2015

ANNUAL REPORT

SFI **METAL** PRODUCTION

# ”THE VERY FIRST YEAR

sfi Centre for Research-based Innovation
The Research Council of Norway

metal production

NTNU
Norwegian University of Science and Technology

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**Thanks to:**
Photo by Thor Nielsen: Portrait of RD-leader, management group, General Assembly and Kick-off
Front Page Photo by Melinda Gaal and Photo design by Eva Kvernes Rygg
NTNU Grafisk senter, Hege Hovd and Ida Kristine Følstad

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## OF THE 2015 ANNUAL REPORT FOR SFI METAL PRODUCTION

# THE VERY FIRST YEAR

NTNU/SINTEF/Teknova and the Norwegian metal producing industry have a long tradition for cooperation on competence building, process development along the whole value chain, environmental issues and education of candidates. There have been numerous research and innovation projects over the years. The Research Council of Norway (RCN) and other public support schemes have given financial support to the majority of the project portfolio. However, there have always been a strong wish and hope for a long-term project with the possibility for strategic thinking and shaping the future of the Norwegian metallurgical industry.

Consequently, the idea of writing an application for the upcoming call for SFI in 2013 (SFI III) was born in January 2013, long before the call text was published by the Research Council of Norway. The scientific groups at NTNU and SINTEF had tried twice, unsuccessfully, to qualify for a SFI. On the basis of all that experience, the new call was very tempting. In addition, the process towards an application for a SFI was also of interest to the Norwegian process / metallurgical industry.

The first meeting with the potential partners, both from research institutes, academia, and industry, was arranged in Trondheim on March 19th 2013. Four similar meetings were held the following year. SFI Metal Production brings together the diverse Norwegian metallurgical industry (from aluminium producers, to ferrosilicon/silicon- ferromanganese and $TiO_2$) and suppliers of equipment, in a programme that will facilitate transfer of knowledge and innovations in the metal sector and between the metal industry and other sectors, as well as co-develop solutions useful for several sectors (e.g. ferroalloys and light metals).

The purpose of the initial consortium meetings was to discuss and receive input from the industry regarding current topics for the proposed SFI Metal Production. One important topic for the industry was to develop robust modelling tools based on reliable data. These modelling tools would help pursue and document knowledge that, in turn, will contribute to maintain Norwegian industry's status as a world leader within metallurgical processing.

A draft application form was submitted to the Research Council of Norway on the 1st of October 2013. The feedback from the Research Council was positive.

An Interim Board was established with a mandate and objective to ensure a successful and effective process for making the final application to the Research Council. The Interim Board's area of responsibility was to handle the primary guidelines for budget, partners, project structure and agreements. The members of the interim board were: Per Anders Eidem (Eramet), Edin Myrhaug (Elkem), Nancy Holt and Trond Furu (Hydro), and Stian Seim (TiZir). Nina Dahl and Aud Wærnes represented SINTEF, and Jostein Mårdalen and Gabriella Tranell were the members from NTNU.

Aud Nina Wærnes (Centre Manager)

A committee with the objective to establish the principles for a Consortium Agreement was formed before the SFI Metal Production was accepted. The rationale was that making a Consortium Agreement is a process that normally takes some time, and starting early would be an advantage for the start-up process later on. Members of the committee were: Åsmund Broli (Hydro), Ragnar Tronstad (Elkem), Benjamin Ravary (Eramet and TiZir), Bjørn Steinar Tanem and Hanne Sørgjerd (NTNU), Øyvind Hennestad and Nina Dahl (SINTEF). Due to the preliminary work in the committee, a signed Consortium Agreement was finalised before the summer holiday of 2015.

The 21th November 2014 was a day with excellent news for the supporters of the SFI Metal Production. The announcement from the Research Council of Norway was positive for the SFI Metal Production. We had succeeded in our effort to establish a SFI centre for Metal Production.

The very first meeting between the research partners and the industry was arranged in February 2015. The main topic was to present the Work Plans for 2015, and receive feedback from each industrial partner regarding their expectations.

The revised project description, work plans etc. were submitted to the Research Council of Norway on the 1st April 2015, e.g. the very first day of the SFI Metal Production.

The Kick-Off meeting of the SFI Metal Production, the big event of spring 2015, was arranged in Trondheim in June. A dinner for the partners and guests was served at Kvilhaugen gård the evening before. The program included presentations from academia, industry and the Research Council of Norway.

