepts for power production cycles, heat pumping technologies and novel business methods for collaboration between industries.

Metals, Materials and Industry Parks

The use of waste heat from aluminium electrolysis has been studied as a case in WP6.1 and 6.4, jointly. For external use, several possibilities were investigated. Vegetable/fruit production in (heated) greenhouses, fish production on land, and the drying of algae seem to be good solutions, partly due to similar existing collaborations between different industries.

For internal use, pre-heating of raw materials has been investigated. Heating of anodes has proven efficient and beneficial, both for energy efficiency and process stability. Pre-heating of the alumina feed has been investigated as well but it seems that the pre-heating temperature would need to be least 500°C, a technical challenge yet to be resolved.

Oil, Gas & Energy

A new tool for evaluation of surplus heat upgrading and heat production at industry partner sites has been developed in collaboration with WP2.1 Heat Exchangers. The tool was applied to a case study on heat production at an electrified LNG plant, which also involved evaluation of a novel and compact heat pump concept that can potentially improve the cost-efficiency of large-scale heat pump implementation. The work package has also contributed to an evaluation of heat-to-power conversion at MIP with WP3.1 Energy-to-power conversion.

Food

Two main case studies were performed in 2018; one related to chocolate production and another related to fish meal production. The chocolate production requires large amounts of electricity and gas for heating. Until recently, no alternative to gas was available, but recent development of high temperature heat pumps now enables large reductions in energy use. The gas demand can be entirely or partially removed, and electricity for direct heating reduced by about 40-80 %. Results for the fish meal case show that the suggested modifications can provide energy savings of up to 55 %, with a reduction in CO_2-emissions of over 60 %.

Research Infrastructure

SINTEF researcher Christian Schlemminger and Michael Bantle are installing a propane-butane cascade heat pump with prototype compressors from Dorin. The installation can deliver hot water at 115 °C without the use of fossil fuels and is 2.5 times as energy efficient as direct driven boilers.

HighEFFLab

HighEFF Lab is a joint national laboratory between various departments at SINTEF and NTNU. The facilities will be located at the NTNU Gløshaugen campus in Trondheim, ensuring close collaboration between students and researchers from institutes and university. The research infrastructure will be accessible for all the partners in HighEFF.

In 2018, HighEFF Lab showed great progress, with several new HighEFF Lab installations. Some test facilities are still in the planning and calculation phase, while others are almost up and running.

The HighEFF Lab research infrastructures consists of more than 12 different installations. Her facilities; the two new big installations, HerculEx and the Expander test rig, are still in the design phase. The Natural refrigerants Laboratory consists of seven different installations, of which two is more or less in "shake down" or operating mode, four will be ready early 2019 while one is still in the design phase. As an example, the propane-butane cascade heat pump with prototype compressors from Dorin has already been in use and the installation can deliver hot water at 115 °C without the use of fossil fuels and is 2.5 times as energy efficient as direct driven boilers.

One challenge we are facing is to finish the rehabilitation of the new calibration room and upgrading of the Dewatering Laboratory on time. This must be finished for us to be able to install the new equipment. The work has been time-consuming until now, but we see a realistic timeline to finish the reconstruction of the different rooms before the summer 2019.

The new HighEFF Lab Dewatering Laboratory will be completed with new equipment:

- Microwave vacuum dryer (3 kW capacity, freeze drying option and inert gas drying possibilities)
- Heat pump dryer (25 kW capacity, 25 m3 tray area). This is expected to be inhouse during 2019
- Finally, a drying system that will operate between -15°C and 200°C and give valuable information of systems behavior and product quality in the specified temperature range. At high temperature, the infrastructure will give possibilities to operate with superheated steam. At low temperatures, the drying will give qualities like the vacuum freeze dryers, but more energy efficiently. At high temperatures the energy efficiency is high due to the heat pump system. This drying system is still in the design phase.

At the Gas and material characterization Lab, the FTIR, QCL and three different microscopes and Alytech gas mixer was received in 2018. The Alytech gas mixer has been used to generate mixtures of CF4 and the FTIR and QCL analytical performance was compared. The results are of strategic importance.

Laboratory director Linda Helander at SINTEF in dialog with engineer Per Egil Gullsvåg regarding the upgrading of the Calibration/Portable Laboratory.

Education and recruitment

Professor Truls Gundersen (NTNU), Scientific Leader

Developing knowledge and expertise at various levels is a main objective and major task in HighEFF. Focus is on energy efficiency in industrial processes, and the main sub-activities are (i) methodologies for analysis, design and optimization, (ii) improved equipment and cycles, and (iii) systems integration including industrial parks (clusters). The education activity takes place at different levels such as Master students having theses related to HighEFF, PhDs and Post.docs with research and publications related to energy efficiency in industry, and employees from user partners taking tailormade intensive courses to become energy efficiency experts in their companies.

By the end of 2018, HighEFF had recruited a total of 22 candidates (17 PhDs, 4 Post.docs and 1 Researcher). The Researcher is a Post.doc position that has been converted to a Researcher at NTNU Societal Research (partly funded by HighEFF). Still to be recruited then are 3 PhDs. These positions will be active from 2019 or 2020 at the latest. One Post.doc finished in 2018. We also have 6 associated PhDs (i.e. working on HighEFF related topics), and one of these finished in 2018.

Our education program also spans across countries and continents. HighEFF academic partners currently include 2 from Norway (NTNU and Nord University), 2 more from Europe (KTH in Sweden and University of Manchester in the UK), 2 in the US (MIT and CMU) and 2 in Asia (Shanghai Jiao Tong University in China and Doshisha University in Japan), a total of 8 universities.

The considerable number of recruited candidates has also resulted in a large number of publications and conference presentations. The statistics show that HighEFF had 27 journal publications and 25 conference presentations in 2018 that had at least one of the recruited candidates as author/co-author. It should also be mentioned that one of the publications received Best Paper Award among 250 papers on the ESCAPE'28 Conference in Graz, Austria, June 2018.

The number of registered master students within HighEFF topics was 8 in 2018, however, the true number is likely to be somewhat higher.

Selected PhDs and Post Docs

RESEARCHER HÅKON FYHN

What are you researching?
I am researching success factors in the emergence of industrial symbiosis. Such symbiosis is characterized by exchange of energy and materials in such a way that waste for one firm becomes resources for another. I am particularly focusing on the role of human and social aspects for the emergence of symbiosis, such as informal networks, trust and shared ideas, but also conditions such as local geography, regulations and governmental incentives. The primary method I apply is close study of selected real-life cases, using ethnographic approaches such as in-depth interviews and participatory observation.

Who is involved in your research?
I am part of RA4.3: Industry clusters and technology integration, led by Kristian Einarsrud. The previous leader, Leiv Kolbeinsen is also engaged in this project. In addition I collaborate with RA5: Society, in particular RA5.1: Innovation, Barriers and Enablers led by Jens Røyrvik. I collaborate closely with PhD candidate Jens Petter Johansen on the case studies. The industry partners in HighEFF are also essential contributors for my case studies.

Why is your research important?
Knowledge about technical solutions enabling industrial symbiosis is way ahead of the knowledge of human and social conditions making such symbiosis happen in real life. There are cases where symbiosis is possible from a technical point of view, economically profitable with an energy gain, but it still is not realized. The reasons for this tend to be found in the human and social conditions. My research is important because it aims to create knowledge about how these conditions can be considered alongside the technical aspects, allowing industrial symbiosis to form.

Tell us about an interesting result.
From a case study of the emergence of a new industry cluster (which also makes symbiotic connections between firms), we have been able to point to several conditions which seem to be necessary for this particular emergence: an informal network between influential stake holders; relations of trust between people in the firms; places and occasions where people from the various firm can meet; inputs and support from local government; and resources to keep up the pace in the process. While these aspects in various ways are described in the international literature, we have additionally found some aspects not being described, for example regarding the meeting grounds: It seems essential that the early inter-firm meetings consist not only of leaders, but also of key workers within the firms. This in order to come up with concrete possibilities for exchange and develop trust between those who will actually carry out the collaboration. The HighEFF cases studies are interesting as there are virtually no Norwegian case studies of emerging symbiosis in the international literature.

Selected PhDs and Post Docs

PD HAOSHUI YU

What are you researching?
My research interests include Work and Heat Exchange Network (WHEN) synthesis and Liquefied Natural Gas (LNG) cold energy utilization. The WHENs problem is an extension of Heat Exchanger Networks (HENs), while both pressure and temperature are considered simultaneously. Optimal design of WHENs can not only improve the energy efficiency, but also reduce the operating cost and even capital cost. As for the other research topic, LNG cold energy utilization by Organic Rankine Cycle is under investigation. Owing to the cryogenic temperature of the LNG regasification process, working fluid, system configuration and operating conditions of the ORC system are very different from the conventional ORCs. My research focuses on the optimal system design including working fluid screening, system configuration determination and process optimization.

Who is involved in your research?
I am part of RA1-Methodologies, where we aim to develop new methodologies and tools to increase the energy efficiency. I am involved in WP1.1 Key performance indicators, energy and exergy analyses. My supervisor is Professor Truls Gundersen at Energy and Process Engineering Department of NTNU.

