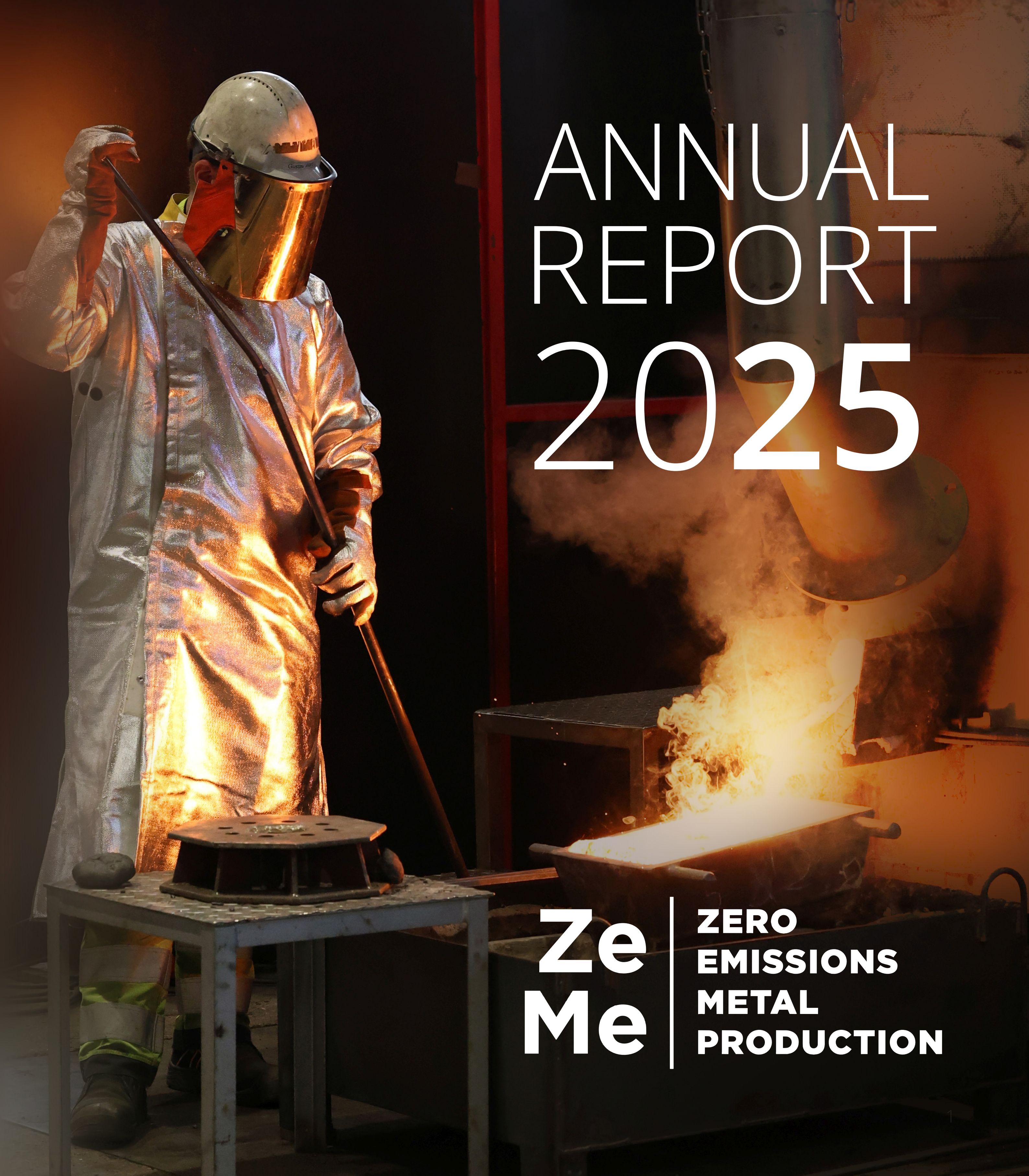


ANNUAL REPORT 2025

ZeMe | ZERO EMISSIONS METAL PRODUCTION

ZERO
EMISSIONS
Ze
Me
METAL
PRODUCTION

Editor: Torleif Nordskog
Layout: Marius Skaug Stokke @ NTNU Grafisk senter
Print: NTNU Grafisk senter

Photo: Marius S. Stokke & MidJourney (AI)

SUMMARY

Photo: Denys Gryshan, NTNU

Message from the Centre Director

Year 0: I am pleased to present the first annual report of FME ZeMe. 2025 was a year of building foundations: scientific, organisational and collaborative, that will shape our work for the eight years ahead.

FME ZeMe was kick-started in January 2025 with a Consortium Meeting for all partners in Trondheim where the project was introduced including short term and longer-term plans. In November 2025 the second Consortium Meeting was held with updates from the work that was performed in 2025.

We have achieved a lot during the first year with seven Ph.D. students starting at NTNU and more than 10 students at master's and bachelor's level involved. SINTEF and NORCE contributed with valuable research.

The Norwegian metallurgical industry remains committed to its long-term strategy of zero-emission production. To cut down on emissions, the metallurgical industry is undergoing a radical technological transition.

Achieving this requires more than excellent research. It demands commitment from the authorities to ensure favourable regulatory conditions for the metallurgical industry in the future, and to guarantee that metals produced with a low carbon footprint will be valued at a premium.

The members of the core group are taking every opportunity to explain to the public and authorities how important our industry is for Norway and for Europe during geopolitically uncertain times.

I look forward to the work ahead and to the results we will achieve together.

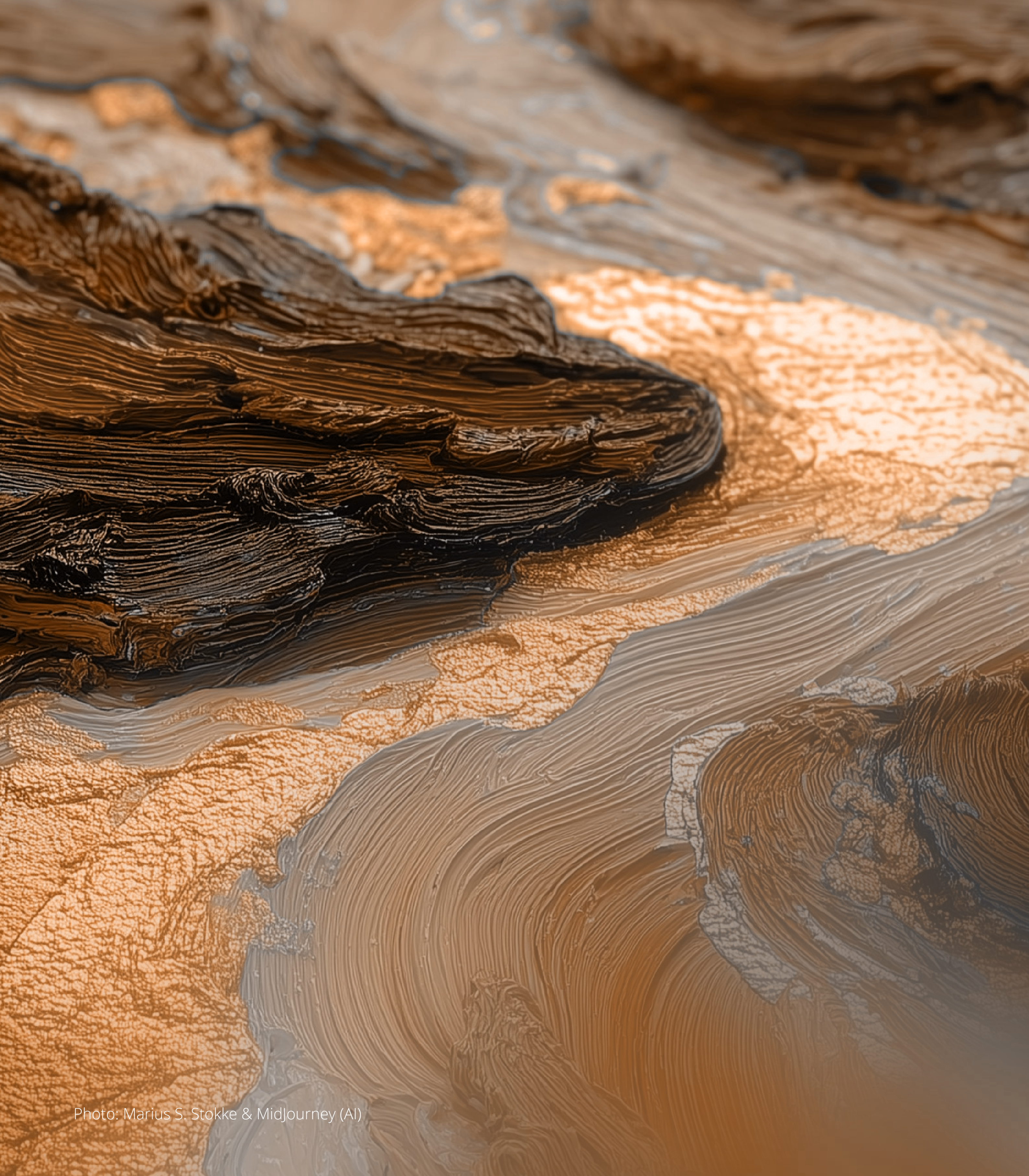


Photo: Marius S. Stokke & MidJourney (AI)

VISION AND RESEARCH STRATEGY

The overall goal of FME ZeMe is to develop the fundamental knowledge and technologies needed to enable the Norwegian metallurgical industry to reach their ambitious goal of becoming climate neutral in 2050. A key step in supporting this vast transformation is to educate and train the experts and professionals that will carry the industry forward.

Our work focusses on:

- Climate neutral and energy efficient production processes
- Processes for optimal carbon capture, utilization and storage
- Circular and resource efficient value chains
- Enhanced emission measurement and accounting tools
- Digitalisation and modelling methods and tools
- Frameworks for designing and evaluating zero emission metal production systems

1. Energy efficient electrolysis
2. Climate neutral reducing agents
3. Facilitating energy efficient carbon capture
4. Circularity and resource efficiency
5. Modelling and digitalisation
6. Enviroment and sustainability framework
7. Analysis Techniques, Emission Monitoring and Control

RA1: ENERGY EFFICIENT ELECTOLYSIS

Objective: Develop fundamental knowledge for increased energy efficiency and the transition to climate neutrality in electrochemical processes.

Aluminium, copper, nickel, and zinc are produced using electrochemical processes (electrolysis), where electricity is used to enable the chemical reactions to take place.

This research area's activities focus on improvement of the energy efficiency of the existing processes, reduction of CO_2 and other greenhouse gas emissions, and research on new processes to produce metals.

RA2: CLIMATE NEUTRAL REDUCING AGENTS

Objective: Develop fundamental knowledge on the use of alternative reductants such as biocarbon and hydrogen to reduce CO_2 emissions from the metallurgical industry.

Fossil carbon is used as reduction material in the production of ferroalloys, aluminum, titanium dioxide and pig iron. It is the main contributor to CO_2 emissions from the processing industry in Norway.

The research area's activities will build fundamental knowledge on the use of alternative reductants such as biocarbon and hydrogen, and linked technologies, to reduce emissions.

RA3: FACILITATING ENERGY EFFICIENT CARBON CAPTURE

Objective: Carbon capture represents one of few strategies to reduce the climate footprint which can be retrofitted to the current metal production facilities. The CO_2 separation technologies themselves are not a part of ZeMe, but the adaptation of current processes to enable carbon capture is. This work package aims to improve both energy and cost efficiency.

The research area's activities will focus on the adaptation of current processes to enable carbon capture and improve energy and cost efficiency.

RA4: CIRCULARITY AND RESOURCE EFFICIENCY

Objective: Reduce the energy consumption, increase the material efficiency, as well as decrease the amount of waste from the metallurgical industry.

The barriers to this are primarily of a technological and/or economic nature. Moreover, several of the new process routes suggested in the metallurgical industry will have different requirements for raw materials and will produce new side streams.

RA5: MODELLING AND DIGITALISATION

The objective is to develop and apply physics and data-based models, combine them with sensor data, and then make these tools available for process control and optimization as well as training and education.

This research area will strengthen and enhance the activities in WP1-WP4 through modelling and digitalization.

RA6: ENVIRONMENT AND SUSTAINABILITY FRAMEWORK

Objective: Develop and apply an analytical framework for design and planning of zero emission metal production.

The framework shall guide a just, effective, and robust transition, and be able to evaluate and integrate design options at the level of processes, value-chains, and sectors.

RA7: ANALYSIS TECHNIQUES, EMISSION MONITORING AND CONTROL

Objective: Develop tools and methods for for process- and material-specific emission monitoring, prediction and accounting.

Real-time characterisation of condensed phases (metal, slag etc) is also a focus of the research area.

Consortium meeting at Scandic Lerkendal, Trondheim, in November. Photos: Denys Gryshan, NTNU

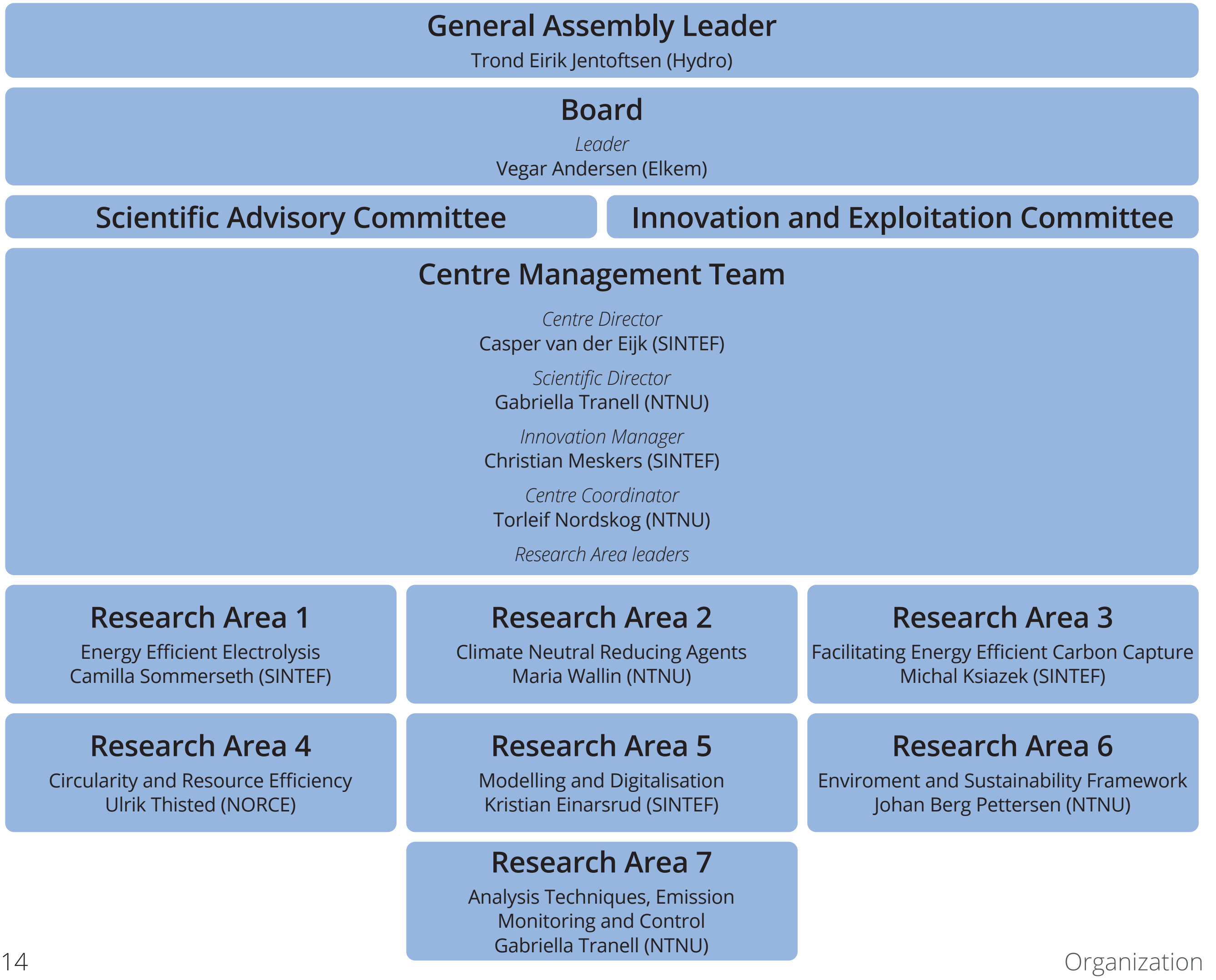
ORGANIZATION

FME ZeMe is hosted by NTNU and the Centre Director is Casper van der Eijk (SINTEF).

GENERAL ASSEMBLY (GA)

All industry partners, research partners and international partners are represented in the GA. Trond Eirik Jentoftsen (Hydro) is chair of the GA.

Casper van der Eijk
Centre Director



THE BOARD

Board meetings are held four times a year.

Members of the board are:

Vegar Andersen, *Elkem ASA (Chair)*
Ida Westermann, *NTNU*
Nina Dahl, *SINTEF AS*
Stian Anfinsen, *NORCE*
Benjamin Ravary, *Eramet Norway AS*
Ellen Bromstad Myrvold, *Alcoa Norway AS*
Maria Førde Møll, *Boliden Odda AS*
Trond Eirik Jentoftsen, *Hydro Aluminium AS*
Viktor Myrvågnes, *Elkem ASA*

Vegar Andersen
Chair

First row: Kristian Einarsrud (SINTEF), Maria Wallin (NTNU), Gabriella Tranell (NTNU and Torleif Nordskog (NTNU).Second row: Camilla Sommerseth (SINTEF), Casper van der Eijk (SINTEF), Ulrik Thisted (NORCE), Michal Ksiazek (SINTEF), Johan Berg Pettersen (NTNU) and Christina Meskers (SINTEF). Photo: SINTEF

THE CENTRE MANAGEMENT TEAM (CMT)

The representatives in the CMT are Centre Director Casper van der Eijk (SINTEF), Scientific Director Gabriella Tranell (NTNU), Innovation Manager Christina Meskers (SINTEF) and Centre Coordinator Torleif Nordskog (NTNU). The Research Area leaders are also part of the management team.