Highlights and expectations to the SFI Metal Production from the speakers of the Kick-Off meeting can be summarized as follows:

- Become a visible flagship for long-term industrial research on an international level.
- Education and recruitment of researchers with a fundamental understanding and knowledge of the process industry.
- Have positive impact on the research-based education.
- Attract international attention – "Look to Norway".
- Value creation as a result of research based innovation.
- Contribute to the establishment of long-term strategic alliances between industry and research
- Establish Innovation Projects initiated by SFI together with the Horizon 2020 and The Research Council of Norway Roadmap and SPIRE.

The official opening of the nine Centres of Research-Based Innovation in Trondheim, was arranged in September. Aud Wærnes, Centre Manager, presented SFI Metal Production and received the SFI Diploma on behalf of all the partners.

In order to ensure a broad dissemination of the project results and get feedback from the industry and the international research community, the SFI Metal Production decided to organise an Autumn- and a Spring-meeting each year for all the stakeholders. The Autumn meeting of 2015 for the SFI Metal Production took place in Trondheim between the 27th and the 29th of October. The main topic for the first session on the 27th was "Metal Production and the Environment" with presentations from the Norwegian Environmental Agency, Industry and Bellona. The first day concluded with a dinner at Scandic Lerkendal.

The second day started with a Workshop on Horizon 2020. Representatives from NTNU gave a presentation on the possibilities for funding on different programs within EU. The members of the SFI wanted the management of the SFI to follow up on different relevant calls in Horizon 2020. The last part of the Autumn meeting was dedicated to the five Research Domains. The Autumn meeting closed with lunch on the 29th of October.

The very first year is all too soon coming to an end, and it is now time to proceed, with 2015 as a platform. We are looking forward to the next exciting years and to future innovations.

***The future depends on what we do in the present***

*(Mahatma Gandhi)*

# SFI METAL PRODUCTION

***Vision:*** ***Resource efficient metal production from a clean industry***

***The Primary objective*** *of the Centre SFI Metal Production, is to strengthen the future of Norway's largest land based industry by establishing an interdisciplinary Research Centre for Metal Production enabling industrial innovation. The Centre will give the industry long-term access to excellent fundamental competence and candidates. The Centre will focus on close collaboration between Industry and Academic/ Research communities in Norway, to enable accelerated implementation of new knowledge in industry practice and innovation.*

Metals are, and will continue to be, a pre-requisite for modern society. The houses and offices we live and work in; the cars, planes and trains we use for transport; the computers and mobile phones we use to communicate – all rely on metals.

Metal producers in Norway are operating in an international market. They have owners with a long-term strategy for further operations in Norway and with an active focus on technological innovations.

The metal producing industry is Norway's largest land-based industry, with total exports valued at 52 billion NOK in 2013. In addition, this industry "manages" about 30 % of Norway's total electricity consumption and employs directly ~10000 people[1]. In 2020, a significant surplus of electricity in Norway is expected, pointing to new opportunities for energy intensive industries[2].

At the same time, the framework conditions for metal producers are changing rapidly:

i. Unprecedented growth in metals demand, mainly due to industrialization and urbanization in emerging market economies;
ii. rising concerns for access to critical raw materials, often used in electronics and new technologies essential for environmental protection;
iii. energy use and GHG emissions need to be reduced drastically to avoid dangerous anthropogenic interference with the climate system;
iv. Mature economies experience an increasing availability of scrap that may be used as a secondary resource and may thereby address (i)-(iii); however, unresolved quality challenges remain. Metals producers need to adjust to these changing boundary conditions in order to remain competitive on the global markets.

This requires several breakthroughs:

i. new technologies for more resource efficient and emissions saving primary and secondary production;
ii. new tools for forecasting changes in the global material cycles and for identifying the most effective combinations of technologies to support decision making in industry and government.

*[1] SSB-2013*
*[2] FAFO-rapport 2012:08. "Klemt mellom Kina og klima". ISBN: 978-82-7422-864-1*

**The Application for SFI Metal Production was evaluated by the Research Council, an international expert committee and representatives from the industry. The panel's verbal evaluation of the application regarding its potential for innovation and value creation is quoted below:**

This is a project with an extraordinarily large potential for innovation and value creation. The application have generally very high scores on all the criteria in the evaluation of potential for innovation and value creation. The application is particularly strong regarding national competence and relevance. The application addresses core issues concerning the status of the metallurgical industry' challenges (environment and energy) and is strategically very important for future value creation and development in the land based industry.

The added value for the industry, by establishing such a centre is considered very high. The application is within an area where the Norwegian research environments and companies, have an international leading position. The application has a very good foundation among the user partners. The industrial partners will be deeply involved in the governance and implementation of the work in the centre. The application has a very good strategical foundation in the host institution. The application falls within the strategic goal of all the companies. The application is important in order to continue the development of the decentralized structure of the industry in Norway. The application has many of the key players within the metal producing industry in Norway as partners. Consequently, the Centre will, to a large extent, contribute to a national competence boost in this important area.