Why is your research important?
Most processes in the chemical and petrochemical industry have specifications on both temperature and pressure. However, a systematic method for WHENs design has yet to be proposed. The thermodynamic path is the first decision to be made. My research focus on identifying the optimal thermodynamic path in WHEN problems. Once the thermodynamic path is determined, the WHEN problem degenerates into a HEN problem.

LNG contains a huge amount of cold energy, which is a perfect heat sink for power cycles. If the LNG cold energy is utilized properly, the energy efficiency of LNG terminals can be improved substantially, and the environmental effects and the CO_2 footprint can be reduced accordingly.

Tell us about an interesting result
We have developed a mathematical model to identify the optimal thermodynamic path in WHEN problems. The outcome has been published in AIChE Journal. Different reformulations of the model are proposed and compared in a conference paper, which received the Best Paper Award at the 28th European Symposium on Computer Aided Process Engineering in Graz, June 2018.

As for the ORC system recovering LNG cold energy, we have performed a systematic investigation on the working fluids. The working fluids whose saturation temperature at 1 bar is in the range -40°C to -50°C are promising candidates. We also found that the target pressure of natural gas has little effect on the optimal working fluids. This work has been published in Energy.

Selected PhDs and Post Docs

PHD CRISTINA ZOTICĂ

What are you researching?
The topic of my research project is "Optimal Operation and Control of Flexible Heat-to-Power Cycles". I am developing a framework that systematically analyzes how to operate and control thermal power plants. As secondary point of interest in my project, I am looking into how to achieve optimal operation using simple control structures based on PID-controllers. These represent an alternative to more advanced controllers such as Model Predictive Control, but are easier to understand, implement and maintain in a process plant.

Who is involved in your research?
I am part of RA1-Methodologies, specifically WP1.2-Process System Engineering, where we work towards developing frameworks for design, simulation and optimization of processes. This research project involves a collaboration with RA3-Cycle, aiming at combing both the process knowledge of RA3, and the systems knowledge of RA1. In addition, I have a small collaboration with the Systems Engineering Research Unit at the University of Oulu, Finland, which have experience with operation ad control of power plants.

Why is your research important?
Power plant control systems have been developed by industrial practices over many years, and it is not entirely clear what the actual specifications and degrees of freedom are. The present control policies are based on traditional control elements such as selectors, and PID and feedforward controllers. These have been developed to a level where it is not easy to make improvements using more advanced and systematic control policies, such as model predictive control, unless one has a really clear definition of the overall control problem. Hence, the objective of this work is to systematically define and solve the optimal operation and control problem for heat-to-power cycles.

Tell us about an interesting result.
At this stage of the project, we have analyzed a simple heat-to-power cycle from a plantwide control perspective. We started by defining a scalar cost function, followed by identifying the operational constraints, the degrees of freedom available for operation and main disturbances. For this simple case, there are only two degrees of freedom left to be use for optimal operation: the heat input and the steam turbine valve. In addition, we have used this analysis to design both the regulatory control layer using PI-controllers, and the supervisory control layer using Model Predictive Control (MPC).

In parallel, we have been comparing different control structures for optimal operation such as split range control, valve position control (also known as mid-ranging control), or two controllers with different setpoints. These structures are common to all chemical plants and can be applied when more than one manipulated variable (e.g. valve, pump) is used to control one variable (e.g. pressure, temperature). They can handle extreme cases such as input saturation (i.e. a valve is maximum open). Among the three, split range control achieves optimal steady-state operation, while the other two achieve near-optimum.

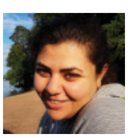
PhDs and Post Docs

One important task of HighEFF is to educate masters and doctoral students to become the next generation energy researcher and employees for the industry. During 2018, 5 PhD students and 3 postdoctoral fellows have been recruited, bringing the total number of candidates to 22, 17 PhDs and 5 Post.docs. In addition, 8 master students have completed their theses related to HighEFF.

PhD Students and Post.docs (PDs) active in 2018

Matias Vikse, PhD
Development of Optimization Models for Work and Heat Exchange Networks
Supervisor: Professor Truls Gundersen

Haoshui Yu, PD
Thermodynamic Approach to Work and Heat Exchange Networks (WHENs)
Supervisor: Professor Truls Gundersen

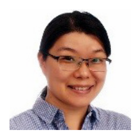


Mina Shahrooz, PhD
Low Temperature Power Cycles for Waste Heat Utilization with Mixtures of natural Fluids
Supervisor: Professor Per G. Lundqvist

Marcin Pilarczyk, PD
Compact and efficient Bottoming Cycles for Offshore Power Production
Supervisor: Professor Lars O. Nord

Håkon Selvnes, PhD
Cold Thermal Energy Storage for Industrial Applications
Supervisor: Professor Armin Hafner

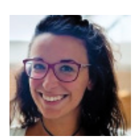
Mandar Thombre, PhD
Optimization of Energy Efficiency in Large-Scale Industrial Systems under Uncertainty
Supervisor: Professor Johannes Jäschke



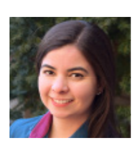
Juejing Sheng, PhD
Exergy Analysis of Offshore Oil & Gas Processing Systems
Supervisor: Professor Ivar S. Ertesvåg

Håkon Fyhn, Researcher
Human factors in development of industrial symbiosis
Supervisor: Professor Leiv Kolbeinsen

Saif Rahaman Kazi, PhD
Optimization of Multi-stream Heat Exchangers (MHEXs) with Phase Change
Supervisor: Professor Lorenz T. Biegler



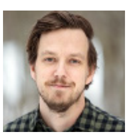
Elisa Magnanelli, PD
Establish KPIs with focus on Energy Efficiency for HighEFF
Supervisor: Professor Signe Kjelstrup



Suzane Cavalcanti, PhD
Nonsmooth Approaches to Process Flowsheet Simulation & Optimization
Supervisor: Professor Paul I. Barton

Trine Asklund Larsen, PhD
Energy Distribution in Mn-alloy Furnaces
Supervisor: Professor Merete Tangstad

Cristina Zotica, PhD
Optimal Operation and Control of Flexible Heat-to-Power Cycles
Supervisor: Professor Sigurd Skogestad



Jens Petter Johansen, PhD
Collective Energy Systems
Supervisor: Professor Per M. Schiefloe

Brede Hagen, PhD
Power production from medium temperature heat sources
Supervisor: Adjunct Professor Petter Nekså

Julia N. Jimenez Romero, PhD
Reduction of Industrial Energy Demand through Sustainable Integration of Distributed Energy Hubs
Supervisor: Professor Robin Smith

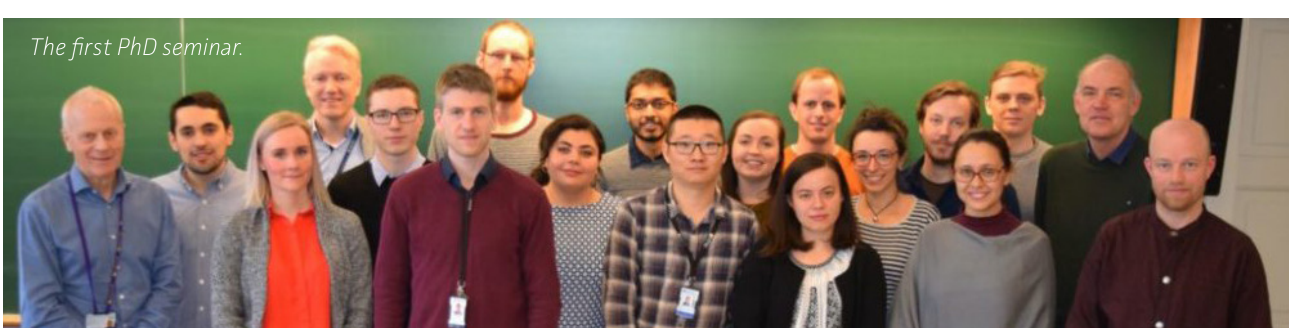
Zhongxuan Liu, PhD
Modeling and Optimization for the Design and Operation of a Network of Distributed Energy Hubs
Supervisor: Professor Truls Gundersen

Knut Emil Ringstad, PhD
CFD based calculation tools for improving components of R744 vapor compression units
Supervisor: Professor Armin Hafner

Ehsan Allymehr, PhD
Heat transfer and pressure drop in small diameter pipes for natural working fluids and mixtures – Measurement and modelling
Supervisor: Professor Trygve M. Eikevik

Ángel Álvarez Pardiñas, PD
Expander test laboratory
Supervisor: Professor Lars O. Nord

Irina N. Isaeva, PhD
How do industries and universities collaborate for the enhancement of environmental innovations?
Supervisor: Professor Einar Rasmussen



The first PhD seminar.