SCIENTIFIC ADVISORY COMMITTEE (SAC)

To advice FME ZeMe on strategic directions and quality of research, we are pleased that four strongly merited scientists have agreed to work with the centre as scientific advisory committee. The committee consists of:

Timo Fabritius

Professor Timo Fabritius is the Head of the Process Metallurgy research unit at University of Oulu, Finland. His main research concerns iron- and steelmaking processes and he is an expert on heat and mass transfer phenomena, thermodynamics, chemical equilibrium and reaction kinetics in high temperature processes. He has been responsible leader of 5 EU-RFCS projects and many national projects and programs in the field of iron- and steelmaking.

Efthymios Balomenos

Assistant Professor Efthymios (Thymis) Balomenos from the School of Mining and Metallurgical Engineering at the National Technical University of Athens in Greece. He has dedicated his research carrier to innovative metallurgical processing, focusing on resource preservation and climate change mitigation. Key research topics include: Industrial residue (bauxite residue, metallurgical slags, spent catalyst, e-waste) valorization, critical metal extraction and recovery, alternative paths to metallic iron and aluminium production, innovation in alumina production, Electric Arc Furnace processing, Microwave processing, thermodynamic modelling, exergy accounting, circular economy and others. He has led several large EU projects in the field of aluminium and critical raw materials.

Dr Quinn Reynolds is technical specialist with MINTEK in Johannesburg, South Africa. His professional interests revolve around the application of high-performance computing to pyrometallurgical problems including, computational magnetohydrodynamics for the study of plasma arc formation and evolution as well as computational fluid dynamics of multi-physics problems. He has also worked extensively with the application of high-speed measurement techniques in pyrometallurgy: photography, videography, and electrical properties.

Dr Quinn Reynolds

Professor Ester van der Voet from Leiden University, the Netherlands, at the Department Industrial Ecology of the Institute of Environmental Sciences, CML. Within the field of Industrial Ecology, she specialises in methodology development: life-cycle assessment, material flow analysis, substance flow analysis, natural resource accounting, and indicator development. These methodologies she applies to different topical areas, especially within the bio-based economy and in metals and the circular economy. She has conducted many research projects for the EU and in other international consortia. She is a member of UNEP's International Resource Panel.

Ester van der Voet

INNOVATION AND EXPLOITATION COMMITTEE (IEC)

The IEC is chaired by Innovation Manager Christina Meskers (SINTEF). The committee will evaluate the innovation potential of emerging results and technologies, identify exploitation opportunities including possible spin-off innovation projects and provide recommendations to both the Board and the General Assembly.

PARTNERS

Research partners

SINTEF NTNU NORCE

Industry partners

Boliden Odda AS

A Norwegian smelter owned by Boliden, specializing in zinc production. It is one of Europe's largest zinc producers and a key part of Norway's process industry.

Glencore Nikkelverk

A refinery in Kristiansand producing nickel, copper, and cobalt. Owned by Glencore, it is among the world's largest nickel refineries.

Kymera International

A global materials company producing specialty metal powders and alloys. The plant in Norway is producing silicon carbide.

REEL Norway AS

Serves the primary aluminium industry and is a technology leader in Gas and Fume Treatment systems. REEL Aluminium is a solution provider dedicated to reduce the carbon footprint in the aluminium industry.

Alcoa Norway AS

Part of Alcoa, producing primary aluminium at plants in Mosjøen and Lista. Alcoa is a global company that produces bauxite, alumina, and aluminum for industries such as transportation, construction, and packaging.

Hydro Aluminium AS

A division of Norsk Hydro, one of the world's largest aluminium producers. It operates across the full value chain from energy to finished aluminium products.

INEOS Tyssedal AS

Produces high-purity iron and Ti slag which is mainly used to produce titanium dioxide, which is then used as a white pigment in products like paint. INEOS is a global chemical manufacturer producing petrochemicals, specialty chemicals, and oil products for a wide range of industries.

Finnfjord AS

A ferrosilicon producer located in northern Norway. Known for energy-efficient production and heat recovery for local energy use.

Wacker Chemicals Norway AS

Produces silicon metal used in chemicals, electronics, and solar cells. Operates a major plant in Kyrksæterøra within Norway's process industry.

Eramet Norway AS

Specializes in manganese alloys like ferromanganese and silicomanganese. Part of the global Eramet group, supporting steel and battery industries.

Elkem ASA

A global materials company producing silicon, silicones, and carbon products. It plays a key role in renewable energy, electronics, and advanced materials.

Ferrolegeringsindustriens Forskningsforening

FFF

The Norwegian Ferroalloy Producers Association (FFF) is an industry organization representing Norway's ferroalloy producers and safeguarding their common interests. It works to promote sustainable production, innovation, and favourable framework conditions for the ferroalloy industry.

International partners

Seoul National University, South Korea.

Université Laval, Canada.

LOCATION

FME ZeMe is hosted by NTNU's Department of Materials Science and Engineering. The centre is located at Campus Gløshaugen in Trondheim, on the third floor of Bergbygget at Alfred Getz vei 2. At FME ZeMe, members from both industry partners and research partners work side by side, enabling close interaction and strong collaboration across all partners.

The Research Area Leaders are based in Trondheim at Campus Gløshaugen and at NORCE in Kristiansand. PhD candidates recruited to the centre work closely together and in close proximity to their supervisors and Research Area Leaders, fostering an integrated and collaborative research environment.

Campus Gløshaugen, Trondheim

Photo: Erik Børseth, Synlig design og Foto AS/NTNU

SCIENTIFIC ACTIVITIES


Photo: Casper van der Eijk, SINTEF

RESEARCH AREA 1.

Energy efficient electrolysis

Research area leader: Camilla Sommerseth, SINTEF

INTRODUCTION

The electrochemical industry in Norway consists of Hydro Aluminium and Alcoa Norway as aluminium producers, Glencore Nikkelverk, which produces nickel, cobalt, and copper, and Boliden, which produces zinc and zinc alloys. The overall aim of Research Area 1 (RA1) in FME ZeMe is to help the electrochemical industries in Norway to reduce their energy consumption and emissions. In Research Area 1, we examine the core of the current production processes to gain insight into how emissions are formed and what process control steps can be taken to avoid excess emissions.

Alternative anode materials for both the aluminium industry and the Ni, Cu, Co, and Zn industries are studied. For the aluminium industry, the aim is to gain knowledge on production of aluminium using inert anodes, where oxygen is the anodic reaction product instead of CO_2 as is the state-of-the-art today.

For the Ni, Cu, Co and Zn industries new anode materials are studied to lower the anodic overvoltage, a direct way of reducing the energy consumption of the process, while at the same time reducing the cost of the anode material.

Two PhD candidates have started their work during 2025: Olaug Marie Aalen, who is studying alumina concentration and its corresponding perfluorocarbon formation mechanisms in primary aluminium production and Zoran Povijac, who is studying energy efficient anode materials for sustainable electrowinning. You can read more about their and SINTEF's research work in 2025, below.

ACTIVITIES AND RESULTS IN 2025

CLIMATE NEUTRAL ALUMINIUM PRODUCTION

In January a workshop was held where the tasks and workplans related to the aluminium industry across all RAs were discussed between the industry and research partners. Another workshop for the aluminium industry was held the day after the consortium meeting in November where the results of 2025 and the workplans for 2026 were discussed.

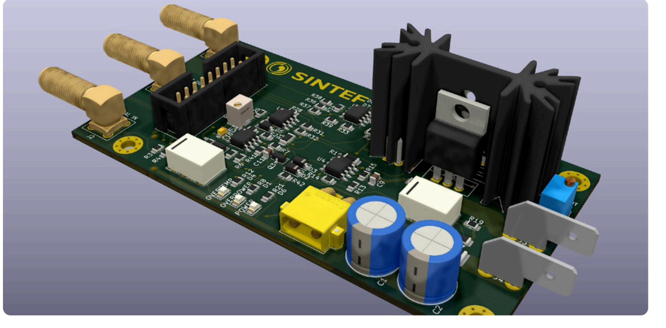
The focus of the task on Climate Neutral Aluminium Production is twofold:

1. A novel process for production of aluminium, more specifically the use of inert anodes which produces oxygen as the anode product instead of CO_2 as is the case in the current Hall-Héroult process, and

2. Focus on the process gases from the current Hall-Héroult process under various operation conditions, more specifically on the formation of perfluorocarbon gases (PFCs) and the corresponding oxide dissolution in the electrolyte.

The work on inert anodes in 2025 mainly focused on a literature study which culminated into a paper which will be published in Light Metals and presented at TMS in March 2026. The paper is titled "Inert Anodes and Wetted Cathodes for Aluminium Production. Principles and Challenges". The work will continue in 2026 by focusing on lower melting electrolytes for producing aluminium when using inert anodes.

SINTEF has, in previous years, developed an equipment which can measure oxygen content in electrolytes online. This equipment is named OxiSens. The working principle of the OxiSens is that it measures peak current or critical current density during a voltage sweep. SINTEF worked in 2025 to improve the electronic hardware (circuit board) so it will be more robust than the first prototype version. An operating manual for the Oxisens has been written, and the documentation of the hardware has been improved too. The OxiSens will be used in PhD 1A, Olaug Marie Aalen's work both in laboratory experiments and during industrial measuring campaigns.



Photos: Camilla Sommerseth, SINTEF

Olaug Marie Aalen started her PhD work in August 2025. Her work will focus on PFC formation in Hall-Héroult aluminium production cells. Her work will study both online techniques for monitoring PFCs and alumina concentration and she will also use more sensitive measuring techniques which give average results over a given time frame. These techniques include the use of measuring equipment such as FTIR, LECO, OxiSens, Medusa-GS-MS. During the autumn she wrote a literature review related to the work that she will perform and made a work plan for her PhD.

She has teaching duties at the Department of Materials Science and Engineering at NTNU and has completed work as scientific assistant in TMT4111 General Chemistry during the autumn of 2025. She has also planned the scope for a measuring campaign at Hydro Årdal and laboratory work. During 2025 a resource group, including members from the industry has been establish with meetings every month.

Reference group meetings have been established as a means of updating the industry on the progress and activities within a Research Area. These take place before Steering Committee meetings.

ENERGY EFFICIENT NICKEL, ZINC AND COPPER PRODUCTION

Zoran Povijac started his PhD work in August 2025. The scope of his PhD is to develop anode materials for Ni, Co, Cu and Zn production at an affordable cost and using an electrocatalyst which gives a low anodic overvoltage. Lowering the anodic overvoltage directly influences the energy consumption of the metal electrowinning process. The tentative title of his PhD work is "Energy efficient anode materials for sustainable electrowinning". In September 2025 a workshop was held at Glencore Nikkelverk in Kristiansand to discuss his workplan. Zoran also got a very thorough and informative guided tour around the industrial plant.

During the autumn of 2025, Zoran has completed two of his PhD courses: MN8000 Doing Science: Methods, Ethics and Dissemination and KP8132 Applied Heterogeneous Catalysis. He is well underway in the laboratory with experimental work, where he has started with reproducing literature results regarding synthesis of RuO_2 and Ta-doped RuO_2 nanoparticles using the alginate sol-gel route. These materials are further electrochemically tested using various electrochemical techniques.

ELECTROWINNING OF SILICON AND MANGANESE

This task will not start until 2030. An associated project of FME ZeMe is currently running, named ZeSiM, and this project has occasionally updated the consortium with main findings during the reference group meetings which are held twice a year.


Photo: Adobe Stock

RESEARCH AREA 2.

Climate neutral reducing agents

Research area leader: Maria Wallin, NTNU

INTRODUCTION

The work in RA2 focuses on developing more sustainable metal production processes. One activity evaluates the potential of biocarbon as a replacement for fossil carbon in aluminium and ferroalloy industries, examining its effects on industrial processes and final products. In aluminium production, biocarbon is studied as a carbon source in anodes for electrolysis, while in silicon and manganese production it is assessed as a reductant, either as pure biocarbon, biocarbon agglomerates, or composite agglomerates.

Another activity investigates the smelting behaviour of hydrogen pre-reduced ilmenite ore, including thermodynamic and kinetic aspects, as well as plasma-based metal reduction processes. This research complements ongoing work in the FME HYDROGENi project.

ACTIVITIES AND RESULTS IN 2025

BIOCARBON UTILISATION IN ALUMINIUM AND IN FERROALLOY PRODUCTION

At our first internal workshop in January, it was clear that the present industrial partners (manganese, silicon, aluminium, titanium concentrate, and silicon carbide industry) had a common interest in further investigating different biocarbon and bio-binders properties. Also they like to know the impact on furnace/electrolysis operation, product quality and emissions such as NOx, SOx and Polycyclic Aromatic Hydrocarbon (PAH).

It was decided to study this in lab, pilot and at industrial scale to better understand opportunities and challenges at different scales. In 2025, the focus has been on conducting experiments in lab-scale at NTNU and SINTEF using one type of Biocarbon, provided by Elkem, to ensure that the results are comparable and consistent regardless of experimental set-up.

Research area 2 has also co-organized the 3rd edition of the Biocarbon in Metallurgy event in Wisla Poland on April 8th-9th 2025. The event was organized by NTNU, SINTEF and the Institute of Energy and Fuel Processing Technology (ITPE, Poland) brought together 146 participants from research, policy and industry ranging from production of coke, biocarbon, metallurgical processing and solution providers. They discussed the latest developments in technology, science, markets and policies. It became clear that good communication among the different stakeholders and political willingness to scale up the production of biocarbon is crucial to facilitate an increased use of biocarbon in metallurgical processes.

From the discussions, it was clear that good communication among the different stakeholders and political willingness to scale up the production of biocarbon is crucial to facilitate an increased use of biocarbon in different metallurgical processes.

To foster growth of the biocarbon market, it was suggested to promote allocation of biomass towards higher value use and also to increase the awareness of carbon as a product.

Identified pre-requisites for metallurgical producers transition to biocarbon:

- Favourable conditions for industry that reduce emissions today
- Development of technology and factories
- Long-term access to biocarbon
- Biocarbon is high-quality, renewable, sustainable and available in large quantities
- Biocarbon must be competitively priced and safe to use
- Risk mitigation strategies from politicians
- Long term agreements with biocarbon producers

Towards the end of 2025, a workshop was organized to define the topic for the next PhD candidate that will work towards the use of biomaterials in the anodes in the electrolysis cells. The candidate will be located at Université Laval in Canada.

In the lab SINTEF has investigated whether there is a direct relationship between fixed carbon content and the mechanical strength of biocarbon intended for use as a reducing agent, or whether the commonly assumed relationship, where lower fixed carbon associated with lower strength.

This is mainly a consequence of differences in wood sources. To address this, biocarbon produced from different wood sources was selected at comparable fixed carbon levels, allowing the effects of wood species to be evaluated independently of fixed carbon.

Photo: Casper van der Eijk, SINTEF

In addition, the influence of wood sources on properties relevant for furnace operation, specifically reactivity toward SiO and CO_2 gas was investigated at comparable fixed carbon contents. This provides the opportunity to examine potential correlations between mechanical strength and chemical reactivity. Finally, to indicate the effect of agglomeration, the strength and reactivity of lump biocarbon were compared with those of briquettes produced from the same raw material (wood source)

At **NTNU**, the PhD candidate Thea Stabbforsmo supervised by Prof. Merete Tangstad studies the influence of biocarbon material on high temperature strength of SiC. In 2025 her focus has been on investigating the compressive hot strength of coal and charcoal at 400, 800 and 1000 by a spark plasma sintering. The results indicate that coal is stronger than charcoal at all tested temperatures and both materials exhibit higher strength at 1000 than at lower temperatures, including room temperature.

Thermal abrasion testing was also conducted and the results indicated that coal is less friable than charcoal, and both materials are more resistant to abrasion after heat treatment at 1000 than at lower temperatures or no heat treatment. Thea has characterized the material using several analytical techniques to identify the degree of graphitization after calcination, the materials density and porosity. It was shown that Fix C increased with increasing HTT, as expected. In addition, SiC from the same coal and charcoal has been produced for hot strength testing. Chemical analysis of the SiC content shows conversion up to 99% for charcoal and 52% for coal after manual sorting. In 2026, the same experiments will be conducted for the SiC converted coal and charcoal materials.

In 2025 two specialization projects have been completed, one by Johanne Grimstad Osberg and one by August Rabben Dalen. Both supervised by Prof. Merete Tangstad. Johanne has worked closely with Thea and her focus has been on investigating the hot strength of carbon materials for Si/FeSi production using a Gleeble 3800-GTC. The method was first evaluated using graphite, for which the Gleeble successfully measured hot strength. However, when applied to charcoal, the method proved unsuitable due to insufficient heating of the material within the machine. Additional characterization was therefore carried out, including mechanical testing of heat-treated samples and analysis of how heat treatment affects the charcoal structure.

The results showed a slight trend of decreasing compressive resistance with increasing heat-treatment temperature. At the same time, the material density increased as the heat-treatment temperature rose. Microstructural analysis revealed that higher heat-treatment temperatures led to larger average pore diameters and thinner pore walls. These changes suggest that the charcoal structure contracts and releases more volatiles at elevated temperatures.

August Rabben Dalen produced biocarbon/manganese agglomerates and investigated these as raw material for FeMn production in his specialisation project. The reason for producing agglomerates is to increase the mechanical properties of the charcoal and to enable the use of under sized fines from Mn ore in the production. In the project August first crushed Mn ore and charcoal to sizes of 100-630μm and 20-60μm respectively, before mixing this with 10 wt% lignosulfonate as a binding agent and then pressed the mixture using a hydraulic press with 1 ton of force for 1 minute.