# THE LEADERS

## OF THE EXECUTIVE BOARD AND GENERAL ASSEMBLY TAKE THE FLOOR

*Anne Borg (Dean NTNU), leader Executive Board*

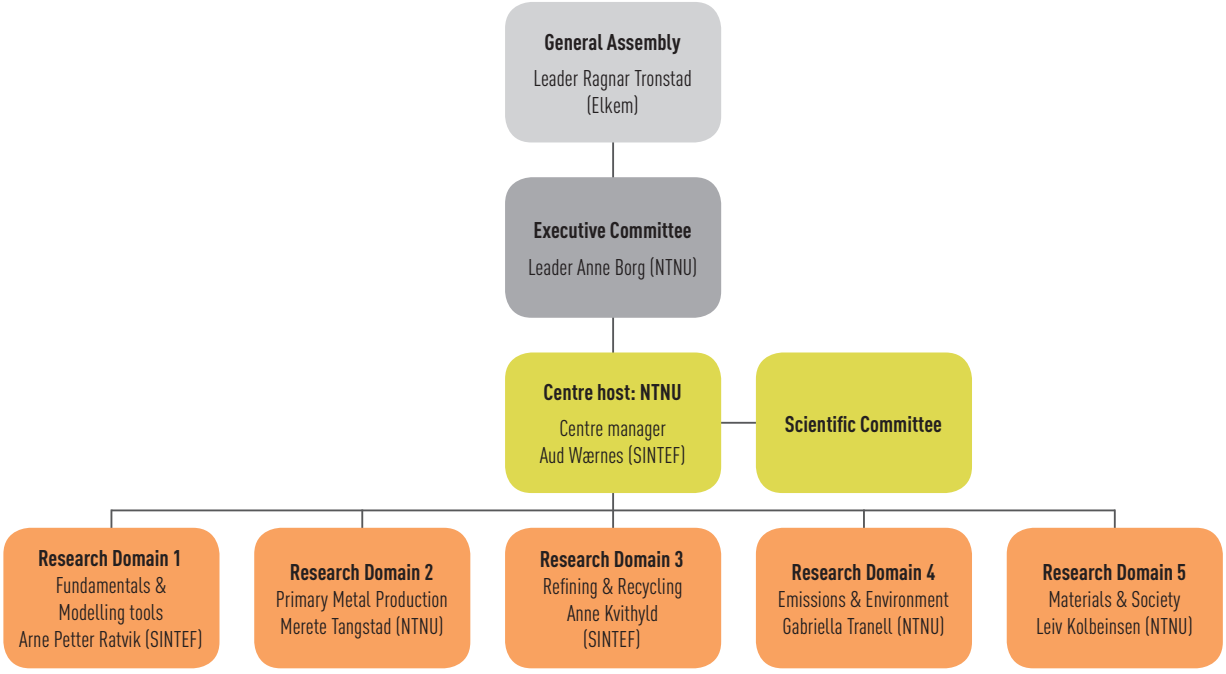
*Ragnar Tronstad (Director R&D, Elkem), leader General Assembly*

The world needs high quality materials for countless applications. The challenge lies in producing and manufacturing materials in a way that is not harmful to the environment – neither when it comes to the use of resources nor emission of different substances. Hand in hand with research institutions, the Norwegian metallurgical industry has already developed environmental standards that are important on a global scale. With this new Centre for Research-based Innovation, SFI Metal Production, we will take several new steps towards a greener metallurgical industry - not only in Norway, but in the world.

Topically, SFI Metal Production is in the core of NTNUs vision "Knowledge for a better world" as well as SINTEFs vision "Technology for a better society". In close collaboration with the industrial partners the ambition of NTNU's Faculty of Natural Sciences and Technology and SINTEF Materials and Chemistry is to contribute to the realization of these visions through our joint research and innovation activities in this centre. We look forward to see scientific achievement, as well as the implementation of the research-based knowledge into useful tools for the industry in the years to come.