HighEFF

Master, Internship and Summer Scientists

MATHIAS GRØNBERG GUSTUM
Spring 2018, WP 6.1, Male, Norway
Supervisor: Kristian E. Einarsrud, NTNU, Dept. of Materials Science and Technology
Thesis: Modelling of gas-solid reactions: Usage of industrial off-gas for pre-reduction of manganese ores

GORAN DURAKOVIC, Spring 2018, WP 3.1, Male, Norway
Supervisor: Petter Nekså, NTNU, Dept. of Energy and Process Engineering
Thesis: Effect of design specifications for off-design operation of low temperature Rankine cycles using zeotropic mixtures and pure working fluids

INÉS ENCABO CÁCERES
Spring 2018, WP 3.1, Female, Spain
Supervisor: Lars O. Nord, NTNU, Dept. of Energy and Process Engineering
Thesis: Techno-economic and thermodynamic optimization of Rankine cycles

JACOPO DEGL'INNOCENTI, Spring 2018, WP 3.1, Male, Italy
Supervisor: Lars O. Nord, NTNU, Dept. of Energy and Process Engineering
Thesis: Compressed air energy storage for clean offshore energy supply

MARIUS REED, Spring 2018, WP 4.3, Male, Norway
Supervisor: Johannes Jäschke, NTNU, Dept. of Chemical Engineering
Thesis: Nonsmooth modelling of multiphase multi-component heat exchangers with phase changes

OLIVER SALE HAUGBERG
Spring 2018, WP 4.3, Male, Norway
Supervisor: Johannes Jäschke, NTNU, Dept. of Chemical Engineering
Thesis: Model predictive control of an LNG liquefaction process using Jmodelica.org

FRANCISCO JAVIER TAGUAS GARZÓN
Spring 2018, WP 3.2, Male, Spain
Supervisor: Armin Hafner, NTNU, Dept. of Energy and Process Engineering
Thesis: Improvement of energy efficiency in a brewery

ESPEN HALVORSEN VERPE
Spring 2018, WP 2.1, Male, Norway
Supervisor: Armin Hafner, NTNU, Dept. of Energy and Process Engineering
Thesis: Low temperature plate freezing of fish on boats using R744 as refrigerant and cold thermal energy storage

PEDER LANDSHOLT HOLMQVIST
Summer 2018, WP3.3, Male, Norway
HighEFF contact person: Hanne Kauko, SINTEF Energi
Topic: Cold thermal storage

SIMON JOHAN NILSEN LINGAAS
Summer 2018, WP3.1, Male, Norway
HighEFF contact person: Monika Nikolaisen, SINTEF Energi
Topic: Heat to power cycles

ANDREAS BOLSTAD, Summer 2018, Male, Norway
HighEFF contact person: Geir Skaugen, SINTEF Energi
Topic: Heat exchangers, visualization

MATHIAS GRØNBERG GUSTUM
Summer 2018, Male, Norway
Place of work: Glencore Managenese Norway
HighEFF contact person: Ida Kero, SINTEF Industri
Topic: Mapping of fluegas containing CO

MATHIAS GRØNBERG GUSTUM
4 months 2018, Male, Norway
HighEFF contact person: Kristian E. Einarsrud, NTNU
Topic: Modelling of fluegas from Mn-oven

JOACHIM SÄNGER, 6 months 2018, Male, Germany
HighEFF contact person: Armin Hafner, NTNU
Topic: Cold thermal storage

IVAN MAYORDOMO, 6 months 2018, Male, Spain
HighEFF contact person: Armin Hafner, NTNU
Thesis: Heat exchangers for cooling

Communication

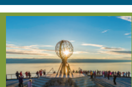
Reaching HighEFF's vision of making Norway the world's cleanest industry requires both industrial and political willingness as well as public acceptance. Communication is a core activity in HighEFF.

Communication activities extend beyond the HighEFF consortium and scientific community to provide facts about energy efficiency and promote innovations to industry.

To strengthen HighEFF's communication activities in 2018 we engaged the Communication department of SINTEF Energy Research to work for us.

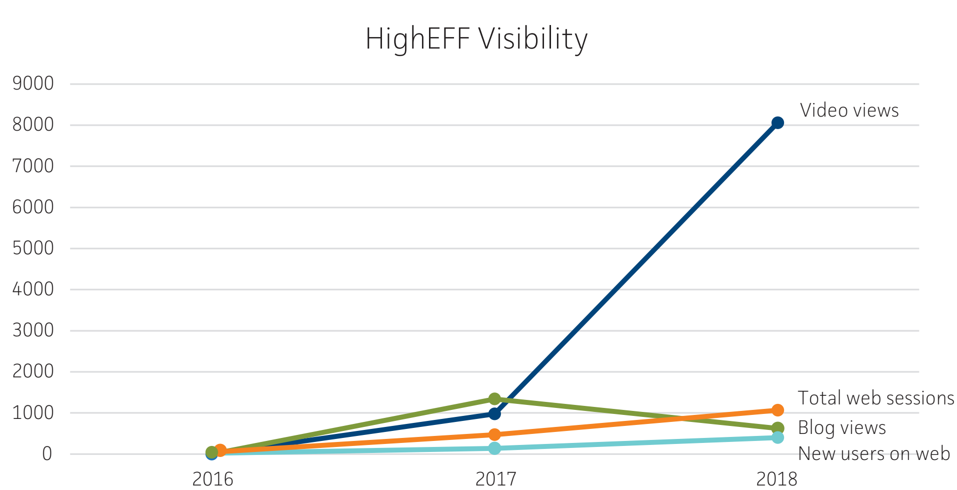
Focus areas for the increased communication effort has been scientific blogs at #SINTEFBlog, video content and keeping higheff.no up-to-date.

Communication strategy

Vision	WHY? FME Goal	WHO? Target groups	WHAT? Message	HOW? Channel/media	Results
 **By increasing energy efficiency, HighEFF will help ensure that Norway has the world's greenest industries.**	In order to become a success in: • research activity • innovation/value creation • internationalisation • training/recruitment • funding • organisation	• Industry • Politicians • Funding parties: RCN/EU+ • Public/NGOs • Partners in the centre • International research organisations	• The world needs energy efficiency to achieve clean industry • HighEff will ensure that Norway has the world's greenest industries • HighEff will increase value creation in Norway	• Webpage • Scientific dissemination • #SINTEFblog • Media • Events • Newsletter • Annual report • SoMe • Webinars	KPI: Increased visibility and knowledge KPI: Increased positive reputation KPI: Increased internal engagement Achieving FME goals

← evaluation - reporting - learning

A simplified graphic representation of the FME HighEFF Communication plan.



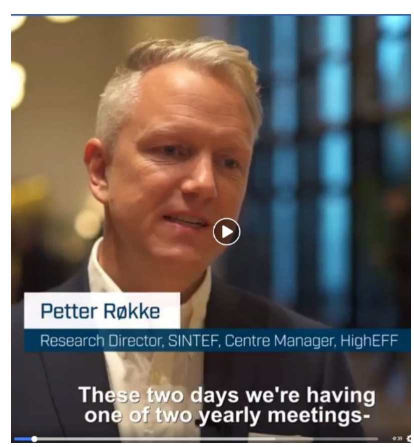
Increased communication efforts resulted in higher visibility in 2018

Visibility

In order to reach a wide audience (outside of the consortium) HighEFF has published op-eds and contributed to media coverage of energy efficiency in industry. In total, HighEFF had 3 media clips, 2 Op-eds, 12 blogs and information material and videos and other multimedia products in 2018. Here are some examples:

MØT OSS PÅ ARENDALSUKA

Arendalsuka is a national annual event held every August. It is a politically independent forum where everyday citizens meet political leaders, business leaders, entrepreneurs, governmental organizations, media and NGO's. This year Camilla Claussen was invited to an event hosted by The Research Council of Norway. At the event she presented results from HighEFF and the EU-project SuperSmart, on natural working fluids making European supermarkets more environment-friendly.



We made a mini video series of 5 episodes for social media with HighEFF Scientific coordinator Petter Nekså. Nekså explained what natural working fluids are, why they are important for energy efficiency and how HighEFF is working with them.

During the 2018 HighEFF Consortium days we made video interviews with Centre Director Petter Røkke and several industry partners. We got their outlook on HighEFF's work so far and the importance of a centre like HighEFF.

Teknologi

Norske forskere bak iskald miljøteknologi

Claude Olsen - Gemini.no
15. aug. 2018 14:53 – Oppdatert 15. aug. 2018 14:53

Liten miljøsynder i sommersol? Ikke ifølge norske forskere, som har utviklet mer miljøvennlig butikkjøling. Nå vil de ha teknologien ut i flere europeiske land. Illustrasjonsfoto: Colourbox.com

I tillegg til å være giftfri, er teknologien energibesparende. Derfor kan du spise is med god klima-samvittighet.

Energiforsker Ingrid Camilla Claussen i SINTEF kan forsikre deg om at norsk is er ekstra miljøvennlig. En av grunnene til dette er at kunstige og svært klimaskadelige kjølemedium er byttet ut med naturlige kjølemedium. Snart gjelder det også for *råvaren* som isen er laget av.

Kombinerer ventilasjon og kjøling

Fryseskapene og kjølediskene som holder maten kald bruker nemlig CO_2 som kjølemedium i stedet for hydrofluorkarboner, som er langt mer miljøskadelige. Og når det er kjølig i været, sender det overskuddsvarmen fra kjølingen inn i ventilasjonsanlegget og bidrar til varme lokaler.