The agglomerates were then reduced in a CO atmosphere at 1200°C, 1500°C and 1500°C with an additional 30 minutes of holding time followed by SEM EDS analysis of the alloy and slag to evaluate their potential use in FeMn production. Weight loss analysis of the samples was also done to evaluate their extent of reduction. Results showed that the agglomerates lost their structural integrity after each experiment, which needs to be improved for the intended use. Weight loss, SEM and EDS analysis showed however that they were efficient in producing FeMn alloys, nearing complete reduction after only 30 minutes.

This project illustrates good potential for these agglomerates as raw materials; however further quantitative analyses and improvements to their thermal and mechanical strength will be conducted in the master's thesis. During spring 2026, August will work closely with the MSc student Aaron Möckel from the Technical University of Munich, Germany. Aaron is doing a 10-week internship at NTNU in research area 2.

In this task student Hedda-Emilie Fjeldseth Wintervoll, as her specialization project work, investigated how silicon carbide (SiC) forms in liquid silicon when these materials are exposed to carbon monoxide (CO) gas. Hedda used a lab-scale induction furnace to reach high temperatures that are used in the industrial silicon and ferrosilicon production. The main goal of her work was to determine whether SiC actually forms under CO exposure, how extensive the formation can become, and how factors such as temperature, holding time, sample size, and alloy composition influence the reaction.

Overall, Hedda's work clearly showed that SiC forms readily when silicon or FeSi75 is exposed to CO gas at high temperatures, and. The key parameters — temperature, sample dimensions, and alloy composition — strongly control both the rate and the structure of the formed SiC. Her findings contribute important insight into reaction mechanisms that are relevant for industrial silicon and ferrosilicon processes. This topic will be continued as her Master work in 2026.

SMELTING OF HYDROGEN PRE-REDUCED ORES AND PLASMA-BASED REDUCTION OF METALS.

This task has not been started yet.

Photo: Casper van der Eijk, SINTEF

RESEARCH AREA 3.

Facilitating energy efficient carbon capture

Research area leader: Michal Ksiazek, SINTEF

INTRODUCTION

Carbon capture represents one of few strategies to reduce the climate footprint which can be retrofitted to the current metal production facilities. The development of CO_2 separation technologies themselves are not a part of ZeMe, but the adaptation of current processes to enable carbon capture is.

This research area aims to improve both energy and cost efficiency by:

1. Improving the off-gas characteristics through process development and

2. Optimisation of multicomponent off-gas systems.

The increased use of surplus-energy, particularly for more energy efficient carbon capturing technologies, is included in this research area.

Research area 3 will work closely with research area 2 and research area 7 to maximize the understanding of using biocarbon on off gases across various processes.

ACTIVITIES AND RESULTS IN 2025

OFF-GAS RECIRCULATION AND ENERGY CONSUMPTION

At Alcoa Mosjøen, a PIA dry scrubbing unit is installed directly adjacent to one of the cells and connected to it. Within the FME ZeMe program, this location was selected as a site to perform future furnace gas recirculation tests. As a first step toward this long term goal, a large-scale measurement campaign was carried out in the summer of 2025.

One approach to making CO_2 capture more feasible for the aluminum industry is to increase the CO_2 concentration in the off gas. This can be achieved by recirculating the furnace gas back into the cell as a cover gas, with controlled re introduction through dedicated nozzles. Before such recirculation is possible, certain gas components—such as HF—must be removed, and it is essential to understand how other components, including sulfur species, behave and move through the system.

Photo: Ole Kjos, SINTEF

The purpose of the measurement campaign was to map concentrations and short term fluctuations of all relevant gas components. These data serve as a foundation for process modeling and for planning future modifications to the PIA unit, with the objective of enabling off gas recirculation and increasing the CO_2 concentration in the gas above 4%.

During summer 2025, two FTIR gas analysers were installed at the PIA facility—one on the outlet gas stream and one on the inlet stream. The outlet gas was sufficiently clean to allow continuous FTIR operation over the entire four-week campaign. In contrast, the inlet gas analyser could only be run when personnel were present to supervise filters and maintain the instrument. In collaboration with SINTEF, Alcoa hired a summer student who was responsible for this supervision and ensured regular measurements throughout the period. The student also assisted in sampling alumina, which was later analysed at Alcoa's laboratory for fluorine and sulfur content. Although average concentrations of these species were already known from earlier work, capturing the variability minute scale and hour scale was essential, as such fluctuations may intensify once the gas is recirculated.

The outcome of the measurement campaign has been compiled into a publication presented in Light Metals 2026, titled "Sulfur balance between dry scrubber and electrolysis cell in order to understand effects of pot gas recirculation." The paper was led by SINTEF, with contributions from Alcoa, REEL Norway, and NTNU.

The work will continue in 2026, focusing on modelling of the electrolysis cell and the exhaust system, as well as planning potential modifications to support gas recirculation experiments.

The accompanying image shows REEL's PIA dry scrubber in the background and the two FTIR analysers in the foreground.

GAS CLEANING FOR ENERGY RECOVERY AND CARBON CAPTURE

On 11 August 2025, Magnus Windfeldt joined our team as a PhD candidate under the supervision of Gabriella Tranell. Since the start of his doctoral work, he has focused on building a strong foundation in both theoretical and practical aspects relevant to gas cleaning, furnace modelling, and biocarbon research. As part of his academic training, Magnus completed two specialized courses: Gas Cleaning with Chemical Solvents and Multivariate Data Analysis. These courses provided him with essential tools for understanding complex gas cleaning processes and for handling large datasets that are typically generated in industrial process modelling.

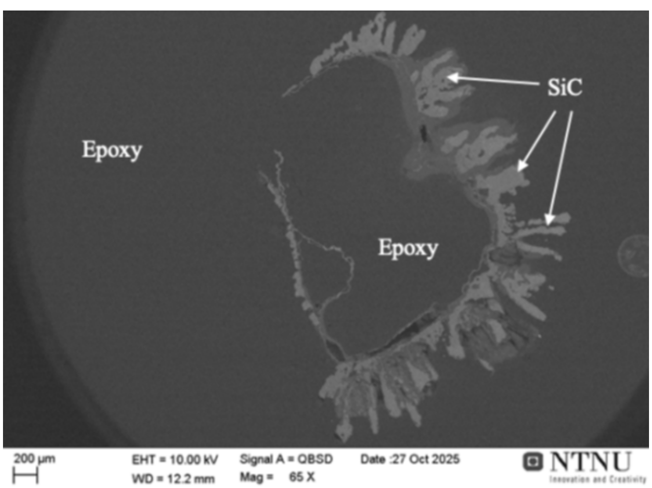


Photo: Hedda-Emilie Fjeldseth Wintervoll, NTNU

In parallel, Magnus began developing a model for flue gas composition from silicon furnaces using HSC Sim. This work aims to develop a predictive tool capable of describing how gas composition evolves under various raw material mixes and operational conditions. This is a key step toward more accurate process simulation and optimization. He also carried out an initial literature review on biocarbon composition and analytical methods, mapping out the state of the art in characterization techniques and identifying knowledge gaps relevant for future research in the project.

To publish his early findings and engage with the broader scientific community, Magnus prepared and submitted an abstract ("Predicting flue gas conditions from bio-based Si production for carbon capture implementation") to the SAIMM Pyrometallurgy Conference 2026, marking his first scientific contribution within the project.

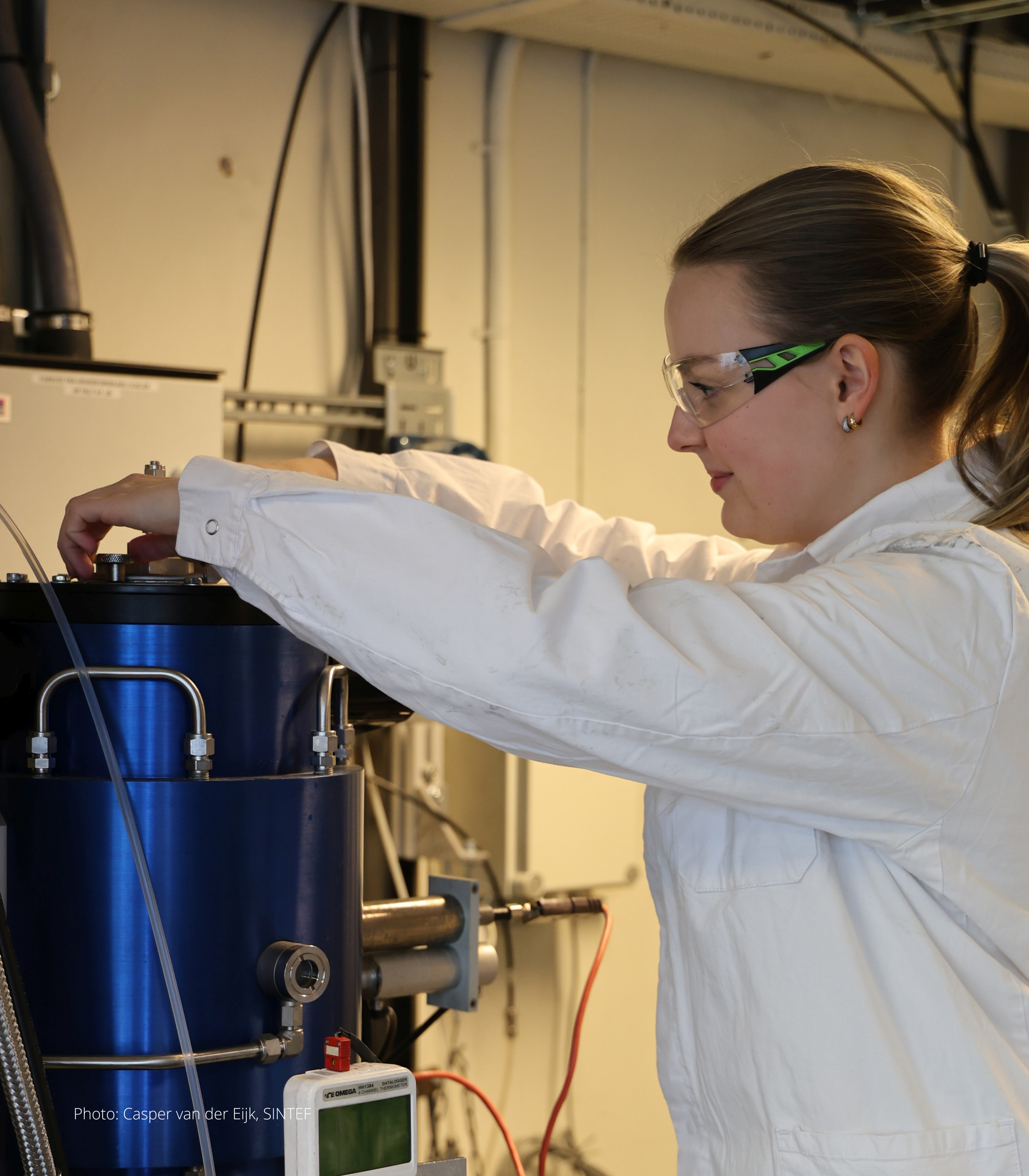


Photo: Casper van der Eijk, SINTEF

RESEARCH AREA 4.

Circularity and resource efficiency

Research area leader: Ulrik Thisted, NORCE

INTRODUCTION

The aim of RA4 is to increase circularity and resource efficiency of the metallurgical industry. The methods for achieving this are primarily to find use of the waste streams produced in secondary processes as well as using materials from secondary sources as raw materials to replace virgin raw materials. The side streams of the metallurgical industry consist mainly of slags, sludge and dust from filtration/scrubbing. Many of the activities are therefore focused on removing impurities from recycled materials to obtain similar quality to primary products.

ACTIVITIES AND RESULTS IN 2025

UTILIZATION OF ALUMINIUM CONTAINING WASTE STREAMS

ELECTROREFINING

The electrorefining activities have focused on fundamental research using a side-byside electrorefining technique where the anode is molten highly-alloyed scrap (impure) aluminium and the cathode consist of refined (purified) liquid aluminium. The electrolyte is a molten NaCl:LiCl:AlF3 mixture.

The project has first operationalised old equipment and techniques developed from earlier projects and has then used this equipment to run a series of experiments. The equipment has a total liquid volume of around 1 L and is operating current in the range of 10-25 A.

Three runs of 8 hours each have been performed of and the last two were considered successful. The results indicate that aluminium can be refined at an energy consumption of less than 7 kWh/kg. The incoming scrap metal and refined products were analysed with respect to the most important metallic impurities.

The results are shown in the table below and indicate a purification of 80-90% on most elements, with the refined product fulfilling the Al99.5E spec on all analysed elements except Si. Overall, the results are promising, and the work will continue in the coming years with the aim of scaling up and optimising the process parameters.

		Si	Fe	Cu	Mn	Mg	Zn	Ti
	Scrap (Anode) before exp. (ppm)	99500	7100	5200	2100	2800	2800	-
Exp. 2	Avg. anode, /ppm	63277	6006	4314	1793	<10	2442	455
	Avg. Cathode, /ppm	2801	983	302	99	<10	155	66
	Purification yield, /%	96	84	93	94	-	94	85
Exp. 3	Avg. anode, /ppm	69705	6123	3376	1866	<10	2238	551
	Avg. Cathode, /ppm	5962	1295	616	234	<10	297	54
	Purification yield, /%	91	79	82	87	-	87	90
	Limit Al99.5E, /ppm	2500	4000	500	500	500	700	ND

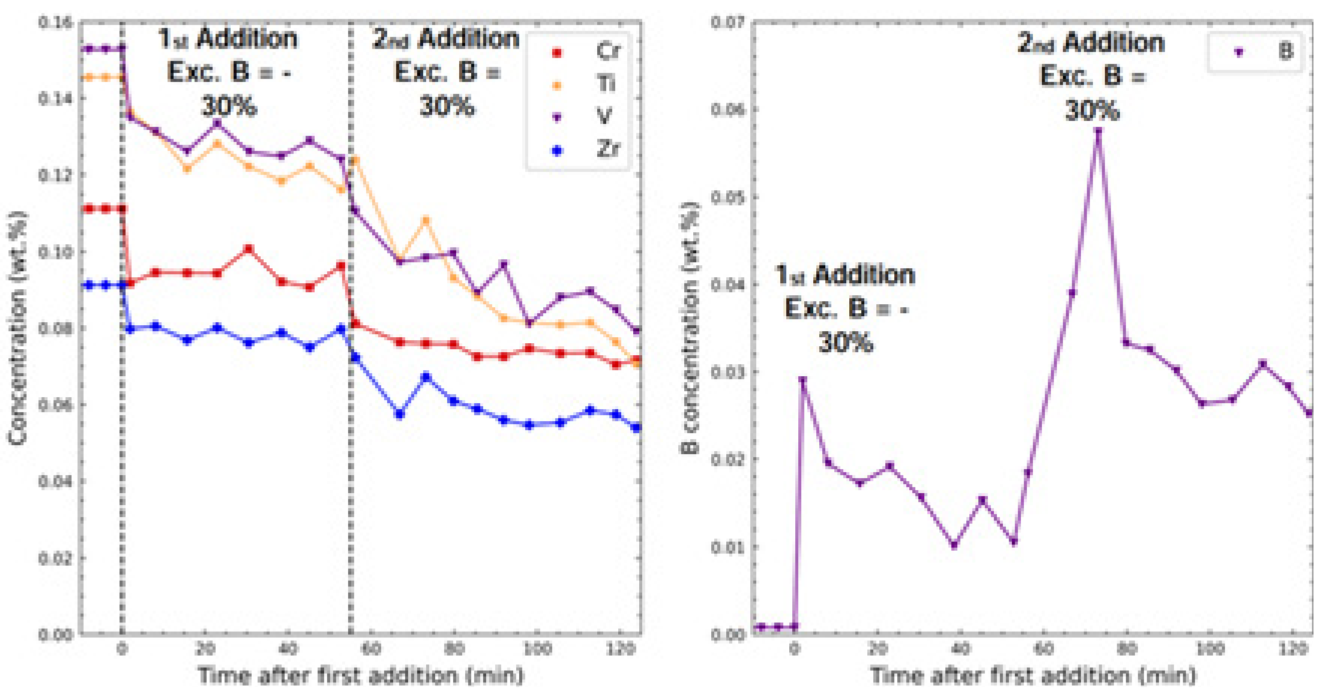
Table: Summary of impurities in starting material and final product for electrorefining tests.

BORON TREATMENT

The transition elements like Ti, Zr, Cr, and V have very low solubility in aluminum. They easily form boride intermetallic phases. Boron is therefore added to molten aluminium in the form of a master alloy containing two types of borides AlB2 and AlB12, in an aim to remove these transition elements to sedimentate at the bottom. After the addition of the master alloy in the liquid state, the dissolution of the AlBx occurs simultaneously, it is therefore of interest to investigate the rate at which these reactions happen.

The utilization of the new LIBS technology in molten metal can reveal in-situ reactions occurring during such treatments.

The figure below is an example of such analysis where the concentration of transition elements is recorded by time in the liquid state to show how they form borides. As can be seen, after addition, both the concentration of transition elements and boron start to decrease in the melt. This indicates that the boride intermetallic phases are formed and sediment to the bottom.