The metallurgical industry in Norway has a long history. With our unique landscape with lakes and waterfalls, Norway could offer cheap and clean energy along the entire coastline. Production plants for silicon, aluminium, ferroalloys and other high-energy consuming products appeared at remote places, close to the power sources, and small villages developed. The first plants had no filtering systems for waste gases and systems for water cleaning did not exist. Over the years, technical solutions have solved the visible challenges and new knowledge and technology have created roadmaps for a better environment. Today, filter systems separate dust from off-gas, dust is made into products, dangerous gas components are neutralized, by-products are developed for new markets and energy consumption is dramatically reduced. However, it is still a long way to go to meet Vision 2050 but a competitive world continuously force the Norwegian industry to improve its ability to innovate. Through common research arenas like FFF ("Ferrolegeringsindustriens Forsknings Forening" - The Norwegian Ferroalloy Producers Research Association), industrial networks like Eyde, innovation and competence projects through the Research Council of Norway our industry, universities and research institutes have obtained global leadership. By being a part of SFI Metal Production we hope to make a foundation [basis] for future generations to maintain this position, and to establish standards for environmentally friendly metal production worldwide.

# ORGANIZATION AND LOCATION




SFI Metal Production is **hosted by NTNU** and the **Centre manager is Aud Nina Wærnes** from SINTEF. The **General Assembly (GA)** where all the partners, ten industry partners and three research partners, are represented makes decisions that involve major changes to the consortium. Ragnar Tronstad (Elkem) was elected as the leader of GA.

The GA approved the members of the **Executive Committee (EC)** and Anne Borg (NTNU) was appointed chair of the EC at the first GA meeting in June 2015. In addition to Anne Borg, the other members of the EC are Nancy Holt (Hydro), Ketil Rye (Alcoa), Leif Hunsbedt (Eramet), Ragnar Tronstad (Elkem), Eli Aamot (SINTEF), Tor Einar Johnsen (The Research Council of Norway, RCN).

*Centre Management Team: Leiv Kolbeinsen (Professor), Gabriella Tranell (Professor), Merete Tangstad (Professor), Marianne Lenes (Coordinator), Aud Wærnes (Senior business developer) , Arne Petter Ratvik (Senior research scientist) and Anne Kvithyld (Senior research scientist).*

SFI Metal Production's Centre management is located at NTNU Gløshaugen in Trondheim. In May 2016 we will be relocated to the third floor in "Bergbygget" at Alfred Getz vei 2. On this floor, industry, SINTEF, NTNU and students will be sitting side by side. We are really looking forward to this co-location and the synergy effects of this.

The **Centre Management Team** consists of the Centre manager Aud N. Wærnes (SINTEF), project coordinator Marianne Lenes (NTNU) and the five Research Domain (RD) leaders. The RD leaders are: Arne Petter Ratvik (SINTEF), Merete Tangstad (NTNU), Anne Kvithyld (SINTEF), Gabriella Tranell (NTNU) and Leiv Kolbeinsen (NTNU). During the very first year, the centre management team has made a lot of effort to get the SFI started, both scientifically and administratively. The scientific work within each research domain has been thoroughly planned together with the industrial partners. The five RD leaders have been responsible for directing the research topics in accordance with the agreed Work Plan and deliverables together with students, PhD students, post docs, researchers and the industry partners. Most of the administrative work has been handled by Aud and Marianne and they have had their hands full this first year with reporting, dissemination and settle the administrative routine in order to get the interaction which is both desirable and necessary for a successful SFI.


*These enthusiastic project partners were present at our first GA meeting in June 2015: Nancy Holt (Hydro), Ragnar Tronstad (Elkem), Anders Sørhuus (GE), Anne Borg (NTNU), Leif Hunsbedt (Eramet), Ketil Rye (Alcoa), Birger Andresen (Fesil), Aud Wærnes (SINTEF), Tor Einar Johnsen (RCN), Haavard Elstad (TiZir), Erlend Olsen (Finnfjord), Svenn Anton Halvorsen (Teknova), Nina Dahl (SINTEF), Petter Nekså (SINTEF Energy), Torbjørn Halland (Wacker) and Bjørn Heiland (Glencore Manganese).*

Elkem AS is a world leading company in the production of environmentally friendly metals and materials. The company was founded in 1904 and today it is owned by China National Bluestar. The company's 21 plants worldwide are mainly producing silicon- or carbon-based products. Of the 3600 employees, 1350 work in Norway, and approximately 10 per cent are involved in R&D. BSI in France runs the biggest R&D Centre with 250 employees, while Elkem Technology in Kristiansand employs close to 100.

Elkem wants to be among the leading producers of silicon-based products also in the future. This presupposes highly qualified employees / excellent education, adaptation of Vision 2050 and extended use of robots in the process line. SFI Metal Production comprises the building blocks for this development by educating new PhD candidates, focusing on fundamental process knowledge, circular economy, product diversity (refining technology) and integration of metallurgical industry in a modern society.