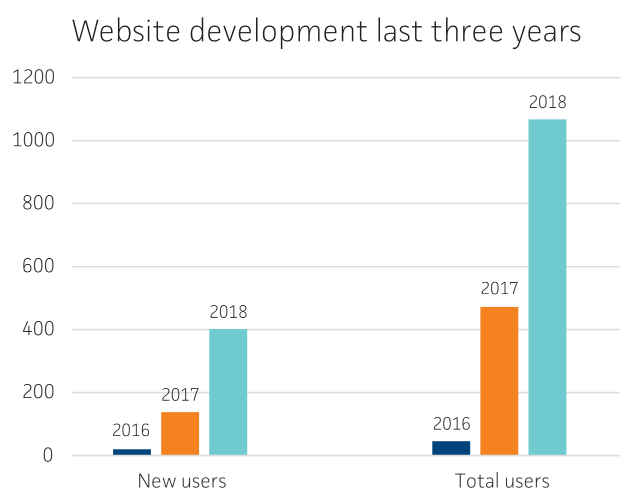
– Ved å kombinere ventilasjonsanlegget med kjøleanlegget i en matvarebutikk, ser vi at man kan spare cirka 30 prosent av energibruken. Det har vi vist i flere norske butikker, sier forskningsleder Ingrid Camilla Clausen i SINTEF.

Les også: Klimamålet kan bli oppjustert

RA 5 Leader, Ingrid C. Claussen, was interviewed on how one can use natural working fluids to make the cooling process of ice-cream more environment-friendly.

Web

The HighEFF web-page provides information about the Centre, its research and other activities like events and conferences.



www.higheff.no

Newsletter

In 2018, 4 newsletters were sent out to over 80 subscribers. Subscribers to the newsletter mainly comes from within the consortium.

- December 21, 2018 HighEFF Newsletter 3-2018
- April 24, 2018 HighEFF Newsletter 2-2018
- February 21, 2018 FME HighEFF: Call for applications "Novel emerging concepts"
- February 12, 2018 HighEFF Newsletter 1-2018


Display problems? Open this email in your web browser.

HighEFF

1 - 2019

Dear HighEFF Friends

Happy new year!
We are already well into a new year and inspired by input from all of you, HighEFF arranged the yearly RA/WP leader meeting focusing on innovation and how we can structure our work to fulfil our ambition on being a platform for innovation in industrial energy efficiency. In this workshop a total of 25 potential innovations were presented and discussed - innovations that we hopefully will see large impact from in the future.

This newsletter includes some recent news regarding one spin-off project, some comments from the Workshop and the upcoming PhD/PD seminar in February. You will also find information about the self-assessment of the Centre which will be carried out in January-March. Please note that all user partners are expected to give feedback on a questionnaire for this self-assessment.

Looking forward to a fruitful HighEFF year in 2019!

Kind regards
Petter E. Røkke
FME HighEFF Center Director

HighEFF Spin-off project

PREMA - Reduced CO2 emissions and consumption of electrical energy in Mn-alloy production

Read our digital annual report for videos and more

www.higheff.no -> Annual report 2018

Blogs

HighEFF has published 8 blogs on the #SINTEFblog in 2018;

- World-class energy efficiency, Monika Nikolaisen (30-01-2018)
- Saving the cold for later: Decoupling supply and demand, SINTEF / Håkon Selvnes (19-04-2018)
- Education and Training in FME HighEFF, SINTEF (04-05-2018)
- HighEFF Annual Meeting- Picture Blogg, Ingrid Camilla Claussen (31-05-2018)
- Matchmaking for industry sectors for waste heat utilization, Marit J. Mazzetti (02-08-2018)
- What are Phase Change Materials? [Will they be the next big thing in Norway?], Alexis Sevault (09-08-2018)
- Phase-out of fossil fuels: SINTEF develops a novel high temperature heat pump, Michael Bantle (06-11-2018)
- HighEFF Cross-sector Workshop 2018, Petter E. Røkke (27-11-2018)


NCCS ANNUAL REPORT 2017
Site Stats ‹ #SINTEFblog — Word
Phase-out of fossil fuels: SINTEF
Contact

#SINTEFblog

The article can be downloaded for free before April 19 2019. Click this link to download.

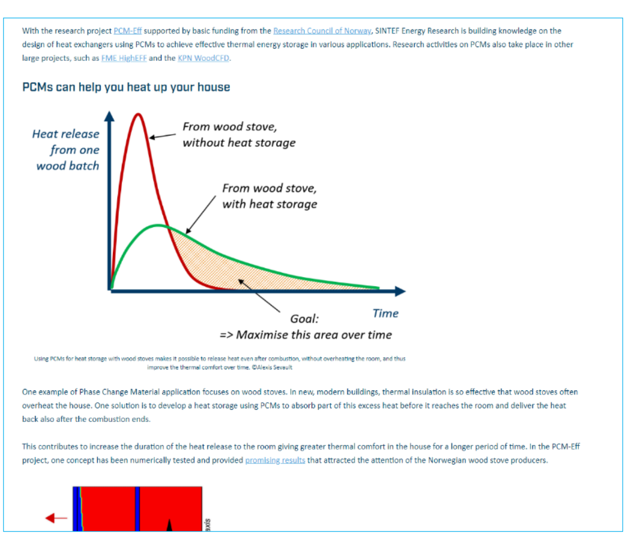
Heat pumps don't match current industrial requirements

Current heat pump solutions are mostly limited to heat supply of around 70°C to 80°C, while industry process are quite often designed for heat supply temperature of around 100°C to 110°C. From an R&D point of view the challenge was therefore to demonstrate that the supply temperature can be increased by 30 °C to 40 °C.

SINTEFs researchers have now developed a prototype heat pump that pushes the current temperature limitations and can be universally used in order to supply process heat of up to 115°C. Considering the climate aspect of fossil fuel it seems illogical to use a valuable energy source like oil or gas in order to produce something as simple as heat around 100°C. Nevertheless, every year around 170 TWh of process heat (Equal to 1,5 times the consumption of all electricity in Norway), especially in the food industry, are produced in the EU28 by exactly this, burning fossil fuels, mostly to supply hot water.

Sintef scientists Christian Schlemminger and Michael Bantle brought the butane heat pump concept from theory into the "real life" through the HeatUp project. Photo: SINTEF/Thor Nielsen

- Read this blog from when we installed the heat pump: HeatUp: New high temperature heat pump prototype installed

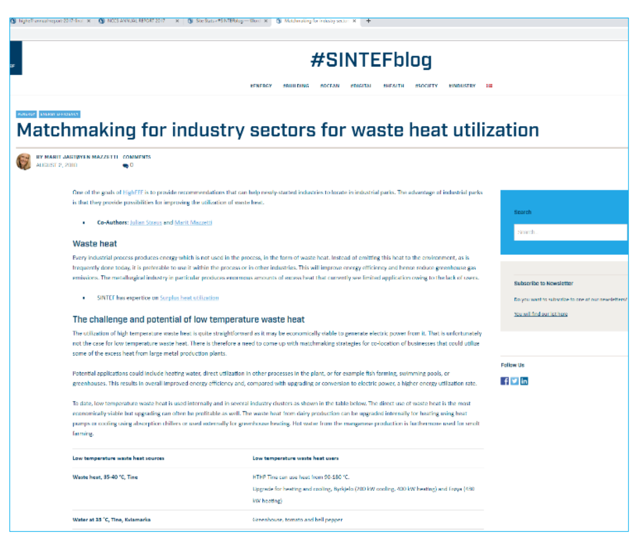

With the research project PCM-Eff supported by basic funding from the Research Council of Norway, SINTEF Energy Research is building knowledge on the design of heat exchangers using PCMs to achieve effective thermal energy storage in various applications. Research activities on PCMs also take place in other large projects, such as FME HighEFF and the KPN WoodCFD.

PCMs can help you heat up your house

Using PCMs for heat storage with wood stoves makes it possible to release heat even after combustion, without overheating the room, and thus improve the thermal comfort over time. ©Alexis Sevault

One example of Phase Change Material application focuses on wood stoves. In new, modern buildings, thermal insulation is so effective that wood stoves often overheat the house. One solution is to develop a heat storage using PCMs to absorb part of this excess heat before it reaches the room and deliver the heat back also after the combustion ends.

This contributes to increase the duration of the heat release to the room giving greater thermal comfort in the house for a longer period of time. In the PCM-Eff project, one concept has been numerically tested and provided promising results that attracted the attention of the Norwegian wood stove producers.


#SINTEFblog

#ENERGY #BUILDING #OCEAN #DIGITAL #HEALTH #SOCIETY #INDUSTRY

Matchmaking for industry sectors for waste heat utilization

One of the goals of HighEFF is to provide recommendations that can help newly-started industries to locate in industrial parks. The advantage of industrial parks is that they provide possibilities for improving the utilization of waste heat.

- Co-Authors: Julian Straus and Marit Mazzetti

Waste heat

Every industrial process produces energy which is not used in the process, in the form of waste heat. Instead of emitting this heat to the environment, as is frequently done today, it is preferable to use it within the process or in other industries. This will improve energy efficiency and hence reduce greenhouse gas emissions. The metallurgical industry in particular produces enormous amounts of excess heat that currently see limited application owing to the lack of users.