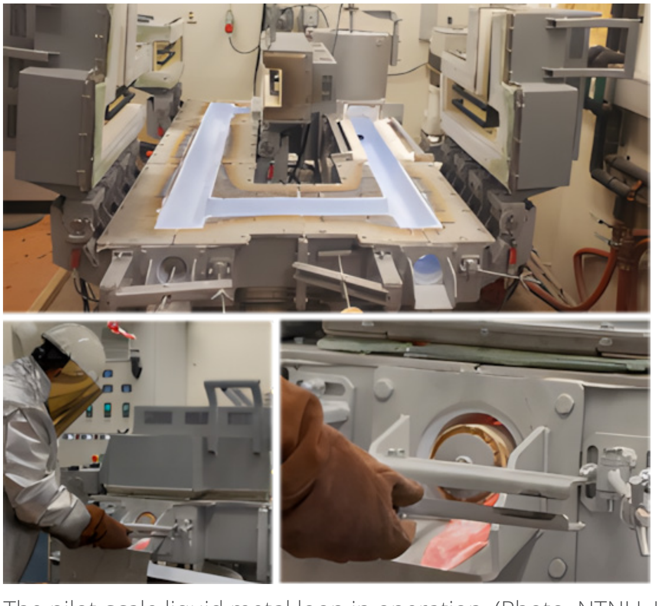


Change of concentration of transition elements (left) and boron (right) in the melt after addition of master alloy.

FILTRATION

Most activities within filtration are centred on the pilot-scale liquid metal loop located at NTNU, which is used to conduct controlled filtration experiments. The aim is to understand how different filters and process conditions influence the removal of non-metallic inclusions from recycled aluminium streams.

The activities in 2025 have focused on assembling, commissioning, and benchmarking the loop, as well as establishing robust operational procedures. Pump characteristics, temperature control, feeding routines, and sampling procedures have been defined and tested, providing a stable baseline for upcoming filtration experiments.



The pilot-scale liquid metal loop in operation. (Photo: NTNU, Institutt for material teknologi.)

SEPARATION OF HETEROGENEOUS MATERIALS

This task is scheduled to start in 2028.

UTILIZATION OF INDUSTRIAL WASTE AND BY-PRODUCTS

The work in Task 4.3 has been distributed across several activities. A characterization of the waste streams in question has been the first step. This has been done for sludge from silico-manganese production, dross, glass from recycled PV panels and skimming slag from Ineos. These investigations have given preliminary indications of the streams, but due to the heterogeneous nature more research is required.

PYRO METALLURGY

Aluminothermic reduction tests have been performed combining dross with either sludge from SiMn or recycled PV-glass. The results indicate that an alloy with desired quality may be obtained from these process routes.

HYDROMETALLURGY

Leaching experiments have been performed for SiMn sludge using various acids as leaching agents. The experiments show reduction in impurity level, but the results are still at a preliminary stage.

RESEARCH AREA 5.

Modelling and digitalisation

Research area leader: Kristan Etienne Einarsrud, SINTEF

INTRODUCTION

Research Area 5 (RA5) aims to strengthen and complement the technical research in research areas 1–4 through physics-based and data-driven modelling, sensor/measurement integration, and digital tools for process control, optimization, and training.

In 2025 we focused on establishing enabling capabilities and formalizing work on data access and management, and preparing a shared modelling toolchain, while starting targeted developments linked to pilot activities and upcoming PhD work.

The overarching ambition is to couple models and measurements so that results can be used directly in process understanding, decision-making, and education, across cases in aluminium and ferroalloy value chains.

Research area 5 is organized in four tasks: Fundamental process modelling, Measurement system integration, Artificial intelligence and control systems, and Digital tools and training. Each task comprises activities that tie into concrete industrial, lab or pilot scale cases. The core team in 2025 brought together expertise from SINTEF, NORCE, NTNU and Seoul National University, with regular interactions with industrial partners.

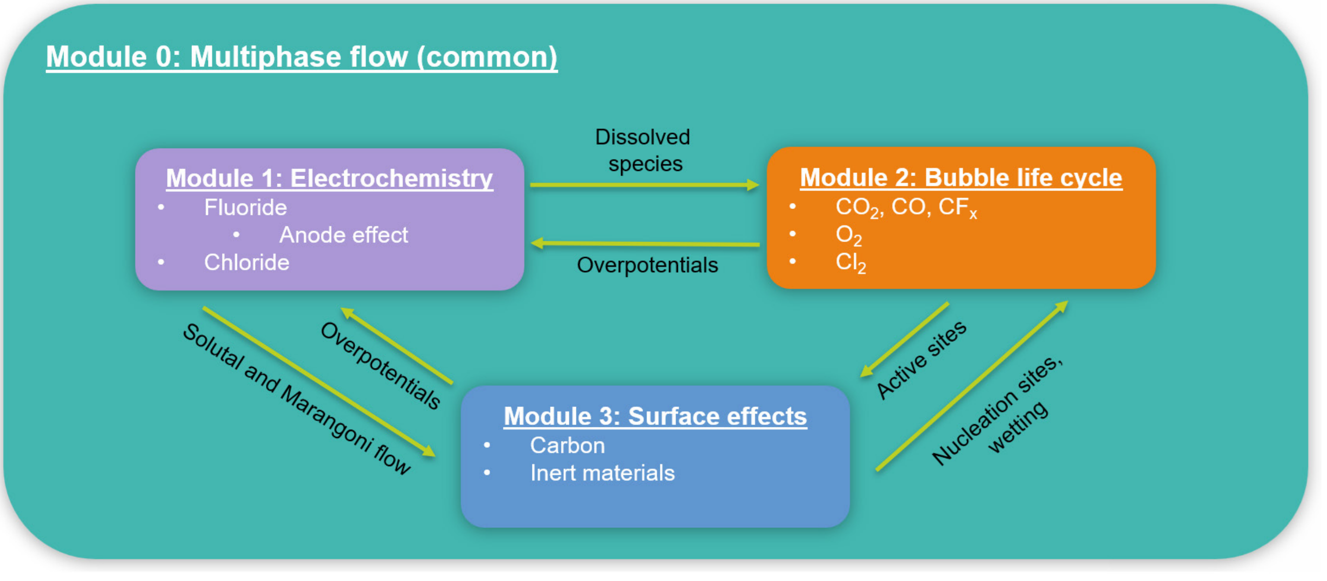
ACTIVITIES AND RESULTS IN 2025

FUNDAMENTAL PROCESS MODELLING

A modular OpenFOAM-based framework for modelling anodic gas evolution in aluminium electrolysis has been proposed by NTNU and SINTEF, as sketched, with a clear path to couple electrochemistry, two-phase hydrodynamics, bubble life-cycle physics, and surface/wetting effects. The 2025 work resulted in a primer that distils state-of-the-art multiphase and electrochemical modelling of gas evolution in the context of aluminium production, and a technical assessment of community developed OpenFOAM solvers to seed the PhD's implementation starting in 2026.

The primer maps the required physics across four modules: multiphase flow, electrochemistry (primary, secondary and tertiary distributions), bubble life cycle, and surface effects and illustrates how each affects current distribution, voltage, and cell stability. It highlights that gas bubbles reduce effective conductivity, alter the active anode area, and can contribute to energy penalties and anode-effect risks; it also documents gaps for inert anodes, chloride melts, and low-voltage local anode effects where open literature is sparse. The framing justifies a stepwise build-up: validate conventional CO_2 evolution first, then extend to tertiary coupling and technology variants.

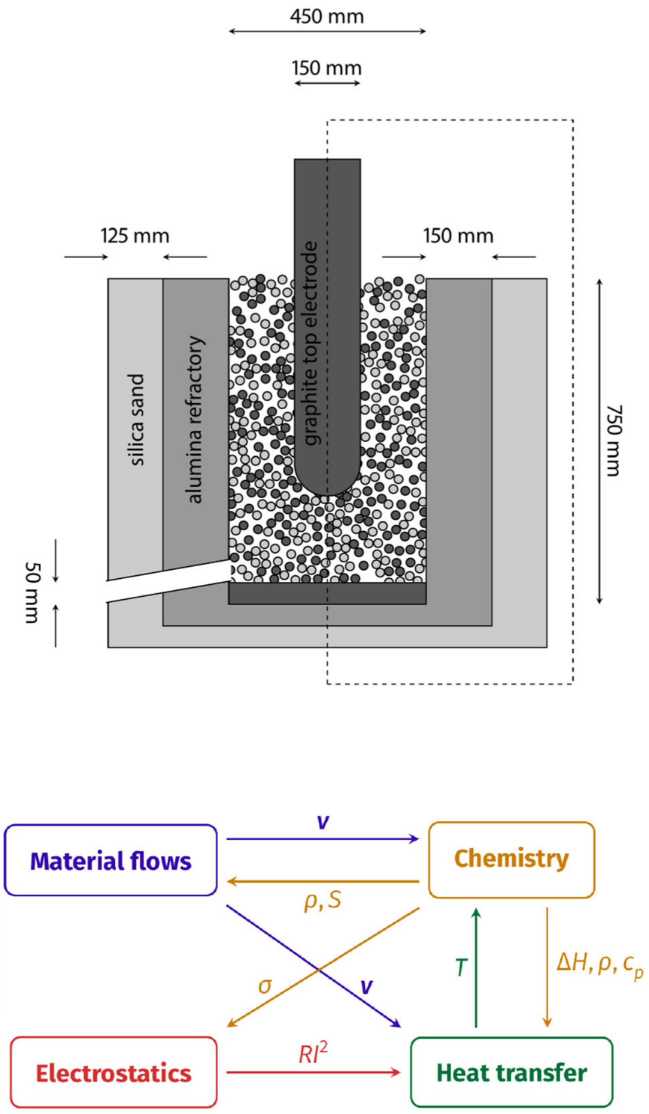
While earlier studies largely rely on primary current distributions and simplified species transport, the review shows that community-developed solvers provide a mature and



Sketch of framework for simulating electrochemicallydriven gas evolution . Photo: NTNU, Institutt for Materialteknologi well-documented foundation for secondary and tertiary current distributions, including migration, multi-reaction kinetics, and electroneutrality constraints, making them the most relevant starting point for the PhD work and the broader RA5 modelling framework. In parallel, the assessment confirmed that two-phase coupling is already feasible for secondary current distributions, by incorporating gas evolution from Faraday's law, bubble-coverage-based loss of active area, and effective conductivity reductions following Bruggeman-type relations. This represents a practical route to model conventional CO_2 evolution with realistic hydrodynamics before introducing more complex tertiary two-phase coupling required for next-generation technologies.

MEASUREMENT SYSTEM INTEGRATION

The emphasis of Task 5.2 has been on the foundation for integrating measurement data into modelling workflows for a ferroalloy case study. A knowledge-gap analysis revealed that while several models for off-gas and volatile evolution exist, they are not directly applicable to planned pilot furnace activities in FME ZeMe. The models suffer from limited kinetic data, particularly for biocarbon, higher manganese oxides, and CO/ CO_2-related reactions. The knowledge gap analysis identified a need for closer coupling between modelling and pilot campaigns, both to guide sensor placement and to ensure model validation, which has been lacking in previous initiatives.



Pilot scale furnace and schematic description of COMSOL model. Figure: NORCE

Building on these findings, an integration plan defined how an existing COMSOL-based pilot furnace model, could be upgraded to support meaningful comparison with measurements. Essential improvements include adding higher manganese oxides, explicitly modelling the Boudouard reaction, and introducing spatially resolved gas-phase transport, enabling more realistic predictions of CO/ CO_2 off-gas composition. These upgrades were motivated by workshops with the industry partners and will allow the model to incorporate data from upcoming pilot experiments, improving both heat-balance accuracy and chemical realism, serving as the computational backbone for integrating modelling with pilot measurements in 2026.

ARTIFICIAL INTELLIGENCE AND CONTROL SYSTEMS

The planned case study on artificial intelligence (AI) applications was cancelled in 2025 so that resources could extend the PhD 5A modelling groundwork. This decision aligns with the research area's priorities, i.e. to establish robust physics-based foundation first, then layer in data-driven components where they add leverage.

DIGITAL TOOLS AND TRAINING

Task 5.4 has focused on strengthening the Centre's digital practices through two closely connected strands, competence building, and practical data-management workflows that partners can apply immediately while a long-term framework is being developed.

A major highlight of the year was the workshop on digital tools and data management. The half-day event combined introductory and hands-on sessions on data documentation, plotting and statistics in Python, basic machine learning, uncertainty quantification, and the use of large language models in research. The workshop targeted FME ZeMe's PhD candidates and MSc students, but was open to all partners.

It helped establish a shared baseline for good digital practice across modelling, analysis, and reporting activities. The format and content were well received and will form the basis for the annual workshops that follow. In parallel, progress has been made on the FME ZeMe's data-management workflow, which aims to operationalise the Centre's Data Management Plan (DMP).

During 2025, research area 5 tested the capabilities of the data.sintef.no platform as the long-term solution for interoperable research data. Pilot implementations focused on understanding how metadata schemas and validator functions could support structured storage and retrieval across diverse data types. These activities provided valuable insight into how a full FAIR-compliant framework can be realised over time.

However, recognising that this long-term framework is still under development, the partners agreed to adopt a practical temporary workflow using SharePoint, referred to internally as the Data@ZeMe solution. This ensures that all data underlying FME ZeMe's deliverables are findable, accessible and reusable, while interoperability is deferred to the long-term solution under development in research area 5.

RESEARCH AREA 6.
Environment and Sustainability Framework

Research area leader: Johan Berg Pettersen, NTNU

INTRODUCTION

The main aim of research area 6 is to describe what we intend with zero emissions and hopefully guide and inspire other research areas in FME ZeMe on how to achieve it. Moreover, Research area 6 holds a synthesis task, to assess the systems sustainability performance of process developments, emissions monitoring data, and novel raw material sources and byproduct thinking.

This first annual report is FME ZeMe's initial step toward zero emissions metal production.

We want to take this chance to describe how we see the term zero emissions and how it relates to some other core sustainability concepts.

Zero emissions is a concept increasingly used across sectors to describe climate-compatible technologies, assets, and value chains. In the scientific literature, however, the term is not understood as the literal absence of emissions. Rather, it is a system-level construct rooted in climate policy. Under the Paris Agreement, the long-term objective is to achieve a balance between anthropogenic greenhouse gas (GHG) emissions and removals, implying global net-zero emissions around 2050. As a result, zero emissions means net-zero greenhouse gas emissions within a defined system boundary and time horizon. It does not describe an absolute or instantaneous state.

Science-based targets have been proposed as ways to make zero emission operable as a pathway-based concept. Science-Based Targets (SBTs) translate global temperature goals into quantitative emission reduction trajectories that apply to sectors, organizations, and value chains. Compliance with science-based targets signals that an actor's emissions decline at a rate consistent with limiting warming to 1.5–2 °C, but it does not imply that emissions are already eliminated. Similarly, the term "Paris-proof" has emerged to describe technologies or investments that are compatible with Paris-aligned transition pathways, meaning they avoid long-term lock-in of emissions and can operate within a net-zero future. Zero emission and SBT are concepts that emphasize trajectory and timing; they are not static end-states but imply a forward-looking condition embedded in a broader decarbonization pathway.

The scope of zero emissions is almost exclusively understood to mean climate change emissions and typically expressed in CO_2-equivalents. Climate change emissions are globally mixed and cumulate over time, and given climate policy goals such as the Paris Agreement, there is a finite carbon budget that we must adhere to. Other environmental pressures—such as freshwater use, land use, toxicity, or nutrient emissions—do not share these properties and therefore do not lend themselves to a universal zero or net-zero framing. As a consequence, most zero-emission or net-zero frameworks treat non-climate impacts as parallel sustainability concerns. Using terminology from systems engineering, environmental and sustainability concerns other than climate emissions are performance metrics, not functional requirements of a zero emissions system.

Planetary boundaries propose a framework of biophysical limits for key Earth system processes that describe a safe operating space for humanity. Climate change is one of several critical boundaries, alongside biosphere integrity, freshwater use, biogeochemical flows, land-system change, and others. Recent research has explored how planetary boundaries can be integrated into life cycle assessment and sustainability assessment to provide absolute environmental benchmarks, against which the impacts of products, technologies, or systems can be evaluated. This approach shifts the question from relative improvement ("lower emissions than before") to absolute compatibility ("within the safe operating space"). The planetary boundaries as a concept highlights the risk of burden shifting, where climate-optimal solutions may exacerbate pressures on other Earth system processes. From this viewpoint, climate neutrality is a necessary but not sufficient condition for sustainability. Planetary boundaries provide a framework to assess whether pathways toward net-zero emissions remain compatible with broader environmental limits, without implying that all impacts can or should be reduced to zero.

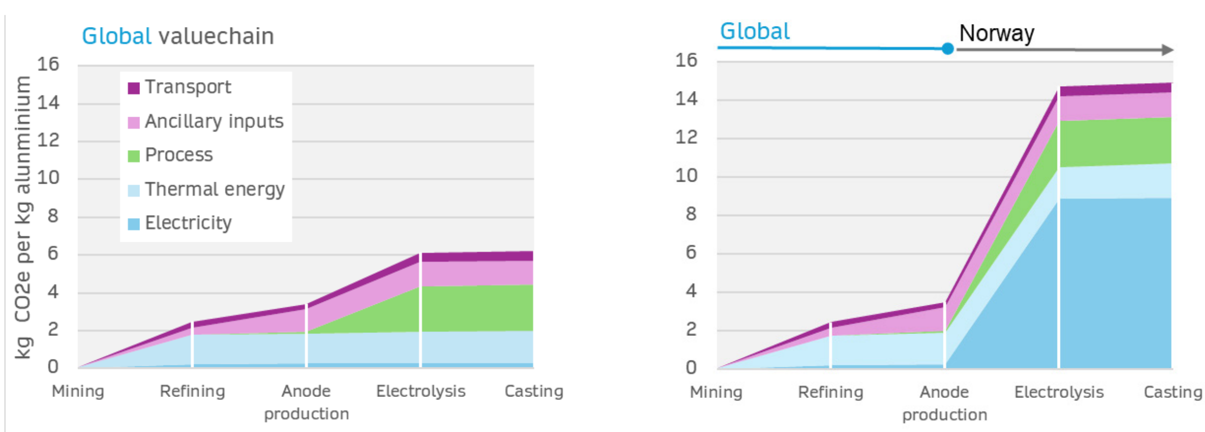
With this short introduction to main concepts, we understand that the following are crucial dimensions of the term zero emissions:

- location in i) time and ii) space, and
- scope with regards to iii) process and iv) criteria.