Many experts from Elkem have contributed to the establishment of SFI Metal Production through their involvement in the idea phase, committee meetings and the first year of project work. The Technology division and Elkem Silicon Materials division have represented Elkem in meetings and one furnace at the Bjølvefossen plant (Foundry division) was available for excavation studies. Specialists are also selected and available for participation in advisory-/work groups under each research domain.

The ERAMET group is the world's second largest producer of manganese ore and manganese alloys, and the world's leading producer of refined manganese alloys. The group focuses on mining and the metallurgical industry, and is a major global player in the following three business areas: special steel, manganese and nickel. Eramet Norway is part of ERAMET's Manganese Division, with processing plants at Sauda, Kvinesdal and Porsgrunn, and an R&D group in Trondheim.

The objective for Eramet in SFI Metal Production is to secure future innovation and development for manganese production by supporting R&D activities within SFI. Innovation and results will be implemented in the industry in the fields of raw materials, recycling, reduced energy consumption and emissions

Eramet's business area brought to this SFI is production of manganese alloys as well as competence in extractive metallurgy, CFD simulations and environmental performance in metallurgical industry.

Eramet is involved in three of the research domains and our main interests are to increase our competence in modelling and extractive metallurgy as well as sharing obtained results in the area of PAH monitoring.



Alcoa is a global leader in lightweight metals technology, engineering and manufacturing. Alcoa innovates multi-material solutions that advance our world. Our technologies enhance transportation, from automotive and commercial transport to air and space travel, and improve industrial and consumer electronics products. We enable smart buildings, sustainable food and beverage packaging, high performance vehicles across air, land and sea, deeper oil and gas drilling and more efficient power generation.

Alcoa leads the way in developing green technologies and has made many breakthroughs in recent years; The aluminium air battery, the unique alloy used in the new model Ford F-150 and the revolutionary Micro Mill technology™ are just a few examples. Alcoa is also working on a new advanced smelting method, which can lead to significant reductions in carbon emissions from the production process. This project is run by Alcoa Technical Center in Pittsburgh and has applied for Enova funds to build a pilot plant in Norway.

Alcoa is supporting the SFI Metal Production as part of our aim to maintaining critical skills and expertise, both within our own industries and in key research institutions such as NTNU and SINTEF. We want to strengthen the cooperation between industry and R & D institutions, as well as to ensure that the research is relevant to our company needs.

We want to build excellence of competence within selected priority areas like; robotics, automation, heat recovery, energy efficiency, lean manufacturing methods and organizational models & culture, renewable- and clean energy, pioneering environmental technology and process technology.

Finnfjord AS, one of the world´s most energy-efficient and environmentally friendly producers of ferrosilicon, is located in Troms County in the far north of Norway. Finnfjord has three electrical reduction furnaces with a production capacity of around 100 000 tons of ferrosilicon and 20 000 tons of silica, and an energy recovery plant with an annual capacity of 340 GWh electrical power.

The SFI centre's research activities lie within the core activities for our company. It is expected that the SFI activities will bring new knowledge, which will be applied, directly in the production of ferrosilicon and to improve productivity and performance. As such, the SFI will be instrumental in a healthy and sustainable economic business development for Finnfjord. We possess skilled personnel, who will participate in relevant projects, and they will be able to convert the obtained scientific results into practical operation and consequently reduced emissions. Environment and energy are common challenges for the metal producing industry in Norway, and well suited for joint research efforts.

So far, the main contribution to the SFI has been on planning PAH activities that will take place in 2016, as well as participation in various committees.



TiZir Titanium & Iron (TTI) is located almost at the end of the Hardangerfjord on the west coast of Norway. The TTI ilmenite upgrading facility has been producing titanium dioxide slag and high purity pig iron (HPPI) since 1986. Owners are Eramet (French) and MDL (Australian) and it is the only such facility in Europe and only one of five in the world.

TTI focus is on understanding the challenges from new raw materials introduced at the smelter. Specifically TTI will seek to improve the overall energy efficiency, as well as climate footprint from the production process. In addition, TTI will seek to improve the knowledge of slag morphology and phase relations to improve product quality and yields.

Our business area within SFI Metal Production is Ilmenite smelting. The expertise brought to SFI Metal Production is the competence of the R&D department at TTI, which consists of three PhDs and two MSc with background from metallurgy, mathematics and automation, and all members will closely follow the work in the centre, participate in workshops, projects committees, as co- supervisor for PhD and M.Sc. projects, etc. The laboratory at TTI is also contributing with analysis of samples.

Glencore Manganese Norway AS (GMN) is a manganese ferroalloy producer placed in Mo i Rana inside Mo Industripark. Mo Industripark is one of Norway's largest industrial clusters with more than 100 companies inside the industrial area. GMN employs 105 people on a full time basis, operating both a sintering plant and two smelters of a total annual capacity if 120.000-180.000 mt of manganese alloys.