- SINTEF has expertise on Surplus heat utilization

The challenge and potential of low temperature waste heat

The utilization of high temperature waste heat is quite straightforward as it may be economically viable to generate electric power from it. That is unfortunately not the case for low temperature waste heat. There is therefore a need to come up with matchmaking strategies for co-location of businesses that could utilize some of the excess heat from large metal production plants.

Potential applications could include heating water, direct utilization in other processes in the plant, or for example fish farming, swimming pools, or greenhouses. This results in overall improved energy efficiency and, compared with upgrading or conversion to electric power, a higher energy utilization rate.

To date, low temperature waste heat is used internally and in several industry clusters as shown in the table below. The direct use of waste heat is the most economically viable but upgrading can often be profitable as well. The waste heat from dairy production can be upgraded internally for heating using heat pumps or cooling using absorption chillers or used externally for greenhouse heating. Hot water from the manganese production is furthermore used for smolt farming.

Low temperature waste heat sources	Low temperature waste heat users
Waste heat, 35-40 °C, Tine	HTHP Tine can use heat from 90-180 °C. Upgrade for heating and cooling, Byrkjelo (200 kW cooling, 400 kW heating) and Frøya (430 kW heating)
Water at 35 °C, Tine, Kvamarka	Greenhouse, tomato and bell pepper

Appendices

Appendix 1 PERSONNEL INVOLVED IN THE CENTRE IN 2018

Number of personnel for various categories:

Personnel category	Number
Key researchers (incl. PhDs/Post Docs)	100
Visiting researchers	-
PDs financed by HighEFF	4
PDs financed from others	-
PhDs financed by HighEFF	17
PhDs financed from others	6
Master degrees	8

Centre Administration		
Petter Egil Røkke	SINTEF	Centre Director
Line Rydså	SINTEF	Centre Coordinator
Einar Jordanger	SINTEF	Centre Coordinator (deputy)
Truls Gundersen	NTNU	Scientific Leader
Petter Nekså	SINTEF/NTNU	Scientific Coordinator

Key researchers		
Name	Institution	Main research area
Akhilesh Srivastava	SINTEF Industri	Thermo-electric power generation
Alexis Sevault	SINTEF ER	High-temperature TES for industrial processes
Ángel Pardiñas	NTNU	PD – Expander test laboratory
Armin Hafner	NTNU	HTHP / Cold thermal storage for industrial applications
Arne Petter Ratvik	SINTEF Industri	Novel emerging concepts
Asbjørn Solheim	SINTEF Industri	Chloride Al processes, inert anode and initial HH improvements
Astrid Lundquist	SINTEF Energi	Communication and Dissemination
Aud Nina Wærnes	SINTEF Industri	Process improvements
Balram Panjwani	SINTEF Industri	Process improvements
Bernd Wittgens	SINTEF Industri	Process improvement
Bjarte Øye	SINTEF Industri	Chloride Al process study
Bjørn Tore Løvfall	SINTEF	Process Improvements
Bodil J Sætherskar	SINTEF Energi	Management
Brage Knudsen	SINTEF Energi	Thermal energy storage potential for the industry, modelling and optimziation of energy exchange in clusters
Brede Hagen	NTNU	PhD - Surplus heat-to-power conversion
Brede Hagen	SINTEF Energi	RA2 components, heat exchangers
Cecilia Gabrielii	SINTEF Energi	Low temperature cooling
Chao Fu	SINTEF Energi	RA4 applications, process improvements

Key researchers		
Name	Institution	Main research area
Christian Kopp	SINTEF Energi	RA2 components work recovery and compressors, RA3 cycles, HTHP cooling and drying
Christian Schlemminger	SINTEF Energi	High temperature heat pumps, food and chemical case studies
Christian Schøning	SINTEF Industri	Energy flows in aluminium production
Christoffer Solberg	SINTEF Energi	Communication and Dissemination
Cristina Zotica	NTNU	Optimal Operation and Control of flexible Heat-to-Power Cycles
Egil Skybakmoen	SINTEF Industri	Utilization of Low Temperature Heat in Al electrolysis
Ehsan Allymehr	NTNU	PhD2.3.1
Einar Jordanger	SINTEF Energi	Management
Einar Rasmussen	Nord Universitet	Supervisor PhD5.1.2: Industry/University collaboration for environ-mental innovations
Elisa Magnanelli	NTNU (now SINTEF Energi)	Establish KPIs with Focus on Energy Efficiency in HighEFF
Geir Skaugen	SINTEF Energi	Heat exchangers, oil, gas and energy case studies
Gerwin Drexler-Schmid	Austrian Institute of Technology	High-temperature thermal energy storage for industrial processes
Goran Durakovic	SINTEF Energi	Surplus heat-to-power conversion, RA6 case studies; industry clusters
Gudveig Gjøsund	NTNU Social Research	Organizational analysis
Halvor Dalaker	SINTEF Industri	Utilization of CO-rich off-gas from Mn-alloy production
Han Deng	SINTEF Energi	Heat exchangers
Hanne Kauko	SINTEF Energi	Thermal energy storage (TES) potential in industry clusters, High-temperature TES for industrial processes
Hans L Skarsvåg	SINTEF Energi	Natural working fluid properties
Haoshui Yu	NTNU	Thermodynamic Approach to Work and Heat Exchange Networks
Henrik Gudbrandsen	SINTEF Industri	Case study – aluminium waste heat
Hiroshi Yamaguchi	Doshisha University	Refrigeration technology
Håkon Fyhn	NTNU	Future success factors of industrial clusters
Håkon Fyhn	NTNU Social Research	Society
Håkon Selvnes	NTNU	PhD – Cold thermal storage for industrial applications
Ida Kero	SINTEF Industri	Metallurgy, materials science, process improvements
Ingrid Camilla Claussen	SINTEF Energi	Dissemination, food case
Irina N. Isaeva	Nord Universitet	PhD5.1.2 - Industry/University collaboration for environmental inno-vations
Ivar S. Ertesvåg	NTNU	Exergy Analysis of Offshore Oil & Gas Processing Systems
Jens Olgard Dalseth Røyrvik	NTNU Social Research	Societal, social and organizational conditions for energy efficiency
Jens Petter Johansen	NTNU Social Research	Barriers and enablers for energy- efficiency and exchange
Johannes Jäschke	NTNU	Optimization of Energy Efficiency in large-scale Industrial Systems under Uncertainty
Juan Christancho	NTNU	Compact and efficient bottoming Cycles for offshore Power Production
Juejing Sheng	NTNU	Exergy Analysis of Offshore Oil & Gas Processing Systems
Julia Jimenez Romero	The University of Manchester	Reduction of Industrial Energy Demand through Sustainable Integra-tion of distributed Energy Hubs
Julian Straus	SINTEF Energi	RA6 Case studies, industry clusters
Karoline Kvalsvik	SINTEF Energi	Integrated heat pump concepts, food and chemical case studies

Key researchers		
Name	Institution	Main research area
Knut Emil Ringstad	NTNU	PhD2.2.1 - CFD for improving components of R744 vapor compression units
Krisitan Etienne Einarsrud	NTNU	Cluster modelling, materials science
Kristina Norne Widell	SINTEF Ocean	HTHP, Cooling and Drying and Case studies food
Lars O. Nord	NTNU	Supervisor PhD #3.1.1
Leiv Kolbeinsen	NTNU	Industrial clusters
Line Rydså	SINTEF Energi	Management
Lorenz T. Biegler	Carnegie Mellom University	Optimization of Multi-Stream Heat Exchangers with Phase Change
Magne Lysberg	SINTEF Industri	Cluster modelling
Mandar Thombre	NTNU	Optimization of Energy Efficiency in large-scale Industrial Systems under Uncertainty
Marcin Pilarczyk	NTNU	PD - Compact bottoming cycles for offshore power production
Mari Voldsund	SINTEF Energi	Future processes
Marianne Therese Steinmo	Nord University	industry/research collaboration in FME centres
Marit Mazzetti	SINTEF Energi	Oil, gas and energy case studies gas and industrial clusters
Matias Vikse	NTNU	Development of Optimization Models for Work and Heat Exchange Networks
Merete Tangstad	NTNU	Energy Distribution in Mn-alloy Furnaces
Michael Bantle	SINTEF Energi	High temperature heat pump (HTHP), low temp cooling next gen drying systems, food and chemical case studies
Michael Lauermann	Austrian Institute of Technology	High temperature heat pump
Mina Sharooz	Kungliga Tekniska Högskolan	PhD - Low temperature waste-heat-to-power conversion
Monika Nikolaisen	SINTEF Energi	Surplus heat-to-power conversion, , oil, gas and energy case studies
Morten Dahle Selfors	Nord University	Society
Natalia Kizilova	NTNU	Key performance indicators
Olaf Trygve Berglihn	SINTEF Industri	KPIs, energy & exergy analyses, process improvements
Ole H Meyer	SINTEF Energi	RA2 Components
Paul I Barton	Massachusets Institute of Technology	Nonsmooth Approaches for Process Flowsheet Simulation andf Optimization
Per Lundqvist	Kungliga Tekniska Högskolan	Supervisor PhD #3.1.3
Per M. Schiefloe	NTNU Social Research	Innovation
Petter Nekså	SINTEF Energi/NTNU	Energy efficiency in industry
Petter Røkke	SINTEF Energi	Management
Robin Smith	The University of Manchester	Reduction of Industrial Energy Demand through Sustainable Integration of distributed Energy Hubs
Ruzhu Wang	Shanghai Jiao Tong University	Heat pumps, cooling and drying
Saif Rahaman Kazi	Carnegie Mellom University	Optimization of Multi-Stream Heat Exchangers with Phase Change
Signe Kjelstrup	NTNU	Establish KPIs with Focus on Energy Efficiency in HighEFF
Sigurd Skogestad	NTNU	Process systems engineering
Stian Trædal	SINTEF Energi	Natural refrigerants for power production cycles
Suzane Cavalcanti	Massachusets Institute of Technology	Nonsmooth Approaches for Process Flowsheet Simulation andf Optimization
Sverre Foslie	SINTEF Energi	High temperature heat pumps and thermal energy storage for industrial processes