What we have said less about is the social dimension of the green transition and what it takes to make metals in a responsible and equitable way.

To exemplify these perspectives, let us look at a simple example of a value chain for production of aluminium. Cumulative life cycle climate change emissions measures as CO_2e is presented for two alternative value chains in Figure 1, to the left for global average production and the right is when global average alumina is shipped to Norway for electrolysis.

The simple presentation in the figure allows us to highlight several of the dimensions we discussed. Replacing global electricity with a Norwegian electricity predominantly made from hydropower greatly reduces emission caused by electrolysis, but it does not make it zero (location in space). Even if process emissions and anode production were avoided, significant emissions remain upstream in mining and refining bauxite into alumina (process scope). It is also expected that decarbonizing electrolysis and mitigation direct emissions will involve some input, implying that certain impacts still occur (criteria scope). Processes are continuously improved, within aluminium production and in society, and power systems in Norway and globally change (location in time).



Cradle-to-gate emissions from primary production of cast aluminium from LCA. Numbers are adapted from IAI Primary Aluminium Greenhouse Gas Emissions Intensity for 2023.

If we move beyond the current, literature and the political landscape indicate a development in the discourse on climate and sustainability policy. If we propose them as basic tenets for what will happen in the quite near term, say towards 2050, it would be:

1. Decarbonization shifts focus to broader environmental and social impacts.
2. Resource and energy constraints make efficiency central to technology development.
3. Circularity evolves from mass-based recycling to value- and functionality-based strategies.
4. Accounting rules such as system boundaries and allocation choices become policy relevant.
5. Planetary boundaries and temporal dynamics pose challenges to sustainability claims.

As energy becomes decarbonized, policy focus will shift toward other environmental impacts, trade-offs of the energy transition, and social issues. We already see competition for energy and resources; soon there will be much more focus on energy and resource efficiency. Energy efficiency, material efficiency, and demand-side strategies are not secondary levers for mitigation, they represent core mitigation strategies.

With more secondary materials, we will move from recycling rates to value-based recycling. For metals it means more focus on alloys and alloying elements and not only the main metal

Here are some selected sources if you want to read more about the various concepts I discuss.

[1]**UNFCCC (2015)**. The Paris Agreement. United Nations Framework Convention on Climate Change (UNFCCC). IPCC (2018). Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways… Intergovernmental Panel on Climate Change (IPCC). URL: https://www.ipcc.ch/sr15/. **Rogelj, J., Shindell, D., Jiang, K., et al. (2018)**. Mitigation pathways compatible with 1.5°C in the context of sustainable development. In: Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., et al. (eds.) Global Warming of 1.5°C. An IPCC Special Report… Intergovernmental Panel on Climate Change (IPCC), Chapter 2, pp. 93–174. **Fankhauser, S., Smith, S. M., Allen, M., et al. (2022)**. The meaning of net zero and how to get it right. Nature Climate Change, 12, 15–21. DOI: 10.1038/s41558-021-01245-w. **Rockström, J., Donges, J. F., Fetzer, I., et al. (2024)**. Planetary Boundaries guide humanity's future on Earth. Nature Reviews Earth & Environment, 5(11), 773–788. DOI: 10.1038/s43017-024-00597-z. **Bjørn, A., Chandrakumar, C., Boulay, A.-M., et al. (2020)**. Review of life-cycle based methods for absolute environmental sustainability assessment and their applications. Environmental Research Letters, 15(8), 083001. DOI: 10.1088/1748-9326/ab89d7. Bjørn, A., & Hauschild, M. Z. (2015). Introducing carrying capacity–based normalisation in LCA: Framework and development of references at midpoint level. The International Journal of Life Cycle Assessment, 20, 1005–1018. DOI: 10.1007/s11367-015-0899-2. **Bataille, C., Åhman, M., Neuhoff, K., Nilsson, L. J., Fischedick, M., Lechtenböhmer, S., Solano-Rodriquez, B., Denis-Ryan, A., Stiebert, S., Waisman, H., Sartor, O., & Rahbar, S. (2018)**. A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris Agreement. Journal of Cleaner Production, 187, 960–973. DOI: 10.1016/j.jclepro.2018.03.107. **Sovacool, B. K., Ali, S. H., Bazilian, M., Radley, B., Nemery, B., Okatz, J., & Mulvaney, D. R. (2020).** Sustainable minerals and metals for a low-carbon future. Science, 367(6473), 30–33. DOI: 10.1126/science.aaz6003

carrier. The body of rules and guidelines for product declarations, product passports and communication is continuously becoming more complex. This leaves room for ambiguity in how environmental performance is measured and communicated. This occurs while environmental issues may start to control market access and influence our capacity for change.

ACTIVITIES AND RESULTS IN 2025

DEVELOP AND TEST ANALYTICAL FRAMEWORK

The work with the framework as a deliverable is postponed. The resource group meeting in November recommended that we gather concrete examples from industry to use as basis in framework development and this work will commence starting Q2 2026.

ENERGY SYSTEM ANALYSIS

The task of energy system analysis has started with three main initiatives in 2025:

Aakriti Deuja started her PhD in august 2025, with focus on life cycle modelling of energy value chains for metallurgy. Her PhD degree is hosted at the Industrial Ecology Programme, Dept. of energy and process engineering under the supervision of Johan Berg Pettersen. Magnus Korpås at Department of electric energy is co-supervisor. Aakriti originates from Nepal. She holds a master's degree in environment and water resources engineering from Mahidol University in Thailand, where she also has worked as researcher publishing work on use and development of LCA.

In the fall of 2025, Lea Lauvland Longva started her final year in MSc Energy and environmental engineering. She completed her project entitled "Life cycle assessment of zero emission aluminium" in December assessing inert anodes using literature data. She will continue her master thesis research in the spring of 2026.

During September and October, Felipe Alejandro Garcia Paz stayed with NTNU as a guest researcher from TU Bergakademie Freiberg where he is a PhD student. Felipe studies production of low-consumption anodes and he came to NTNU Industrial Ecology Programme to develop his LCA model of anode production and use. The work has been submitted to review.

MATERIAL FLOW ANALYSIS

Is not started yet.

CLIMATE POLICY ANALYSIS

Is not started yet.

Photo: Casper van der Eijk, SINTEF

RESEARCH AREA 7.

Analysis Techniques, Emission Monitoring and Control

Research area leader: Gabriella Tranell, NTNU

INTRODUCTION

Implementation of new technologies and reductants in metal production will have significant effects on process emissions, both in terms of gaseous and particulate emissions. The use of, in particular new bio-based reductants and binders might result in more dusting and other emissions. Recirculation of off-gases or restricted air-intake in order to facilitate CCS/CCU may also change the emission profiles from different production processes.

Similarly, more mixed feeds to recycling processes of the future will see a need for in-line characterization of both raw material and its effects on emissions. These developments will require new combinatory approaches to characterize complex offgases and raw materials. With the rapid development of artificial intelligence (AI) and advanced digital tools, new opportunities for process control and prediction of associated off-gases and their fenceline dispersion arise. New processes, reductants and digital solutions will bring forward new definitions ofBest Available Technology (BAT) in the international and EU communities.

FME ZeMe will seek to be a connector between the Norwegian platform and the international communities in this respect.

ACTIVITIES AND RESULTS IN 2025

CHARACTERISING VOLATILE EMISSIONS FROM DIFFERENT BIO-CARBON MATERIALS USED IN MANGANESE ALLOY PRODUCTION

In the current manganese alloy production process, fossil carbon is used as a reductant for manganese ore. Pursuing low-CO_2 footprint production, Eramet is working on several solutions to mitigate greenhouse gas emissions. One approach is the use of bio-carbon sources in the production. However, little is known of how the properties of these reductants affect the total emission profile and dynamics of volatile emissions (CO, H2, H2O, CHx, SOx, Px, PAH, etc) as well as the associated dust generation.

As part of the work in RA7, dynamic measurement/characterisation techniques (combinations of Gas Chromatography, FTIR and filter/solvent capture/analysis) for off-gases during production are being developed by SINTEF and NTNU along with dust analysis using SEM, EPMA, XRD, ICP-MS etc.

In addition to existing equipment, a combination of thermogravimetric analysis during a reductant heating cycle has been built for testing of industrial bio-carbon materials. Initial trials have revealed significant differences between bio-reductants in the amount and composition of volatiles released during heating, affecting both the energy in the off-gas, potential for reduction of iron oxides in the ore, as well as the Boudouard reaction in the furnace.

COUPLING FUGITIVE EMISSION MEASUREMENTS TO RAW MATERIAL COMPOSITION AND PROCESS DATA

One of the objectives in RA7 is to develop tools and methods for accounting and measuring emissions on/in-line and coupling such measurements to raw material composition and process data.

In dust measurement campaigns, finding and documenting the connection between the various sources in the process and air quality impacts has proven to be very difficult due to uncertainty, noise and resolution in the data affecting current statistical analysis. As such, NORCE has set out to demonstrate generative AI capabilities and potential in emissions accounting based on existing measurement campaign data sets.

An industry-academia workshop was held to discuss possibilities and available data-sets. As a result, Hege Indresand, senior scientist with NORCE, is in charge of an industry- NORCE working group pursuing a test data set from Eramet Sauda, a site with data availability from several different fence line campaigns.

Data sets were fed and analyzed with the ChatGPD 5.2 model. One of the analyses in focus was the US EPA's PMF methodology that examines the co-variation of data to find source contributors. The AI model was able to find known and new correlations and source attributions, suggest other relevant add-on analysis and generate graphs.

The advantage of generative AI is the speed at which a quick overview of the statistical relationships in these large data sets can be generated, making it a great aid in choosing a statistical methodology to prove correlation hypotheses, interpret results and relate those to other process knowledge. Ongoing work is related to reproducing and validating statistical conclusions to demonstrate the AI capability.

NORCE leads the satellite project initiative "LESS DIFFUSE" together with some of the ZEME partners that will expand on this activity in 2026.

Ole Kjos (SINTEF), affiliated with RA7.
Photo: Morten Onsøien, SINTEF

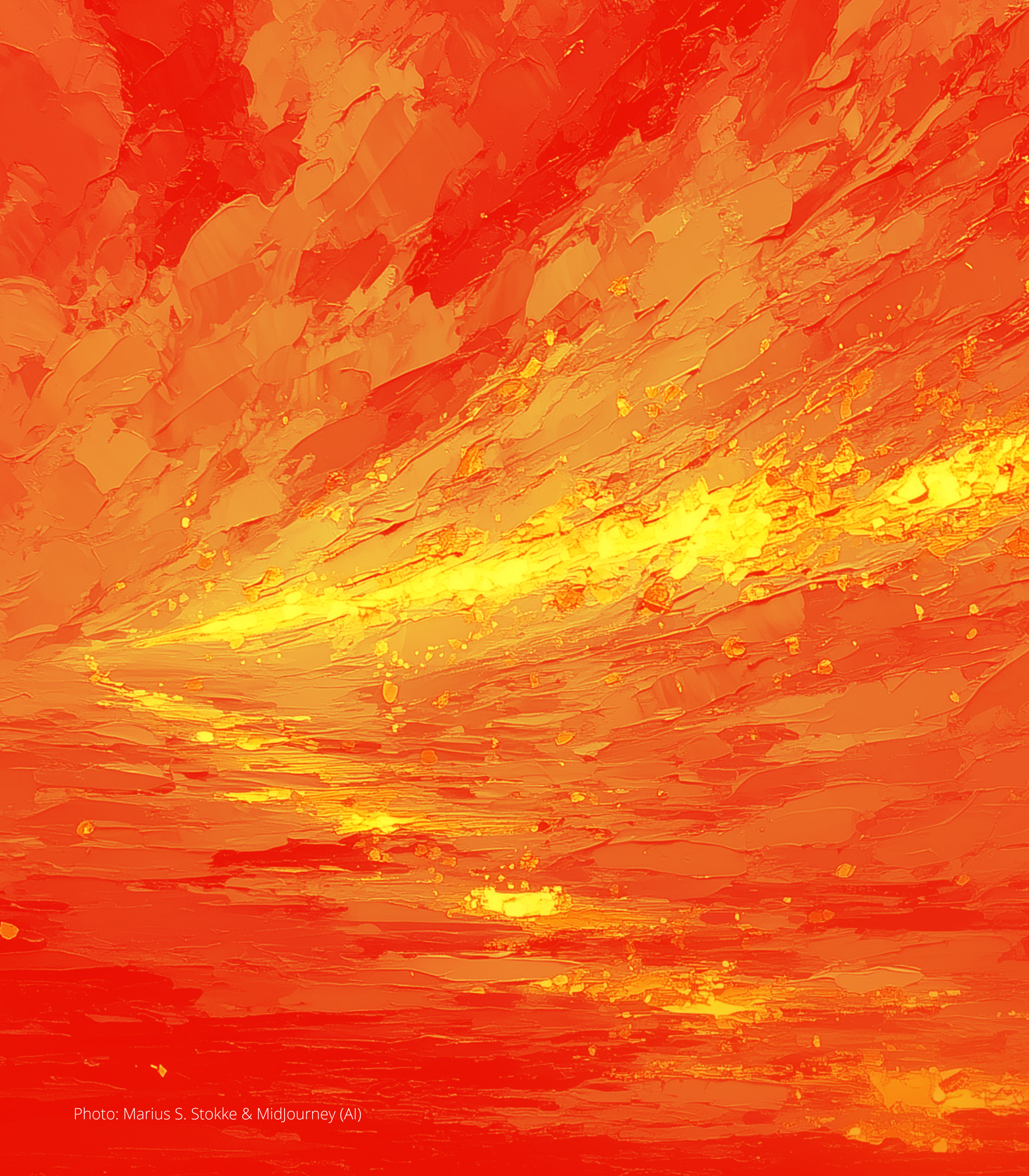


Photo: Marius S. Stokke & MidJourney (AI)

INNOVATION AND EXPLORATION COMMITTEE (IEC)

MANDATE

The objectives of the Innovation and Exploitation Committee (IEC) are defined in the FME ZeMe consortium agreement. The IEC will:

1. Evaluate the innovation potential of evolving results and technology

2. Identify exploitation opportunities, including spin-off innovation projects

3. Give advice to the Board and General Assembly.

The IEC plays a key role in bringing the research results and technologies generated in the centre further into industrial practice.

The mandate has been converted into specific activities:

- Identification of potential exploitable results and exploitation pathways
- Update the innovation database
- Initiate exploitation activities, including spin-off projects
- Monitor possibilities / opportunities for external funding (national and EU).
- IP protection as part of exploitation pathways
- Identify and follow-up FME ZeMe associated projects
- Identify and follow-up international cooperation
- Establish procedures to support the above activities.

As part of the exploitation pathways, the identification of new industry partners is part of the activities.

MEMBERSHIP

The IEC is chaired by FME ZeMe's Innovation Manager. Each partner has one representative on the committee. In addition, the Centre Director and Scientific Director are ex officio members of the committee. To avoid any conflict of interest between the centre and the partners, SINTEF and NTNU have representatives that are independent of the centre leadership.

Industry	
Alcoa Norway AS	Ellen Bromstad Myrvold
Boliden Odda AS	Torgeir Matre Sandvik
Elkem ASA	Marit Dolmen
Eramet Norway AS	Benjamin Ravary
Finnfjord	Erlend Hauge
Glencore Nikkelverk	Oluf Bøckman
Hydro Aluminium AS	Trond Eirik Jentoftsen
INEOS Tyssedal	Stephen Lobo
Kymera	Trygve Eidet
REEL	Anders Sørhuus
Wacker	Birger Andresen

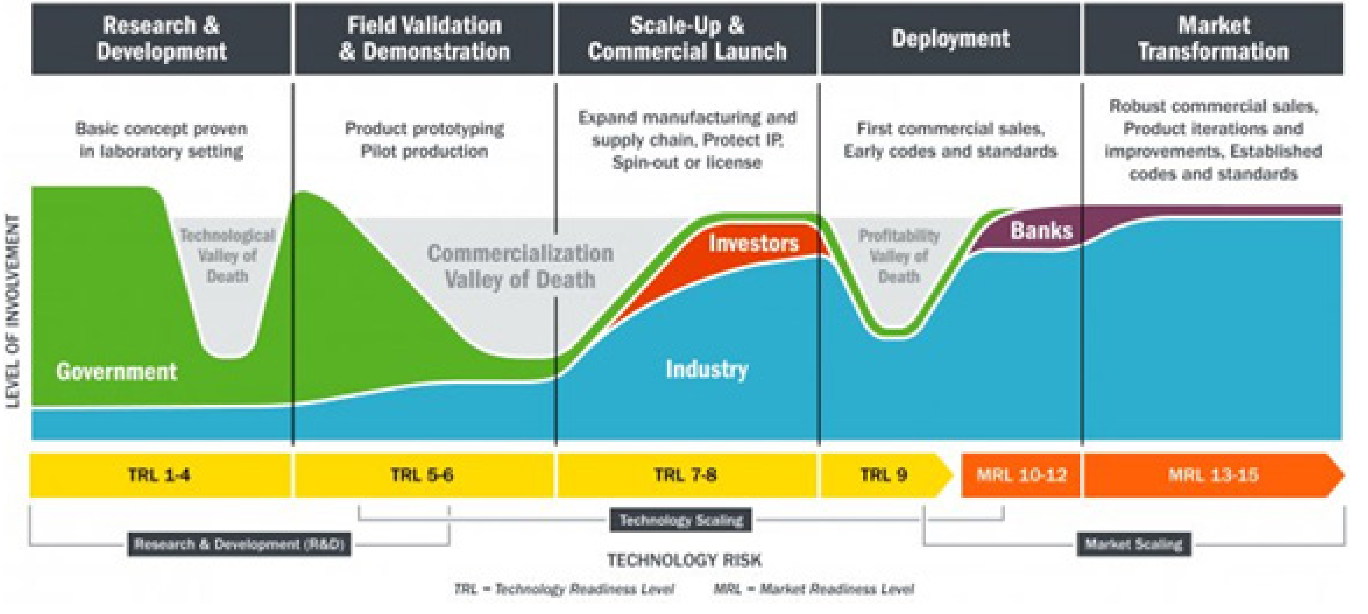
University and RTO	
NORCE	Ellen Nordgård-Hansen
NTNU	Frode Seland
SINTEF	Rannveig Kvande

FME ZeMe	
Innovation Manager, IEC chair	Christina Meskers
Centre Director	Casper van der Eijk
Scientific Director	Gabriella Tranell

ACTIVITIES 2025

The activities of the IEC started with an introduction presentation on what innovation is at the FME ZeMe kick-off meeting (15 January, 2025). The different stages in innovation pathways, types of innovation and the interaction with communication and dissemination were briefly introduced.