GMN wants to participate and contribute to the SFI in order to push for a general technical development of the process industry in Norway and thereby strengthen Norway's position as one of the world leading nations as regards process- and environmental technology.

Our business areas are Manganese alloy production and related environmental issues.

We are engaged in specific topics: in-kind resources in specific trials and test-campaigns as well as certain tests/investigations at site at GMN. Our General Manager and Senior Process Engineer contribute to the centre with their expertise.



The FESIL Group is among the world's leading producers of ferrosilicon. The production plant FESIL Rana Metall AS is located in Mo i Rana, Norway. Special products, including granulated and refined qualities, make up the bulk of the production. The plant is certified according to ISO 9001 and ISO 14001.The Group has a significant trading business with a whole variety of metal alloys, which are handled by FESIL Sales AS, with sales subsidiaries in Germany, Luxemburg, Spain, USA and China.

Our objective in the SFI is to improve our production processes, product qualities and working conditions in the plant, and to reduce the environmental footprint significantly. The SFI is essential in reaching our $CO_2$ goals for 2030 and 2050, as well as developing new products.

We bring extensive process experience and knowledge to the SFI and will be involved in most SFI research domains relevant to the production of silicon and ferrosilicon, especially new process designs with low $CO_2$ emissions, low energy consumption and low emissions to air, water and land.

Wacker Chemicals Norway AS, Holla, has been an integral part of the production line in Wacker Silicones since the 1st of July 2010, when the plant was purchased from Fesil AS. The plant has approximately 180 employees and is located in Kyrksæterøra, Trøndelag, Mid-Norway . The first two furnaces were put into production in 1964, and we now have round-the-clock production on four furnaces, producing approximately 50 000 tons of silicon and 25 000 tons of silica annually.

We expect that the SFI activities will bring new knowledge, which can be applied directly to our smelting furnaces and which will help to improve productivity and performance. We also expect that the activities will help us to make a safer and more environmentally friendly process. Wacker Norway has a focus on development of employees' knowledge and skills as part of the strategy to become one of the leading silicon producers in the world. As such, the SFI Metal Production allows for synergies and activities of the utmost importance for the company.

The expertise Wacker Chemicals Norway AS brings to the SFI includes: (i) knowledge about silicon production, with all its challenges, from operator to R&D level, (ii) CFD (Computational fluid Dynamics) skills and (iii) knowledge of environmental challenges for the silicon production.

The contribution to the centre will consist of scientific personnel participating in project work, raw materials supply and the company's own smelting shop facilities (industry furnaces) which will be available for industrial test campaigns managed by the SFI Centre. Specific activities include excavation of two furnaces.


GE Norway AS – ECS. The environmental control solutions (ECS) within Alstom became a part of GE in November 2015, when GE took over most of the Alstom power business. Within ECS, the Norwegian branch based in Oslo has focused on the development and sale of gas treatment and alumina handling for the global aluminium industry over the last fifty years. From the Oslo office, GE also supplies environmental control solutions and services for any other major industry and power segment including the Mongstad CCS chilled amonia pilot plant.

Our long lasting relationship with the Norwegian pioneering aluminium industry, universities and intitutes has been a vital part of our ability to survive as a market leader in our segment. Our objective for the participation in the SFI Metal Production is to maintain our ¨close to the customer¨ approach to develop our technology further, according to the needs in the industry related to the business area of gas treatment and alumina handling.

The main knowledge and expertise brought to the consortium includes experience within dry scrubbing of HF with alumina, removal of other pollutants (SO2, particulates , PAH etc), and waste heat recovery including design of heat exchangers and use of low grade heat.

So far the contributions in the SFI are related to the PAH measurement campaigns at Alcoa Mosjøen as well as participation in various technical committees etc.

Hydro Aluminium is a fully integrated aluminium company including mining of bauxite, refining of bauxite to alumina, electrolysis, casting, rolling and recycling. In addition, Hydro holds 50 % of the shares of SAPA, the world largest extrusion company.

Through our participation in SFI Metal Production, we get the opportunity to work closely with other metal producing industries in Norway, as well as NTNU and SINTEF. Our focus within the partnership is on the reduction in energy consumption and emissions, better utilization of waste as well as improving the product/melt. Research and competence building on these topics relevant to our industry, will lead to important industrial innovations.