Key researchers		
Name	Institution	Main research area
Thomas Lauvås	Nord University	industry/research collaboration in FME centres
Tom S. Nordtvedt	SINTEF Ocean	HTHP, Cooling and Drying and Case studies food
Torbjørn Pettersen	SINTEF Industri	Case study modelling in report KPIs
Torgeir Kolstø Haavik	NTNU Social Research	Sociotechnical analysis
Trine Asklund Larssen	NTNU	Energy Distribution in Mn-alloy Furnaces
Trond Andresen	SINTEF Energi	Surplus heat-to-power conversion
Truls Gundersen	NTNU	Pinch analyses
Trygve Eikevik	NTNU	Natural refrigerants
Vidar Skjervold	SINTEF Energi	Surplus heat recovery
Zhongxuan Liu	NTNU	PhD 1.2.3 - Modelling and Optimization for the Design and Operation of a Network of Distributed Energy Hubs
Åsmund Ervik	SINTEF Energi	RA2 components, work recovery and compression

Appendix 2 STATEMENT OF ACCOUNTS 2018

Costs (1000 NOK)	Amount	Funding (1000 NOK)	Amount
Host institution (SINTEF Energi)	26 205	Research Council of Norway	25 078
Research partners	29 416	Host institution (SINTEF Energi)	8 580
User partners	4 811	Research partners	8 010
Equipment	0	User partners	18 764
Total	60 432	Total	60 432

Appendix 3

HighEFF publications registered in Cristin

(Current Research Information SysTem In Norway)

Peer reviewed Journal publications

Search criteria:
From: 2018 *sub-category:* Academic article *sub-category:* Academic literature review *sub-category:* Short communication *All publishing channels*

Bamigbetan, Opeyemi Olayinka; Eikevik, Trygve Magne; Nekså, Petter; Bantle, Michael; Schlemminger, Christian.
Experimental investigation of a prototype R-600 compressor for high temperature heat pump. *Energy* 2018 ;Volume 169. p. 730-738
ENERGISINT NTNU

Bamigbetan, Opeyemi Olayinka; Eikevik, Trygve Magne; Nekså, Petter; Bantle, Michael; Schlemminger, Christian.
Theoretical analysis of suitable fluids for high temperature heat pumps up to 125 °C heat delivery. *International journal of refrigeration* 2018 ;Volume 92. p. 185-195
ENERGISINT NTNU

Fini, Riccardo; Rasmussen, Einar; Wiklund, Johan; Wright, Mike.
Theories from the Lab: How Research on Science Commercialization can Contribute to Management Studies. *Journal of Management Studies* 2018
NORD

Fu, Chao; Vikse, Matias; Gundersen, Truls.
Work and heat integration: An emerging research area. *Energy* 2018 ;Volume 158. p. 796-806
ENERGISINT NTNU

Hayter, Christopher S; Rasmussen, Einar; Rooksby, Jacob H.
Beyond formal university technology transfer: innovative pathways for knowledge exchange. *Journal of Technology Transfer* 2018 p. 1-8
NORD

Jakobsen, Siri; Lauvås, Thomas Andre; Steinmo, Marianne Terese.
Collaborative dynamics in environmental R&D alliances. *Journal of Cleaner Production* 2018 ;Volume 212. p. 950-959
NORD

Kauko, Hanne; Kvalsvik, Karoline Husevåg; Rohde, Daniel; Nord, Natasa; Utne, Åmund.
Dynamic modeling of local district heating grids with prosumers: A case study for Norway. *Energy* 2018 ;Volume 151. p. 261-271
ENERGISINT NTNU

Magnanelli, Elisa; Berglihn, Olaf Trygve; Kjelstrup, Signe.
Exergy-based performance indicators for industrial practice. *International Journal of Energy Research* 2018 ;Volume 42.(13) p. 3989-4007
NTNU SINTEF

Nilsen, Trond; Lauvås, Thomas Andre.
The Role of Proximity Dimensions in Facilitating University-Industry Collaboration in Peripheral Regions: Insights from a Comparative Case Study in Northern Norway. *Arctic Review on Law and Politics* 2018 ;Volume 9. p. 312-331
NORD NORUT

Rammohan Subramanian, Avinash Shankar; Anantharaman, Rahul; Gundersen, Truls.
Conceptual design of an efficient Hydrogen production process from Natural Gas using an extension to the "G-H" methodology. *Computer-aided chemical engineering* 2018 ;Volume 44. p. 379-384
ENERGISINT NTNU

Rammohan Subramanian, Avinash Shankar; Gundersen, Truls; Adams, Thomas Alan.
Modeling and simulation of energy systems: A review. *Processes* 2018 ;Volume 6:238.(12) p. 1-45
NTNU

Reyes-Lúa, Adriana; Zotica, Cristina Florina; Das, Tamal; Krishnamoorthy, Dinesh; Skogestad, Sigurd.
Changing between Active Constraint Regions for Optimal Operation: Classical Advanced Control versus Model Predictive Control. *Computer-aided chemical engineering* 2018 ;Volume 43. p. 1015-1020
NTNU

Reyes-Lúa, Adriana; Zotica, Cristina Florina; Skogestad, Sigurd.
Optimal Operation with Changing Active Constraint Regions using Classical Advanced Control. *IFAC-PapersOnLine* 2018 ;Volume 51.(18) p. 440-445
NTNU

Rohde, Daniel; Andresen, Trond; Nord, Natasa.
Analysis of an integrated heating and cooling system for a building complex with focus on long–term thermal storage. *Applied Thermal Engineering* 2018 ;Volume 145. p. 791-803
ENERGISINT NTNU

Sevault, Alexis; Soibam, Jerol; Haugen, Nils Erland L; Skreiberg, Øyvind.
Investigation of an Innovative Latent Heat Storage Concept in a Stovepipe. *Chemical Engineering Transactions* 2018 ;Volume 65. p. 25-30
ENERGISINT NTNU

Solheim, Asbjørn.
Inert Anodes – the Blind Alley to Environmental Friendliness?. *Light Metals* 2018 p. 1253-1260
SINTEF

Steinmo, Marianne Terese; Lauvås, Thomas Andre; Eidem, Per Anders; Salamonsen, Krister; Paulsen, Monica.
Bedrifters innovasjonstilnærming i perifere regioner. *Søkelys på arbeidslivet* 2018 ;Volume 35.(03) p. 221-238
NORD SINTEF

Steinmo, Marianne Terese; Rasmussen, Einar.
The interplay of cognitive and relational social capital dimensions in university-industry collaboration: Overcoming the experience barrier. *Research Policy* 2018
NORD

Straus, Julian; Skogestad, Sigurd.
Self-Optimizing Control in Chemical Recycle Processes. *IFAC-PapersOnLine* 2018 ;Volume 51.(18) p. 536-541
NTNU

Straus, Julian; Skogestad, Sigurd.
Surrogate model generation using self-optimizing variables. *Computers and Chemical Engineering* 2018 ;Volume 119.(2) p. 143-151
NTNU

Vikse, Matias; Watson, Harry AJ; Gundersen, Truls; Barton, Paul I.
Versatile Simulation Method for Complex Single Mixed Refrigerant Natural Gas Liquefaction Processes. *Industrial & Engineering Chemistry Research* 2018 ;Volume 57.(17) p. 5881-5894
NTNU

Vikse, Matias; Watson, Harry AJ; Gundersen, Truls; Barton, Paul I..
Simulation of dual mixed refrigerant natural gas liquefaction processes using a nonsmooth framework. *Processes* 2018 ;Volume 6.(10)
NTNU

Watson, Harry AJ; Vikse, Matias; Gundersen, Truls; Barton, Paul I.
Optimization of single mixed-refrigerant natural gas liquefaction processes described by nondifferentiable models. *Energy* 2018 ;Volume 150. p. 860-876
NTNU

Yu, Haoshui; Eason, John; Biegler, Lorenz T; Feng, Xiao; Gundersen, Truls.
Process optimization and working fluid mixture design for organic Rankine cycles (ORCs) recovering compression heat in oxy-combustion power plants. *Energy Conversion and Management* 2018 ;Volume 175. p. 132-141
NTNU