The IEC was formally established in the steering committee meeting in June 2025, its mandate and specific activities confirmed by the steering committee in August. Partners designated their representatives in Q3, 2025 and the first meeting of the IEC was held on 4 December. In the first IEC meeting the activity plan for 2026 was decided on. The IEC decided to learn from other FMEs and build on their best practices in innovation and exploitation in its way of working.



Innovation is an activity consisting of different stages. In each stage the role of the actors changes, and the main focus moves from technology development to market development.

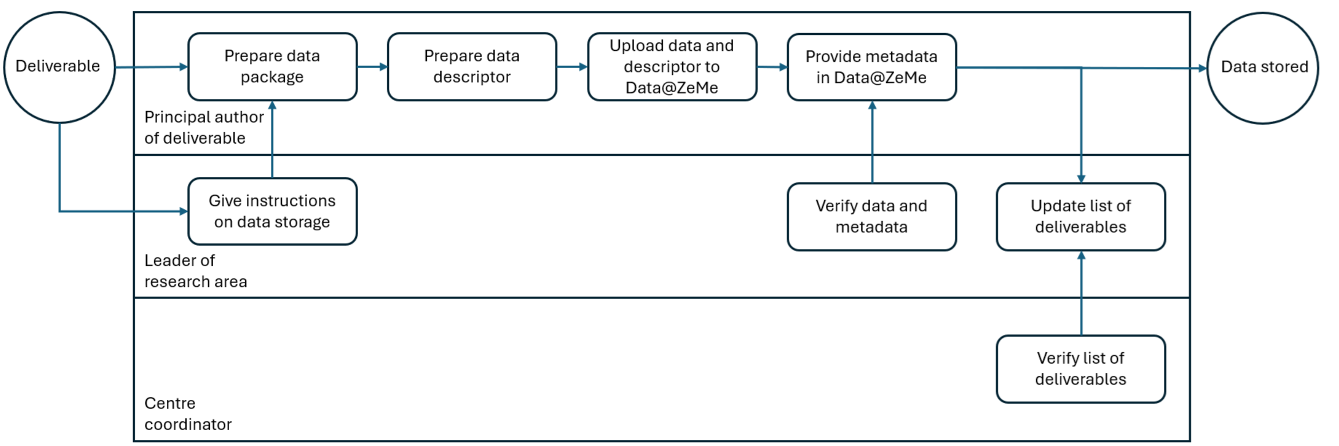
DATA MANAGEMENT

Effective data management is essential for ensuring long-term value, transparency, and reusability of the research conducted in FME ZeMe. To support this, ZeMe has established a centre-wide Data Management Plan (DMP) that outlines principles for handling research data throughout the project lifecycle. During the past year, good progress has been made in operationalizing the DMP and implementing a consistent, practical workflow for all partners.

A key development has been the establishment of Data@ZeMe, a dedicated SharePoint-based solution that serves as ZeMe's central repository for research data. In accordance with the DMP, only data connected to approved deliverables are stored centrally. This provides a clear scope and ensures that datasets are contextualized and meaningful. Deliverables already undergo structured quality control, and integrating data handling into this existing workflow has enabled a manageable and predictable process for all contributors.

For each deliverable, the responsible author prepares a data package that includes all underlying data used to produce the results—such as raw and processed datasets, log files, scripts, experimental descriptions, or simulation outputs. The data package is accompanied by a structured data descriptor, a short, standardized text file describing the deliverable, contributors, research methods, and the contents of the package. Together, these files ensure that data remain understandable and reusable even years after production.

Upon upload to Data@ZeMe, users provide a small set of metadata, including data owner, classification level, research area, deliverable



Overall workflow for data storage in FME ZeMe. Figure: SINTEF

ID, link to the published deliverable, and document status (draft or verified). Research Area leaders verify that deliverables and associated data packages are correctly uploaded, ensuring consistent quality and traceability across the centre. This system already meets the "FAR" requirements of FAIR data principles - Findable, Accessible, and Reusable -by centralizing storage, providing structured documentation, and enabling users to search and retrieve files reliably.

While interoperability ("I" in FAIR) requires a more sophisticated technical architecture, work is ongoing in Research Area 5 to develop a long-term solution using the data.sintef.no platform. This future system will support richer metadata, standardized data models, and cross-dataset integration, enabling more advanced data exploration and reuse within and beyond the consortium.

Overall, 2025 has shown good progress in translating the DMP from an abstract plan into a functioning, centre-wide practice. The combination of a clear scope (data linked to deliverables), a simple workflow, and a user-friendly platform ensures that research data in ZeMe is preserved, understandable, and ready for future exploitation, as required for a long-term, high-impact research centre.

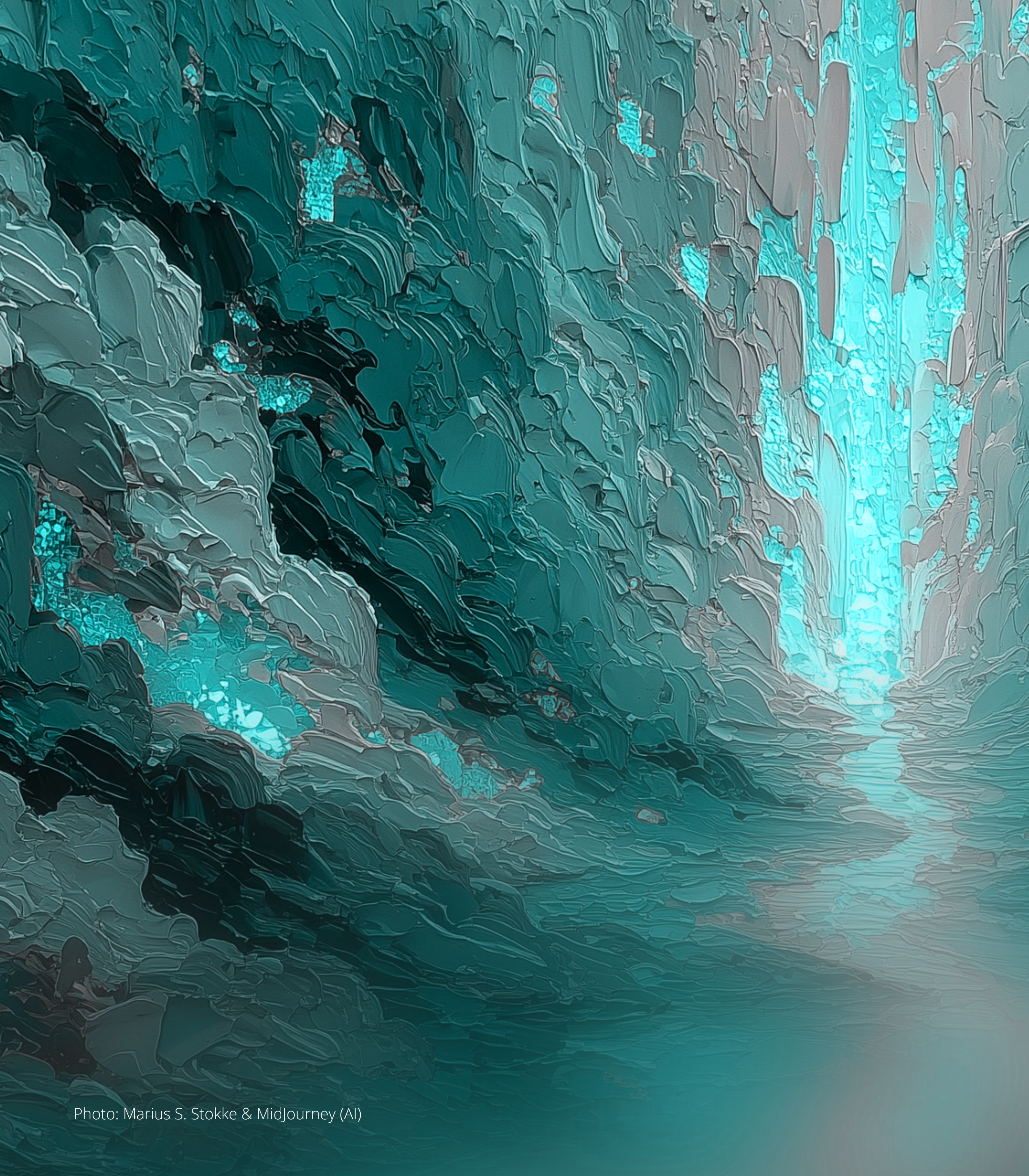


Photo: Marius S. Stokke & MidJourney (AI)

OUR PHD CANDIDATES

Our PhD candidates

During the eight years Centre period we will recruit and educate numerous PhD candidates, Postdoctors and master students. We are looking for competent and motivated candidates in all of the Centre's research areas.

Seven highly qualified PhD candidates have been recruited to FME ZeMe, of whom three are women. We look forward to following their scientific development in the years ahead. Below is a brief introduction to our PhD candidates.

Photos: Casper van der Eijk, SINTEF

NEW PHD CANDIDATES IN 2024/2025
Linus Meistad (2024-2027)

Topic: *Valorization of Manganese Sludge*

Supervisor: Gabriella Tranell

Linus Meistad is a PhD candidate working on valorization of manganese sludge. His research explores turning sludge from a liability to a resource through three main approaches:

Aluminothermic reduction using Al-dross to produce high purity Mn alloys, hydrometallurgical leaching to either extract high purity Mn, or remove impurities such as Zn or Pb from the sludge, and the recycling of sludge, together with FeMn slag, into the existing SiMn process. His work aims to increase the resource efficiency of Mn production and reduce environmental impact from the disposal of the sludge.

Thea Stabbforsmo (2025-2028)

Topic: *Hot strength of SiC from biocarbon*

Supervisor: Merete Tangstad

Thea Stabbforsmo is a PhD candidate investigating the influence of biocarbon materials on the high-temperature strength of silicon carbide (SiC) as an intermediate in the production of Si metal. Her research focuses on replacing fossil carbon with renewable biocarbon in silicon metal production to reduce the CO_2 footprint.

She studies the mechanical properties of SiC formed during production, using various testing methods including Spark Plasma Sintering for hot strength testing and thermal abrasion strength tests, to understand how biocarbon affects furnace operation. As the properties of the SiC intermediate are highly dependent on the carbon precursor, the mechanical properties of coal and charcoal have also been investigated.

Zoran Povijac (2025-2028)

Topic: *Energy efficient anode materials for sustainable electrowinning*

Supervisor: Svein Sunde

Zoran Povijac is researching energy-efficient anode materials for sustainable electrowinning. His work addresses the scarcity, cost, and toxicity of current electrocatalysts like iridium oxide and lead anodes.

He employs literature review, wet synthesis methods, electrochemical and structural characterization to develop stable, low-overpotential materials with reduced noble metal content. Promising candidates will be tested in industrial oxygen evolution conditions. His goal is to lower the cost and environmental impact of critical metal production.

Olaug Marie Aalen (2025-2029)

Topic: *Alumina Concentration and PFC Formation Mechanisms in Primary Aluminium Production*

Supervisor: Espen Sandnes

Olaug Marie Aalen is conducting research on monitoring alumina concentration and PFC emissions in primary aluminium production. Her project aims to improve understanding of PFC formation mechanisms, especially during early-stage anode effects, to reduce greenhouse gas emissions.

She combines lab-scale electrolysis experiments with industrial measurement campaigns, using both online and offline monitoring of alumina concentration and gas emissions, together with studies of carbon anode surface characteristics, to understand the dynamics of PFC generation under normal operation and during anode effects.

Bo Raadam (2025-2028)

Topic: *Aluminium Melt Filtration and Impurity Removal - Improving Secondary Melt Quality through Pilot-Scale Testing*

Supervisor: Ragnhild Elizabeth Aune

Bo Raadam is working on improving aluminum melt quality through filtration and scrap pre-treatment. His project will begin with commissioning NTNU's semi-industrial liquid metal loop before using it to study how filter design and operating conditions affect impurity removal.

A literature review and industry feedback will help focus the work of improving pilot-scale filter performance. Bo will also evaluate how scrap pre-treatment methods, such as coating removal and pre-melting, can enhance melt cleanliness and filtration efficiency, aiming to increase recyclability and reduce the environmental impact of aluminum production.

Photos: Casper van der Eijk, SINTEF

Aakriti Deuja (2025-2028)

Topic: *Environmental energy system analysis for zero emission metal production*

Supervisor: Johan Berg Pettersen

Aakriti Deuja is a PhD candidate analyzing environmental energy systems for zero-emission metal production. Her research integrates prospective life cycle assessment (LCA) with energy system analysis to examine decarbonization pathways for aluminum and ferroalloy value chains under future energy scenarios.

She develops parameterized models to evaluate mitigation strategies, resource constraints, and technology mixes, contributing to sustainable transitions in the metallurgical sector.

Magnus K. Windfeldt (2025-2028)

Topic: *Facilitating Carbon Capture in the Si industry*

Supervisor: Gabriella Tranell

Magnus K. Windfeldt is researching how to enable carbon capture from flue gas in silicon production. His project investigates how reduced air intake and increased biocarbon use influence flue gas conditions and furnace operation.

Using process modelling and data analysis, he studies how these operating changes affect concentrations and temperatures in the flue gas, and what this implies for dust handling, energy recovery, and gas cleaning systems under the resulting conditions.

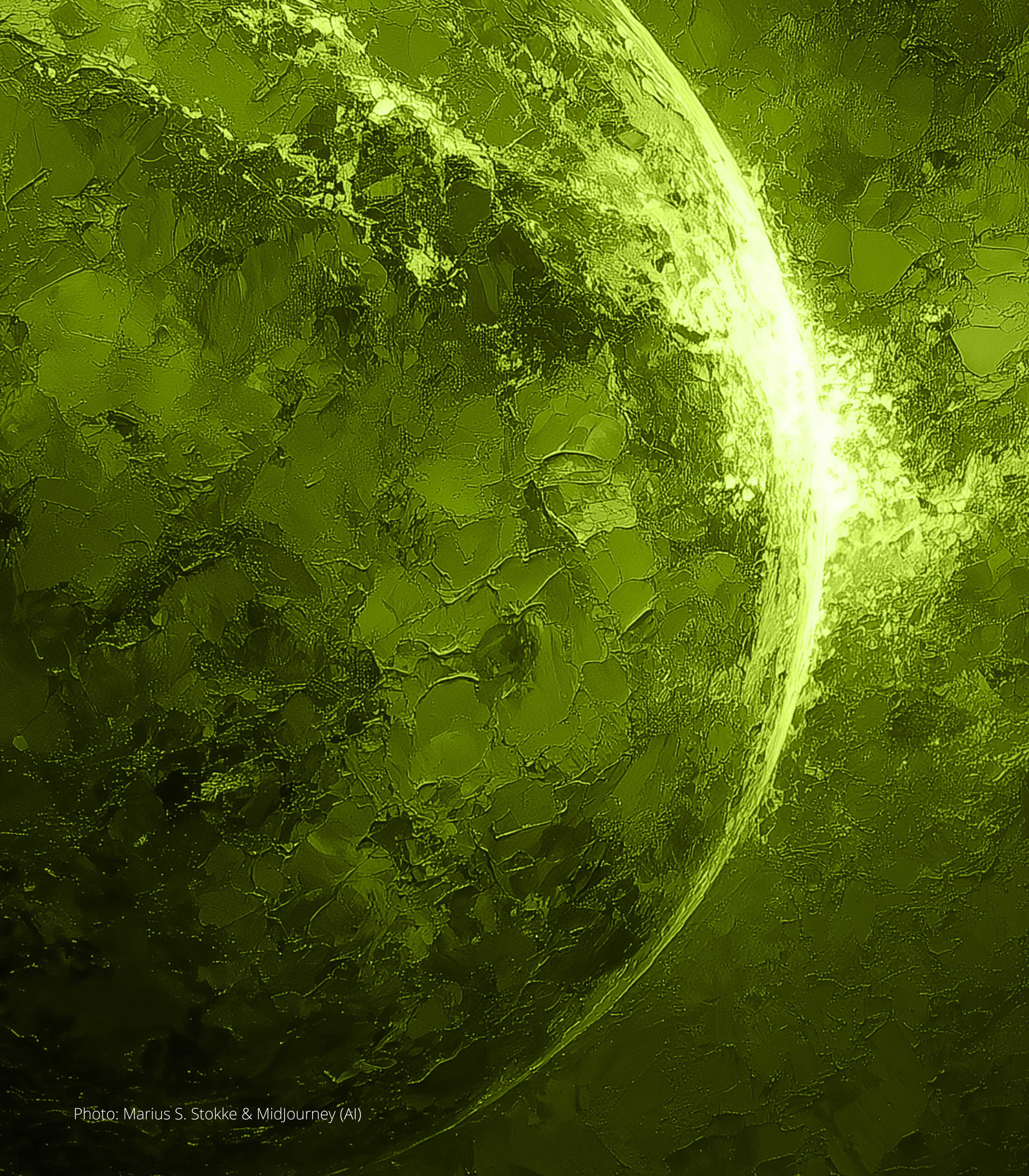


Photo: Marius S. Stokke & MidJourney (AI)

INTERNATIONAL COOPERATION

Joint Ph.D. collaboration
Good collaboration has been established with the University of Seoul in South Korea and Université Laval in Canada where the planned Ph.D.'s will start in RA5 respectively RA2.