The business area we bring to the SFI Metal Production is Primary Metal. Hydro will contribute to the Centre with knowledge on relevant topics within aluminium production, refining and recycling. Personnel from Hydro will spend time at the Centre. Furthermore, Hydro will contribute with industrial expertise to the education of PhDs and follow up projects to support the activity in the Centre and campaigns in small pilot scale at the Research Centres at Sunndalsøra or/and Årdal



Teknova is an independent research institute located in an area recognised for its clusters of world-leading offshore related and processing industries, in the Agder region in South Norway.

Through applied research and development, Teknova is focusing on providing state-of-the-art innovative solutions, creating value for clients in the region and beyond.

Enabling technological innovations through local insight and global outlook

Teknova contributes to the SFI Metal Production mainly through our expertise in mathematical modelling of various metallurgical processes, as well as through our network with European leading experts within industrial mathematics. Teknova's expertise and network supplement the modelling expertise of other SFI partners. We will also contribute within fugitive emissions, and possibly also with our capabilities within some high temperature measurement techniques.

Together with the other partners in SFI Metal Production, we intend to strengthen the Norwegian research within metallurgy significantly, thus contributing to ensure that the Norwegian metallurgical industry stays in the forefront.

The SINTEF group is the largest independent research organization in Scandinavia with approximately 2100 employees. SINTEF delivers innovation by developing knowledge and technologies that are applied and brought into practical use, and contribute to value creation and increased competitiveness within the private and public sectors. SINTEF offers world-leading laboratories within a broad spectrum of technology areas. For the SFI Metal Production, we offer tests and R&D services together with NTNU along the whole value chain of metals production, spanning from pilot furnaces to TGA/DTA measurements.

SINTEF s major objectives in the SFI Metal Production are as follows:

- Actively contribute to fulfil the vision of the Centre by deliver results in agreed activities and thereby build needed and relevant competence for future technological challenges.
- Active participation in the management and governing of the Centre through the centre management (as centre leader), General Assembly and Board.
- Actively use the SFI to prepare the ground for affiliated projects parallel to the SFI activities.

SINTEF resources in the Centre are mainly within metal production technologies; process metallurgy, electrochemistry, recycling, modelling and environmental issues, heat recovery concepts for particle laden gases. We have an important role both with respect to management of the centre (with the centre manager) and as researchers in the agreed focus areas.

Photo: Ingunn Kjøllmoen, private

NTNU

At NTNU, the Norwegian University of Science and Technology, we create knowledge for a better world and solutions that can change everyday life. From 2016, NTNU, the University College in Gjøvik, the University College in Sør-Trøndelag and the University College in Ålesund are merged to become one university. This gives us a more comprehensive range of study programs and larger research communities. Through interdisciplinary cooperation, NTNU's strategic research areas address complex challenges of great importance for society. Our aim is to meet global challenges with an interdisciplinary and flexible organization, to strengthen cooperation with the world of work and business as well as our innovative capability, and to increase our share of international research funding.

NTNU, Faculty of Natural Sciences and Technology through the Department of Materials Science and Engineering hosts the SFI Metal Production. Internationally, NTNU is acknowledged as the top education facility for candidates studying ferroalloy/silicon and aluminium production. SFI Metal Production has given us the opportunity to continue this research and innovation training within this highly competent centre for Metal Production together with SINTEF, Teknova and the ten industrial partners.

Our scientific personnel are involved in all the five research domains with a special focus on research, education and supervising of the PhD students and the Post Docs.

# 1 FUNDAMENTALS AND MODELLING TOOLS

***RD1 will combine existing knowledge and new fundamental data for production and refining of metals in an easily accessible and user-friendly library and work towards a generic, standardized framework for coupled scientific computing.***

*RD-leader: Dr. Arne Petter Ratvik (Senior Research Scientist, SINTEF)*

## RESEARCH OBJECTIVES

- Establish a library for existing and new experimentally derived data accessible across various software platforms.
- Explore and develop a generic, standardized framework for coupled scientific computing.