Yu, Haoshui; Fu, Chao; Gundersen, Truls.
Work and Heat Exchange Networks – Opportunities and Challenges. *Computer-aided chemical engineering* 2018 ;Volume 44. p. 481-486
ENERGISINT NTNU

Yu, Haoshui; Fu, Chao; Vikse, Matias; Gundersen, Truls.
Work and heat integration—A new field in process synthesis and process systems engineering. *AIChE Journal* 2018 p. 1-16
ENERGISINT NTNU

Yu, Haoshui; Fu, Chao; Vikse, Matias; He, Chang; Gundersen, Truls.
Identifying optimal thermodynamic paths in work and heat exchange network synthesis. *AIChE Journal* 2018 ;Volume 65.(2) p. 549-561
ENERGISINT NTNU

Yu, Haoshui; Gundersen, Truls; Feng, Xiao.
Process integration of organic Rankine cycle (ORC) and heat pump for low temperature waste heat recovery. *Energy* 2018 ;Volume 160. p. 330-340
NTNU

Presentations

Search criteria:
Main category: Conference lecture and academic presentation *All publishing channels*

Allymehr, Ehsan.
Characteristics of condensation and evaporation of hydrocarbons. HighEFF Cross-sector Workshop 2018; 2018-10-24 - 2018-10-25
NTNU

Andresen, Trond.
RA3 Cycles - Introduction. HighEFF Cross-sector Workshop 2018; 2018-10-24 - 2018-10-25
ENERGISINT

Andresen, Trond; Lindqvist, Karl Erik Artur.
Exploring a possible path for off-gas HEX design improvement. HighEFF Cross Sector Workshop 2019; 2018-10-24 - 2018-10-24
ENERGISINT NTNU

Bantle, Michael.
Development and demonstration of high temperature heat pumps for the process industry. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
ENERGISINT

Claussen, Ingrid Camilla; Røyrvik, Jens Olgard Dalseth; Nekså, Petter.
Role of Industry Clusters for improving energy efficiency. 10th KIFEE symposium; 2018-10-05 - 2018-10-08
ENERGISINT NTNU

Elgsæter, Steinar Morisbak.
Statoil Energy portal. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03

Fyhn, Håkon.
A Model for Human Factors in Industrial Symbiosis Formation. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
SAMFORSK

Fyhn, Håkon.
A systematic approach to industrial symbiosis formation. HighEFF Annual Consortium Meeting; 2018-05-02 - 2018-05-03
SAMFORSK

Fyhn, Håkon; Kolbeinsen, Leiv; Røyrvik, Jens Olgard Dalseth; Johansen, Jens Petter.
Approaching the human factor in formation of industrial symbiosis. SAM12; 2018-05-23 - 2018-05-24
NTNU SAMFORSK

Gundersen, Truls.
Work and Heat Exchange Networks (WHENs). HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
NTNU

Kauko, Hanne; Knudsen, Brage Rugstad; Sund-Olsen, Terje.
Thermal storage and model predictive control for improved utilization of industrial waste heat in district heating. The 4th International Conference on Smart Energy Systems and 4thGeneration District Heating; 2018-11-13 - 2018-11-14
ENERGISINT

Kauko, Hanne; Selvnes, Håkon; Knudsen, Brage Rugstad; Hafner, Armin; Nekså, Petter.
Thermal storage for improved energy efficiency in the industry. 10th KIFEE symposium; 2018-10-05 - 2018-10-08
ENERGISINT NTNU

Knudsen, Brage Rugstad; Kauko, Hanne; Andresen, Trond.
Optimizing exchange of time-varying surplus heat in industry clusters. FME HighEFF - Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
ENERGISINT

Larssen, Trine Asklund.
Reduction of Mn ores in CO atmosphere. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
NTNU

Larssen, Trine Asklund; Tangstad, Merete; Kero, Ida.
Energy Distribution in HC FeMn and SiMn - Energy vs Exergy Analyses. Infacon XV; 2018-02-25 - 2018-02-28
NTNU SINTEF

Lauvås, Thomas Andre.
Forskningssamarbeid: utfordringer og muligheter. Samling NCE Aquaculture; 2018-05-07
NORD

Lium, Arnt-Gunnar.
ENOVA and the national Pilot E call. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03

Magnanelli, Elisa.
Energy Efficiency KPIs for Industrial Practice: Opportunities, Challenges and Limitations. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
NTNU

Magnanelli, Elisa; Voldsund, Mari; Kjelstrup, Signe.
Energy efficiency in the process industry: Learning from nature. IOR Norway 2018; 2018-04-24 - 2018-04-25
ENERGISINT NTNU

Magnanelli, Elisa; Wilhelmsen, Øivind; Kjelstrup, Signe.
Energy Efficient Design of Membrane Processes by use of Entropy Production Minimization. Twentieth Symposium on Thermophysical Properties; 2018-06-25 - 2018-06-29
ENERGISINT NTNU

Mazzetti, Marit Jagtoyen; Bantle, Michael.
Case studies: Energy efficiency possibilities at Tine and Nidar. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
ENERGISINT

Nikolaisen, Monika; Andresen, Trond.
Power production from variable-load industrial surplus heat: Modelling and optimizing system design and performance. 10th KIFEE symposium; 2018-10-05 - 2018-10-08
ENERGISINT

Pardiñas, Ángel Á..
HighEFFLab WP3. Expander Test Laboratory. HighEFF Cross-sector Workshop 2018; 2018-10-24 - 2018-10-25
NTNU

Pilarczyk, Marcin; Nord, Lars O..
Determination of transient thermal stresses within components of Heat Recovery Steam Generators (HRSG). FME HighEFF Cross-sector workshop 2018; 2018-10-24 - 2018-10-25
NTNU

Reyes Lua, Adriana; Zotica, Cristina Florina; Skogestad, Sigurd.
Optimal Operation using Classical Advanced Control Structures. Nordic Process Control Workshop 2018; 2018-01-18 - 2018-01-19
NTNU

Ringstad, Knut Emil.
CFD modeling of ammonia ejectors. HighEFF Cross-sector Workshop 2018; 2018-10-24 - 2018-10-25
NTNU

Røyrvik, Jens Olgard Dalseth.
Media discourse on energy efficiency. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
NTNU

Sauermoser, Marco; Magnanelli, Elisa; Kjelstrup, Signe.
A Non-Equilibrium Thermodynamic Approach for the Re-Design of Membrane Systems. Twentieth Symposium on Thermophysical Properties; 2018-06-25 - 2018-06-29
NTNU

Selvnes, Håkon.
Strategies for integrating cold thermal energy storage. HighEFF Cross-sector Workshop 2018; 2018-10-24 - 2018-10-25
NTNU

Selvnes, Håkon; Hafner, Armin.
Cold thermal energy storage for industrial applications. 10th KIFEE Symposium; 2018-10-05 - 2018-10-08
NTNU

Sheng, Juejing.
Advanced exergy analysis of the oil and gas processing on a North Sea platform. HighEFF Cross-sector Workshop 2018; 2018-10-24 - 2018-10-25
NTNU

Skaugen, Geir.
Advanced heat exchanger and system modelling. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
ENERGISINT

Steinmo, Marianne Terese.
The Role of University-Industry Collaboration for Circular Innovation Processes. Circular Economy conference; 2018-05-30
NORD

Steinmo, Marianne Terese.
University-Industry Collaboration for Innovation. HighEFF Cross Sector Workshop 2018; 2018-10-24 - 2018-10-25
NORD

Steinmo, Marianne Terese; Lauvås, Thomas Andre.
University-industry collaboration in research centres. Research seminar; 2018-06-26
NORD

Tangstad, Merete.
Obligations and privileges of a PhD student in the SiManTi student group. HighEFF Annual Consortium Meeting 2018; 2018-05-02
NTNU

Thombre, Mandar.
Data-driven model predictive control of a thermal storage system with time-varying uncertainty. HighEFF Cross-sector Workshop 2018; 2018-10-24 - 2018-10-25
NTNU

Thombre, Mandar.
Dynamic Optimization of a Thermal Storage System. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
NTNU

Widell, Kristina Norne; Nordtvedt, Tom Ståle.
Increasing energy efficiency in fish processing industry. 48th Conference of the West European FishTechnologists' Association; 2018-10-15 - 2018-10-18
OCEAN NTNU

Wittgens, Bernd.
Process improvements in Ferroalloy. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
SINTEF

Yu, Haoshui.
Work and Heat Exchange Networks – Opportunities and Challenges. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
NTNU

Zotica, Cristina Florina.
Optimal Operation of Heat to Power Cycles. HighEFF Annual Consortium Meeting 2018; 2018-05-02 - 2018-05-03
NTNU

Zotica, Cristina Florina.
Optimal operation of heat to power cycles. HighEFF Cross-sector Workshop 2018; 2018-10-24 - 2018-10-25
NTNU

Peer-reviewed papers

Search criteria:
sub-category: Academic chapter/article/Conference paper *All publishing channels*

Hafner, Armin; Kvalsvik, Karoline Husevåg.
Direct CO2-ground condensers. I: *Proceedings of the 13th IIR Gustav Lorentzen Conference, Valencia, 2018*. International Institute of Refrigeration 2018 ISBN 978-2-36215-026-5. p. -
ENERGISINT NTNU