Nordic collaboration:
All master students in FME ZeMe presented their projects during the international seminar on November 20th-21st , 2025. This is based on a long-term collaboration between NTNU, KTH, and University of Oulu in which yearly international seminars are organised.

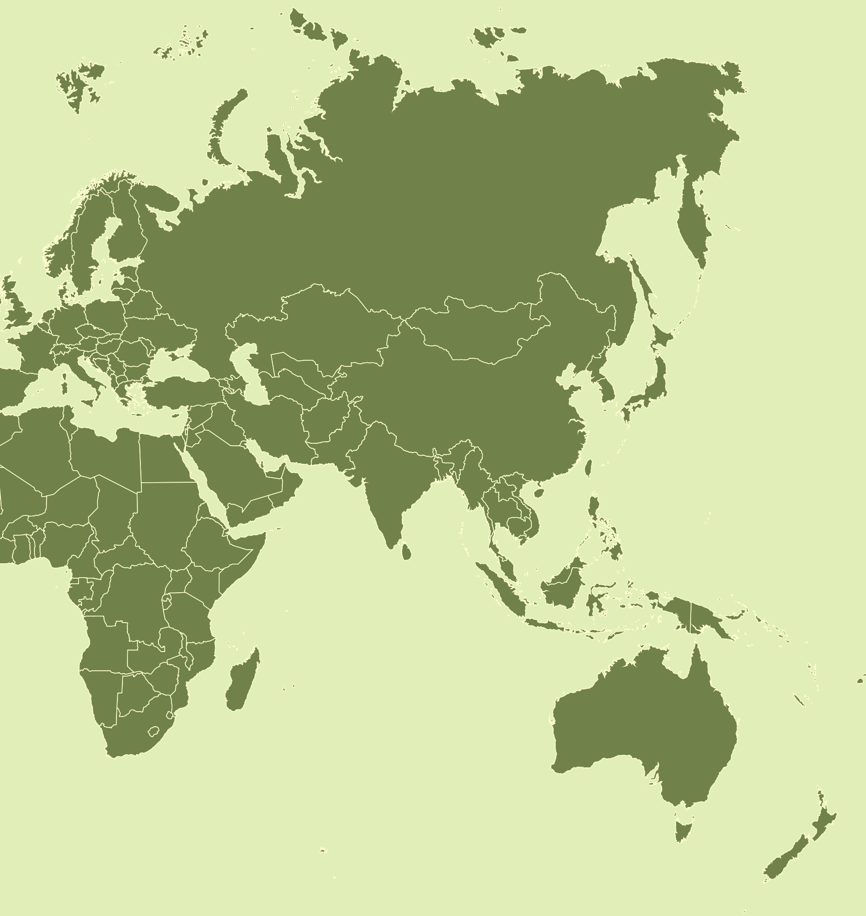
HILT CRC, Australia
Contacts were made with the Heavy Industry Low-carbon Transition Cooperative Research Centre (HILT CRC) supports in Australia. HILT CRC supports collaborative research effort between heavy industry, researchers and governments to assist the decarbonisation of the Australian iron/steel, alumina/aluminium and cement & lime producers. It is focused around regional hubs of coincident minerals and renewable energy sources, cross-cutting technologies and processes and on Australian heavy industry and jobs. It's vision and scope are well aligned with FME ZeMe.

South Africa

MINTEK has been a key player in metallurgical and mineral research for a long time. Collaboration between MINTEK, NTNU and SINTEF has mainly been established through several European projects over the years which has also strengthen the collaboration with other organisations in mainly South Africa. Quinn Reynolds from MINTEK is member of the Scientific Advisory Committee. Through his broad experience in modelling of metallurgical processes Quinn's competence aligns well with the challenges that FME ZeMe addresses.

European collaboration:

NTUA among other European organisations are important collaborators for FME ZeMe both from a knowledge perspective but also as partners in ongoing EU projects and EU initiatives. Prof. Efthymios Balomenos from NTUA is a member of the Scientific Advisory Committee and especially his strong connection and knowledge about the aluminium industries and its value chain is valuable expertise for FME ZeMe. In addition, FME ZeMe attracted many new industrial contacts in the biocarbon metallurgical area through the organisation of "Biocarbon in Metallurgy 2025".



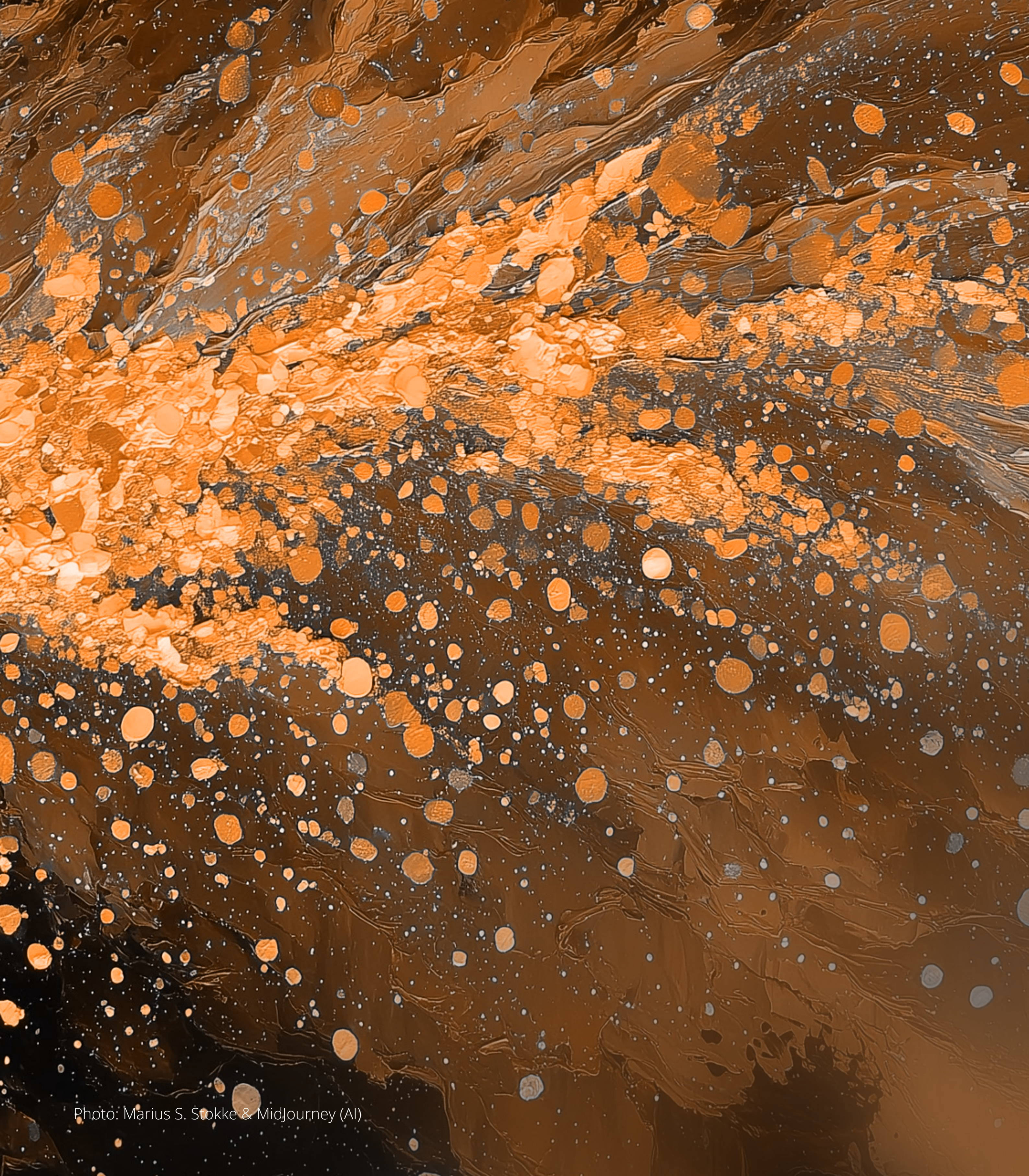


Photo: Marius S. Stokke & MidJourney (AI)

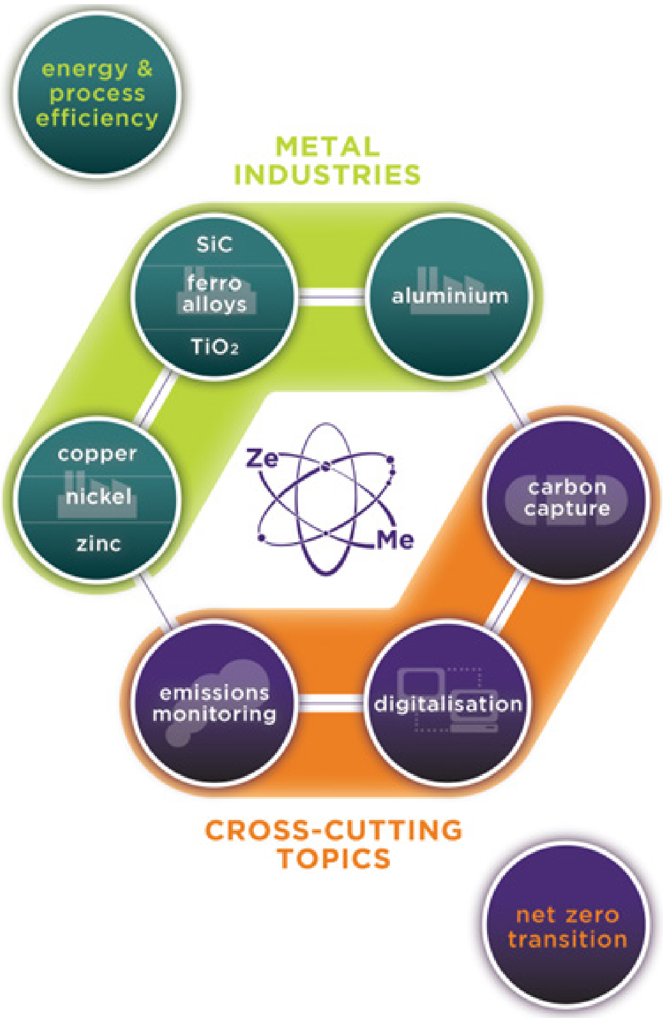
COMMUNICATION AND DISSEMINATION ACTIVITIES

In the first year of FME ZeMe the communication activities were divided into external and internal communication. The external communication focussed on introducing FME ZeMe, its partners and activities, combined with dissemination of the first results of the centre at conferences and in publications. The internal communication focussed on creating community-feeling around the centre's mission, activities and results. We aimed to highlight topics of common interest between the aluminium, non-ferrous and ferro-alloy industries. This is complemented by activities focussing on the industry-specific challenges. Furthermore, we highlight the zero-emission and energy efficiency dimensions of FME ZeMe, and place the metallurgical research activities in this broader context.

The developed visual identity of the centre reflects in its colors the zero-emission dimension (green) and metal production (orange), pyrometallurgy (orange) and hydrometallurgy (blue) process metallurgy and chemistry through the reference to the atomic structure, their interconnectedness through the color changes and the progress from research to industrial application, and the development of PhD researchers, in the changing size of the dots. Purple has been chosen as the support color.

FME ZeMe logo. Photo credit: FME ZeMe.

The objectives, research areas and industry sectors and the connection between them are highlighted in the centre's concept figure.



Caption: FME ZeMe concept figure. Photo credit: FME ZeMe.

FME ZeMe established online presence, and is using LinkedIn as its main communication channel:

Website: www.ntnu.edu/fmezeme

LinkedIn: www.linkedin.com/company/fme-zeme/

As of today FME ZeMe's LinkedIn page has over 650 followers. We post and repost content both in Norwegian and English to address national and international audiences, reaching 300-1500 impressions per post.

Webinars

Since January 2025, we have regularly invited all partners to attend webinars featuring scientific presentations on topics relevant to FME ZeMe members. The presentations have been well received. In 2025, we organized 20 webinars with an average of 26 participants.

Kickoff

The kickoff was held on January 14 at Scandic Nidelven in Trondheim. The NTNU Rector, Tor Grande, opened the event, followed by presentations from the other research partners. Representatives from Hydro, Eramet and Boliden also gave presentations on behalf of the industry partners. Each Research Area was also given the opportunity to present itself.

The day was a success, with a good balance of formal sessions and scientific content.

The following day, two workshops were held: one focusing on biocarbon and one on aluminium.

Consortium meetings

Consortium meetings are held twice a year. The autumn meeting took place over two days in Trondheim in November. Quinn Reynolds (Mintek) and Timo Fabritius (University of Oulu), members of the Scientific Advisory Committee, opened the meeting with their respective presentations. A pitch session featuring our PhD and Master's students was also organized. The main part of the day was dedicated to presentations of the FME ZeMe Work Packages.

On the second day, workshops were held under the themes Aluminium Industry and Pilot and Industrial. A General Assembly was also conducted during the two-day event.

Norwegian events

Arendalsuka, Norway's largest democracy festival, is a place where experts meet politicians. Researchers and policymakers sat shoulder to shoulder to discuss decarbonizing the Norwegian metallurgical industry. Centre director, Casper van der Eijk, presented FME ZeMe which is on a mission: help Norway's metallurgical industry go climate-neutral by 2050.

FME Konferanse

The FME konferanse (3 April, Trondheim) was jointly organized by all FMEs. It brought together researchers, industry partners, and decision makers to discuss how the FME centres can contribute to smart energy value chains and increased competitiveness. FME ZeMe coorganised parallel sessions and our Scientific director Gabriella Tranell participated in the panel on how to enhance innovation.

Photo: Casper van der Eijk, SINTEF

International events

Biocarbon in Metallurgy 2025

The 3rd edition of the conference took place April 8-9, in Wisla, Poland. The event connects researchers, policymakers, and industry stakeholders involved in biomass production (including biochar, biocarbon, and charcoal), metal processing and conventional carbon reductants to explore the current state and recent advancements in technology, science, markets, and policy.

Keynote speakers included Biochar Europe, NIBIO, Carbonfuture, OFZ, Outokumpu EvoCarbon, Envigas, among others, as well as FME ZeMe partners Elkem, Eramet, NTNU, and SINTEF. With over 100 participants from across Europe and beyond, the event was a great success. The 2026 edition is already planned.

Organised by FME ZeMe, NTNU, SINTEF, ITPE – Institute of Energy and Fuel Processing Technology – Poland, and the projects QUEEN and BioMet.

Sponsored by: Händle, OZEN, ProCarbon and Verdés.

Website: 8th-9th April 2025 in Poland - New event: Biocarbon in Metallurgy 2025 - NTNU

Photos: Casper van der Eijk, SINTEF

CRU Silicon Market Forum 2025

The global silicon industry met 23-25 September in Lyon, France to connect, exchange ideas, and do business. Producers, consumers, suppliers, and traders of silicon metal, polysilicon and silicones discussed the latest market, technology and production trends. FME ZeMe was well-represented with Centre Director Casper Van der Eijk providing an overview of FME ZeMe, Merete Tangstad (NTNU), and Gabriella Tranelll (NTNU) discussed emissions from silicon production. ZeMe partner Elkem (Anne Gry Messelien) presented the Elkem Sicalo® process concept in which silicon production is combined with carbon looping. Harry Rong (Elkem) addressed the challenges in the recycling of silicon cuttings (kerf) into high-purity silicon.

Centre director Casper Van der Eijk at CRU Silicon Market Forum 2025. Photo credit: CRU Communities

Anne Gry Messelien, Elkem presenting at CRU Silicon Market Forum 2025. Photo credit: Casper Van der Eijk / SINTEF

HILT conference 2025

FME ZeMe presented its activities at the annual conference of the Australian research centre for the Heavy Industry Low-carbon Transition (HILT), held 14-16 October in Perth. Over 250 delegates from 85 organisations, including the 60+ HILT centre partners, attended. They discussed how to de-risk the de-carbonisation of the heavy industry. The speakers from industry, research and policy highlighted the global opportunities and challenges in developing green metals and low-carbon products.

Centre Director Casper Van der Eijk presents at the 2025 HILT CRC annual conference. Photo credit: HILT CRC.

Industrial decarbonisation conference

LinkedIn activities

Highlight: Meet the partners video series

The first part of the "Partner Prat" video series was published on LinkedIn in May and June. The partners highlight (in Norwegian) why FME ZeMe is important to their business, and their expectations from FME ZeMe. We interviewed Alcoa, Elkem, Eramet, Hydro, Norce, NTNU, SINTEF. Also, two stakeholder interviews were published, with the Research Council of Norway and Prosess21. The Research Council interview focussed on the goals of the FME program, and Process21 focussed on the broader metal processing industry. The videos have been well received with 300-800 views each.

Publications

Opinion article in Teknisk Ukeblad

FME ZeMe published its first opinion article (debattinnlegg) in Teknisk Ukeblad on 24 March 2025. Camilla Somerseth and Casper Van der Eijk (SINTEF), with Johan Berg Pettersen (NTNU) argue that without clever people it will be difficult to produce metal. The article highlights the importance of investment in education for maintaining and enhancing competitiveness and innovation capability in the metal processing industry.

TU

Logg inn Abonner

Debatt

Uten kloke hoder blir det vanskelig å produsere metall

Tollmurer og høye energipriser er mørke skyer i horisonten for norsk metallindustri. Men mest truende er faren for at vi skal gå tom for dyktige medarbeidere i denne næringen.