Kvalsvik, Karoline Husevåg; Bantle, Michael.
Generating hot water for food processing plant using waste heat, high temperature heat pump and storage. I: *Proceedings of the 13th IIR Gustav Lorentzen Conference, Valencia, 2018*. International Institute of Refrigeration 2018 ISBN 978-2-36215-026-5.
ENERGISINT

Rohde, Daniel; Hagen, Brede Andre Larsen; Trædal, Stian; Andresen, Trond.
Comparison of Rankine cycle and trilateral flash cycle for power production from low temperature heat sources. I: *Proceedings of the 13th IIR Gustav Lorentzen Conference, Valencia, 2018*. International Institute of Refrigeration 2018 ISBN 978-2-36215-026-5. p. -
ENERGISINT

Schlemminger, Christian; Bamigbetan, Opeyemi Olayinka; Svendsen, Eirik Starheim; Bantle, Michael.
Design und experimentelle Resultate einer Hochtemperatur-Propan-Butan-Wärmepumpe. I: *DKV-Tagungsbericht 2018 Aachen, 21. – 23. November 2018.* DKV - Deutscher Kälte- und Klimatechnischer Verein 2018 ISBN 978-3-932715-96-9.
ENERGISINT

Selvnes, Håkon; Hafner, Armin; Kauko, Hanne.
Cold thermal storage integration in a large industrial refrigeration system. I: *Proceedings of the 13th IIR Gustav Lorentzen Conference, Valencia, 2018.* International Institute of Refrigeration 2018 ISBN 978-2-36215-026-5. p. 1231-1238
ENERGISINT NTNU

Sevault, Alexis; Banasiak, Krzysztof; Bakken, Jørn; Hafner, Armin.
A novel PCM accumulator for refrigerated display cabinet : design and CFD simulations. I: *12th IIR/IIF International Conference on Phase-Change Materials and Slurries for Refrigeration and Air Conditioning - PCM 2018 : book of proceedings.* International Institute of Refrigeration 2018 ISBN 978-2-36215-025-8. p. 43-49
ENERGISINT NTNU

Sevault, Alexis; Soibam, Jerol; Haugen, Nils Erland L; Skreiberg, Øyvind.
Numerical modelling of a latent heat storage system in a stovepipe. I: *ENERSTOCK2018 - the 14th International Conference on Energy Storage : proceedings book.* International Energy Agency (IEA) 2018 ISBN 978-975-487-218-7. p. 969-983
ENERGISINT NTNU

Shahrooz, Mina; Lundqvist, Per; Nekså, Petter.
Natural refrigerants for low temperature power cycles. I: *Proceedings of the 13th IIR Gustav Lorentzen Conference, Valencia, 2018.* International Institute of Refrigeration 2018 ISBN 978-2-36215-026-5.
ENERGISINT

Verpe, Espen Halvorsen; Bantle, Michael; Tolstorebrov, Ignat.
Evaluating plate freezing of fish using natural refrigerants and comparison with numerical freezing model. I: *Proceedings of the 13th IIR Gustav Lorentzen Conference, Valencia, 2018.* International Institute of Refrigeration 2018 ISBN 978-2-36215-026-5.
ENERGISINT NTNU

Zühlsdorf, Benjamin; Schlemminger, Christian; Bantle, Michael; Evenmo, Kjetil; Elmegaard, Brian.
Design recommendations for R-718 heat pumps in high temperature applications. I: *Proceedings of the 13th IIR Gustav Lorentzen Conference, Valencia, 2018.* International Institute of Refrigeration 2018 ISBN 978-2-36215-026-5.
ENERGISINT

Report/thesis

Search criteria:
Main category: Report/thesis *All publishing channels*

Bantle, Michael.
Presentation HTHP at annual meeting of Norwegian Refrigeration Association. : SINTEF Energi AS 2018 29 p.
ENERGISINT

Bantle, Michael; Cecilia, Gabrielii.
Low temperature refrigeration with CO2. Trondheim: SINTEF Energi AS 2018 240 p.
ENERGISINT

Bolstad, Andreas.
Visualisering og 3D-printing av varmevekslermodeller. Trondheim: SINTEF Energi AS 2018 15 p.

Foslie, Sverre Stefanussen.
Energy analysis of a fish meal factory. : SINTEF Energi AS 2018 38 p.
ENERGISINT

Kero, Ida; Dalaker, Halvor; Håkonsen, Silje Fosse; Khalil, Roger Antoine.
Potential uses of CO-rich off-gas from Mn ferroalloy production. Trondheim: SINTEF Energi AS 2018 24 p.
ENERGISINT SINTEF

Lingaas, Simon Johan Nilsen.
Thermal storage aided heat-to-power conversion from an intermittent heat source. Trondheim: SINTEF Energi AS 2018 22 p.

Nikolaisen, Monika.
Case planning 2019. Trondheim: SINTEF Energi AS 2018 5 p.
ENERGISINT

Nikolaisen, Monika; Andresen, Trond.
Potential for heat-to-power conversion from excess heat in existing boilers at Mo Industrial Park. Trondheim: SINTEF Energi AS 2018 18 p.
ENERGISINT

Skjervold, Vidar T..
Status on surplus heat database development. : SINTEF Energi AS 2018 21 p.
ENERGISINT

Media contributions

Search criteria:
Main category: Media contribution *sub-category*: Popular scientific article *sub-category:* Interview Journal *sub-category:* Article in business/trade/industry journal *sub-category:* Sound material *All publishing channels*

Claussen, Ingrid Camilla.
Norske forskere bak iskald miljøteknologi. abcnyheter.no [Business/trade/industry journal] 2018-08-15
ENERGISINT

Kauko, Hanne.
District Heating Warms Cities Without Fossil Fuels. ecowatch.com [Business/trade/industry journal] 2018-01-15
ENERGISINT

Sevault, Alexis.
Har du hørt om faseendringsmaterialer?. *Kulde og varmepumper* 2018 ;Volume 5. p. 12-14
ENERGISINT

Sevault, Alexis.
Har du hørt om faseendringsmaterialer?. *Gemini* 2018
ENERGISINT

Sevault, Alexis.
Har du hørt om faseendringsmaterialer?.. Har du hørt om fase-endringsmaterialer?. [Business/trade/industry journal] 2018-09-05
ENERGISINT

Blogs and information material

Search criteria:
Main category: Information material(s) *All publishing channels*

Bantle, Michael.
Phase-out of fossil fuels: SINTEF develops a novel high temperature heat pump.
ENERGISINT

Claussen, Ingrid Camilla.
HighEFF Annual Meeting – Picture Blogg.
ENERGISINT

Foslie, Sverre Stefanussen; Sevault, Alexis; Kauko, Hanne; Drexler-Schmid, Gerwin; Beck, Anton.
High-temperature TES for industrial processes.
ENERGISINT

Gundersen, Truls.
Education & Training in FME HighEFF.
NTNU

Mazzetti, Marit Jagtoyen.
Matchmaking for industry sectors for waste heat utilization.
ENERGISINT

Nikolaisen, Monika.
Energieffektivitet i verdensklasse.
ENERGISINT

Nikolaisen, Monika.
World-class energy efficiency.
ENERGISINT

Røkke, Petter Egil.
HighEFF Annual Report 2017.
NTNU

Røkke, Petter Egil.
HighEFF Cross-sector Workshop 2018.
NTNU

Selvnes, Håkon.
Saving the cold for later: Decoupling supply and demand.
NTNU

Sevault, Alexis.
Hva er faseendringsmaterialer (PCM) og vil det slå an i Norge?.
ENERGISINT

Sevault, Alexis.
What are Phase Change Materials? (Will they be the next big thing in Norway?).
ENERGISINT

Multimedia products

Search criteria:
sub-category: Multimedia product *All publishing channels*

Bantle, Michael.
FME HighEFF: TINE case, English. SINTEF Energi 2018
ENERGISINT

Bantle, Michael.
FME HighEFF: TINE case, Norsk. SINTEF Energi 2018
ENERGISINT

Bantle, Michael.
FME HighEFF: TINE case (Youtube). SINTEF Energi AS Trondheim 2018
ENERGISINT

Bantle, Michael.
HighEff og TINE - 40 % mindre energiforbruk. SINTEF Energi 2018
ENERGISINT

Kjølle, Gerd Hovin.
Hilsen fra FME CINELDI leder Gerd Kjølle. SINTEF Energi 2018
ENERGISINT

Nekså, Petter.
Naturlige arbeidsmedier Ep1: Utnytte industriell overskuddsvarme. SINTEF Energi Facebook 2018
ENERGISINT

Nekså, Petter.
Naturlige arbeidsmedier Ep1: Utnytte industriell overskuddsvarme. SINTEF Energi 2018
ENERGISINT

Nekså, Petter.
Naturlige arbeidsmedier Ep2: Hvor bruker man arbeidsmedier?. SINTEF Energi 2018
ENERGISINT

Nekså, Petter.
Naturlige arbeidsmedier Ep2: Hvor bruker man arbeidsmedier?. SINTEF Energi 2018
ENERGISINT

Nekså, Petter.
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