Website: https://www.tu.no/artikler/uten-kloke-hoder-blir-det-vanskelig-a-produsere-metall-br/557092

Opinion article in Teknisk Ukeblad and Gemini

FME ZeMe's 2nd opinion article appeared in Teknisk Ukeblad on 27 October and was reprinted in Gemini. Casper Van der Eijk (SINTEF) points out that Norway is Europe's largest producer of critical raw materials such as aluminium, silicon, nickel and manganese. This is essential for our own and Europe's self-sufficiency. The Norwegian metal industry thus plays a key role in defense and security policies.

TU

Ledige stillinger Nyhetsbrev Nyhetsstudio Tips oss Logg inn

Debatt

Norsk metall styrker Europas sikkerhet

Metaller fra Norge roses ofte for det lave fotavtrykket sitt. Men akkurat nå teller det enda mer at de blir til i et europeisk demokrati.

Weblink: https://www.tu.no/artikler/norsk-metall-styrker-europas-sikkerhet/563686 and https://gemini.no/2025/10/norsk-metall-styrker-europas-sikkerhet/

PERSONELL FME ZEME

Centre administration		
Casper van der Eijk	SINTEF	Centre director
Gabriella Tranell	NTNU	Scientific Director/RA7-leader
Christina Meskers	SINTEF	Innovation manager
Torleif Nordskog	NTNU	Administrative coordinator
Dani Cárcel Latorre	NTNU	Project controller

Research Area 1		Energy Efficient Electrolysis
Camilla Sommerseth	SINTEF	Aluminium production, novel aluminium production
Senanu Samuel	SINTEF	Novel aluminium production
Skaftun Siri Marie	SINTEF	Energy efficient Ni, Cu, Co, Zn electrolysis
Skybakmoen Egil	SINTEF	Aluminium production, novel aluminium production
Solheim Asbjørn	SINTEF	Novel aluminium production
Ole Kjos	SINTEF	Aluminium production, novel aluminium production
Espen Sandnes	NTNU	Aluminium production
Svein Sunde	NTNU	Energy efficient Ni, Cu, Co, Zn electrolysis

Research Area 2		Climate Neutral Reducing Agents
Maria Wallin	NTNU	Climate Neutral Reducing Agents
Canaguier Vincent	SINTEF	Biocarbon for the ferro alloy industry
Jahrsengene Gøril	SINTEF	Biocarbon for the aluminium industry
Jayakumari Sethulakshmy	SINTEF	Biocarbon for the ferro alloy industry
Ringdalen Eli	SINTEF	Biocarbon for the ferro alloy industry
Schanche Trygve Lindahl	SINTEF	Biocarbon for the ferro alloy industry
Merete Tangstad	NTNU	Ferroalloys using biocarbon, Si and Mn
Houshang Darvishi Alamdari	LAVAL	Biocarbon for the aluminium industry

Research Area 3		Facilitating Energy Efficient Carbon Capture
Michal Ksiazek	SINTEF	Carbon capture from ferro alloy production
Ole S Kjos	SINTEF	Carbon capture from aluminium production
Camilla Sommerseth	SINTEF	Carbon capture from aluminium production
Gøril Jahrsengene	SINTEF	Carbon capture from aluminium production
Gabriella Tranell	NTNU	Facilitating Energy Efficient Carbon Capture
Maria Wallin	NTNU	Facilitating Energy Efficient Carbon Capture
Trond Andresen	SINTEF	Facilitating Energy Efficient Carbon Capture
Heiko Gaertner	SINTEF	Facilitating Energy Efficient Carbon Capture
Katarina Jakovljevic	NTNU	Facilitating Energy Efficient Carbon Capture

Research Area 4		Circularity and Resource Efficiency
Ulrik Thisted	NORCE	Circularity and Resource Efficiency
Derya Dispinar	SINTEF	Aluminium recycling
Einar Jonsson	SINTEF	ICP-analyses
Anne Kvithyld	SINTEF	Aluminium recycling
Kurt Sandaunet	SINTEF	Aluminium recycling
Cathrine Kyung Won Solem	SINTEF	Circularity and Resource Efficiency
Martin Syvertsen	SINTEF	Aluminium recycling
Zhaohui Wang	SINTEF	Circularity and Resource Efficiency
Gabriella Tranell	NTNU	Waste stream utilisation
Merete Tangstad	NTNU	Ferro alloy processes
Ragnhild Aune	NTNU	Aluminium recycling
Øyvind Sunde Sortland	NORCE	Flowsheet modelling

Research Area 5		Modelling and Digitalisation
Kristian Einarsrud	SINTEF	Management, data framework, electrolysis modelling
Sylvain Gouttebroze	SINTEF	Data framework
Kseniia Koseniuk	SINTEF	Electrolysis modelling
Jan Erik Øvrebø Olsen	SINTEF	Management
Vetle Kjær Risinggård	NORCE	Ferroalloy pilot scale
Mads Fromreide	NORCE	Ferroalloy pilot scale
Tomas Manik	NTNU	SiC formation in porous C materials

Research Area 6		Environment and Sustainability Framework
Johan Pettersen	NTNU	Environment and Sustainability Framework
Søren Djørup	NORCE	Environment and Sustainability Framework
Christina Meskers	SINTEF	Environment and Sustainability Framework

Research Area 7		Analysis Techniques, Emission Monitoring and Control
Gabriella Tranell	NTNU	Analysis Techniques, Emission Monitoring and Control
Heiko Gartner	SINTEF	Analysis Techniques, Emission Monitoring and Control
Hege Indresand	NORCE	Fenceline dust measurements
Katarina Jakovljevic	NTNU	Analysis Techniques, Emission Monitoring and Control
Trygve Schanche	SINTEF	Emission monitoring ferro alloy industry
Ole Kjos	SINTEF	Emission monitoring aluminium industry

Visiting Researchers		
Name	Affiliation	Topic
Felipe Alejandro Garcia Paz	TUB Freiberg	LCA of low-consumable anodes for aluminium production
Hugo Letartre	Un de Lorraine	Biocarbon in manganese production
Antonio Prudencio	Islands Universitet/DTE	Boron refining alumimium

PhD students with financial support from the centre budget		
Olaug Marie Aalen	2025-2029	Alumina Concentration and PFC Formation Mechanisms in Primary Aluminium Production
Zoran Povijač	2025-2028	Energy efficient anode materials for sustainable electrowinning
Thea Stabbforsmo	2025-2028	Hot strength of SiC from biocarbon
Magnus Kyrre Windfeldt	2025-2028	Facilitating Carbon Capture in the Si industry
Bo Raadam	2025-2028	Aluminium Melt Filtration and Impurity Removal - Improving Secondary Melt Quality through Pilot-Scale Testing
Linus Meistad	2024-2027	Valorization of Manganese Sludge
Aakriti Deuja	2025-2028	Environmental energy system analysis for zero emission metal production

Graduated Master students	
Lars Smemo	Aluminothermic Production of Different Alloys from Al Dross and Industrial Waste Streams

Photo: Marius S. Stokke & MidJourney (AI)

ANNUAL ACCOUNTS

Budget

The total budget for the eight-year FME ZeMe centre period is 271 mill NOK. The financing of FME ZeMe is based on contribution from The Research Council of Norway and cash and in-kind contribution from the user partners and NTNU. Results for 2025:

Funding (1000 NOK)	Amount	Costs (1000 NOK)	Amount
Research Council	12 072	Host Institution (NTNU)	12 749
Host Institution (NTNU)	3 219	Research Partners*	13 547
Research Partners*	2 454	User Partners**	3 859
User Partners**	12 410	Equipment	0
Total	30 155	Total	30 155

*SINTEF AS, SINTEF Energy AS and NORCE.

** Boliden Odda AS, Glencore Nikkelverk, Fiven Norge AS, REEL Norway AS, Alcoa Norway AS, Hydro Aluminium AS, INEOS Tyssedal AS, Finnfjord AS, Wacker Chemicals Norway AS, Eramet Norway AS, Elkem ASA,

Funding

Research Council	40,0%
Host Institution (NTNU)	10,7%
Research Partners	8,1%
User Partners	41,2%

Costs

Host Institution (NTNU)	42,3
Research Partners	44,9
User Partners	12,8

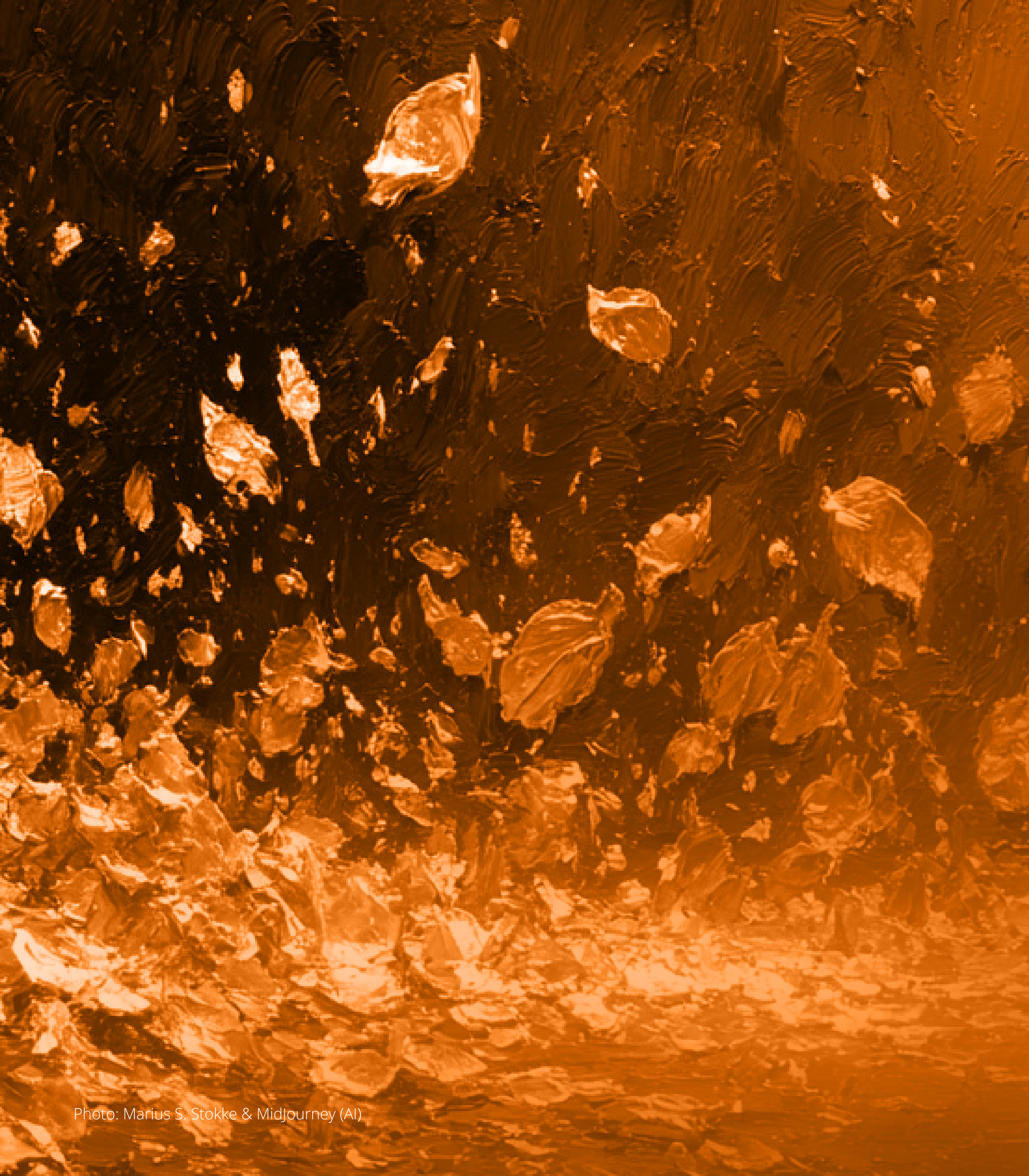


Photo: Marius S. Stokke & MidJourney (AI)

PUBLICATIONS AND CONFERENCE PRESENTATIONS

Scientific contributions

Samuel Senanu, Egil Skybakmoen, Arne Petter Ratvik, Zhaohui Wang, Asbjørn Solheim. *Review of Lining Materials and Their Degradation in Aluminium Electrolysis Cells.* The International Committee for Study of Bauxite, Alumina & Aluminium Conference, Proceedings of the 43 International ICSOBA Conference, Nanning, 26 – 31 October 2025. https://doi.org/10.71659/icsoba2025-al076

Egil Skybakmoen, Zhaohui Wang, Zhigang Huang, Andreas Rugaard Lund. *Quality Evaluation of Self-Bonded SiC as Sidelining Materials in Aluminium Electrolysis Cells.* The International Committee for Study of Bauxite, Alumina & Aluminium Conference , Proceedings of the 43 International ICSOBA Conference, Nanning, 26 – 31 October 2025 https://doi.org/10.71659/icsoba2025-al077

Merete Tangstad, Eli Ringdalen. *Decarbonization Ferroalloy Production Using Biocarbon.* Minerals 15, no. 3: 228. https://doi.org/10.3390/min15030228

Conference presentations

Casper van der Eijk. Decarbonising the Norwegian metallurgical industry. HILT CRC Annual Conference: De-risking Decarbonisation

Casper van der Eijk. *The Norwegian centre for Zero Emission Metal Production (ZeMe).* 15th CRU Silicon Market Forum

Christina Meskers, Anne Kvithyld. *Key challenges for upcycling to obtain high-quality materials.* TMS annual meeting & exhibition 2025 - Revitalisation of materials through upcycling symposium

Christina Meskers. *Circularity and zero-emission metal production a Norwegian perspective.* M2i thematic meeting: towards the circular economy in metals

Popular science publications

Trond Andresen. Prosjektsamarbeid mellom bedrifter og FoU aktører. Hvorfor og hvordan. ACT partnerskapssamling

Casper van der Eijk. *FME ZeMe.* Prosess 2030-konferansen

Casper van der Eijk. *Derfor må vi fortsette å avkarbonisere norsk industri!* Arendalsuka

Casper van der Eijk. *Norsk metall styrker Europas sikkerhet.* Gemini

Casper van der Eijk. *Norsk metall styrker Europas sikkerhet* | Tu.no. Teknisk Ukeblad

Christina Meskers, Casper van der Eijk. *FME ZeMe: collaborative research for the transition to zero emissions metal production.* Extraction 2025

Cathrine Kyung Won Solem. *Elektrokjemi i kampen mot klimautslipp.* Forsker på skjerm v/ Heimdal VGS

Cathrine Kyung Won Solem. *Elektrokjemi i kampen mot klimautslipp.* Forsker på skjerm v/ Guri Kunna VGS

Cathrine Kyung Won Solem. *Elektrokjemi i kampen mot klimautslipp.* Forsker på skjerm v/ Stranda VGS

Camilla Sommerseth, Casper van der Eijk, Johan Berg Pettersen. *Uten kloke hoder blir det vanskelig å produsere metall.* Teknisk Ukeblad

Maria Wallin, *Gjenvinning er en viktig del i det grønne skiftet - Hvordan kan vi bidra til dette?* 26.03.2025. Mandal VGS

Maria Wallin, *Gjenvinning er en viktig del i det grønne skiftet - Hvordan kan vi bidra til dette?* 28.03.2025. Dalane VGS

Maria Wallin, *Gjenvinning er en viktig del i det grønne skiftet - Hvordan kan vi bidra til dette?* 02.06.2025. Mære Landbruksskole

Webinars

Title	Who	Organisation
Environmental life cycle assessment of silicon metal production	Elisa Pastor Valles	NTNU
Inert anodes for aluminium production - status today and current research	Samuel Senanu, Asbjørn Solheim, Egil Skybakmoen	SINTEF
BioCarbUpgrade overview – Upgrading biocarbon for sustainable metallurgical industries.	Gøril Jahrsengene	SINTEF
Pelletization and Hydrogen Reduction of Bauxite Residue in Pilot Scale	Casper van der Eijk	SINTEF
Opportunities that the ground-breaking SmeltDirect technology presents (Cr and Mn alloys as well as green steel.)	Henk Bouwer	ARM
Manufacturing FeSiB phase change material through metallothermic reduction method	Jianmeng Jiao	NTNU
Modelling electrical conditions in 3-phase furnaces	Mads Fromreide	NORCE
Metal pad roll waves in aluminium smelters and liquid metal batteries	Gerrit Horstmann	HZDR
Sampling with emphasis on circular value chains	Ulrik Thisted	NORCE
Gas permeability in Si charges with coal and charcoal	Hedda Haugedal og Aslak Lüllau Aaknes	NTNU

Title	Who	Organisation
BioMet project	Vincent Canaguier	SINTEF
Removal of Zn and other volatile elements from molten Al by vacuum refining	Sarina Bao	SINTEF
Zero emission Silicon and Manganese production through Electrowinning (ZeSiM)	Gøril Jahrsengene	SINTEF
Disintegration of Six Different Quartz Types during Heating to 1600 °C	Marit Buhaug Folstad	NTNU
Emission monitoring	Hege Indresand	NORCE
DigiPro and the Prosess21 report: "Digitalisation in the process industry 2025”	André Larsen	SINTEF
ELECTRA - Electrification of high temperature and flexible technologies for transforming cement, lime and pulp industry	Halvor Dalaker	SINTEF
A Numerical Study of Cr(VI) Emissions from Slag Stockpiles for Improved Life Cycle Inventory	Shana Joy Baumgartner	NTNU
Modelling of the FeMn process in HSC Sim – from PreMa to BioMet	Vincent Canaguier	SINTEF
Impressions and info from the ICSOBA 2025 conference in Nanning, China 25-31.10.	Egil Skybakmoen and Samuel Senanu	SINTEF

ZERO EMISSIONS Ze

Me METAL PRODUCTION

Funded by The Research Council of Norway