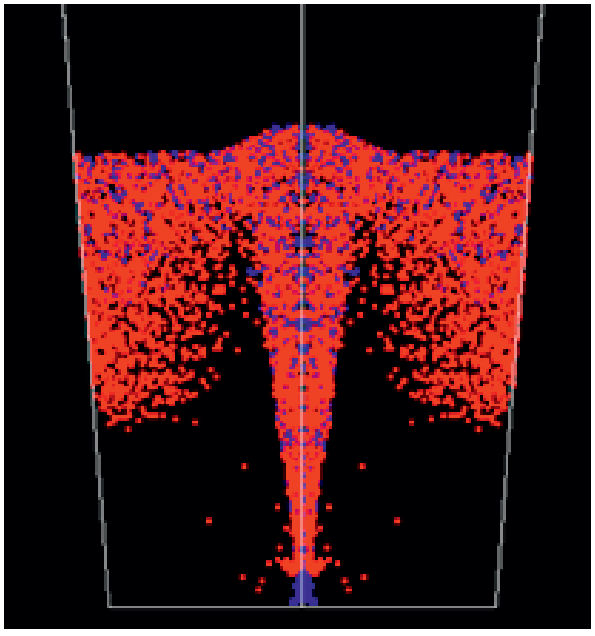
## HIGHLIGHTS IN 2015

**Library functions** for experimentally obtained data, that are standardized and work across different software platforms are scarce. Initial exploratory work is focused on using extensible mark-up language (XML), which is designed to store and transport data in both machine and human readable format. As a demonstration task, SINTEF is converting an existing experimental dataset to ThermoML (designed for experimental thermophysical and thermochemical data) and extract the converted data to different software platforms using structured query language (SQL).

**Methodology coupling of modelling tools** are currently applied to silicon refining as a case study in cooperation with RD3. Key elements, requiring heavy computational power and long calculation times, are developed in Fluent before being applied in a Mathlab model that can

describe a complete refining cycle with moderate use of calculation time. Later, it is the intention to adopt this approach to model thermodynamics and kinetics of oxidative refining aluminium.

**Modelling smelting operations** are complex and not straightforward. However, the extensive pilot scale experimental test program (RD2) is believed to be a good input for verifying the modelling of reactions, transport of materials, and the heat flow in and out of the furnace, under development at NTNU. As an alternative to commercial software for computational fluid dynamics, the current approach is to use the free and open code software OpenFOAM (Open Field Operator And Manipulation). The software is continuously developed by voluntary contributions from the user community. Based on the experience gained in using OpenFOAM on a very complex furnace model, we hope to be able to establish an approach that is later extended to aluminium studies, as well as other processes of importance to the participating industry. Currently, the main activities are at NTNU and SINTEF with support from Teknova. We expect the industrial involvement to increase as the established tasks evolve. Future activities in RD1 will be the established based on an up-coming road map.



*The figure shows the surface of bubbles and droplets extracted over short time-intervals by computational fluid dynamics (CFD) modelling for implementation in a fast Mathlab model.*

# 2 PRIMARY METAL PRODUCTION

*RD2 aims to develop fundamental knowledge and competence to support industrial innovations for the next generation metal production processes.*

*RD-leader: Professor Merete Tangstad (NTNU)*

## RESEARCH OBJECTIVES

- Find experimentally, and then model, reactions and reaction rates for ferromanganese-, silicon- and aluminium metal producing reactions.
- Determine the effect of raw material properties on operational parameters such as energy consumption and $CO_2$ emissions.

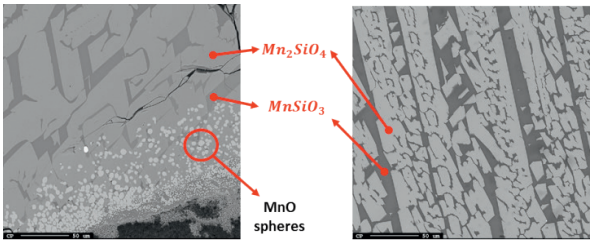
## HIGHLIGHTS IN 2015

**Furnace excavations at Elkem Bjølvefossen and Wacker Holla** were carried out as part of RD2 activities in 2015, with NTNU, SINTEF and personnel from the industry involved. Materials from the excavations will, when characterized, yield important information to help us understand fundamental reaction mechanisms inside the furnace. During demolition of industrial furnaces, the focus is on removing the interior of the furnace as soon as possible and obtain valuable information through a "fast-track" process. Consequently, one of the goals of RD2 is to find the optimal procedure for "fast-track" demolitions in order to harvest metallurgical knowledge of furnace- and reaction zones.

**Method development for pilot scale furnace experiments.** During 2015, two pilot scale experiments were performed. The goal was to optimize the operation of

pilot scale experiments. The experiments were a coordinated effort between the industry and SINTEF/NTNU. Industry representatives were present together with both NTNU and SINTEF operators. The overall goal of these experiments was to produce a 16-18 % silicon alloy with Assmang ore and HC slag.

**SiMn-reaction mechanisms.** Significant effort is made in RD2 to understand reaction mechanisms involved in silicomanganese production, through both experimental and modelling work. Experimental results show that the raw materials in the process are dissolved already at 1250 °C and that the reduction happens at different temperatures depending on fluxes and type of ore. For SiMn production, the particle size seems to be inconsequential to the reduction rate.

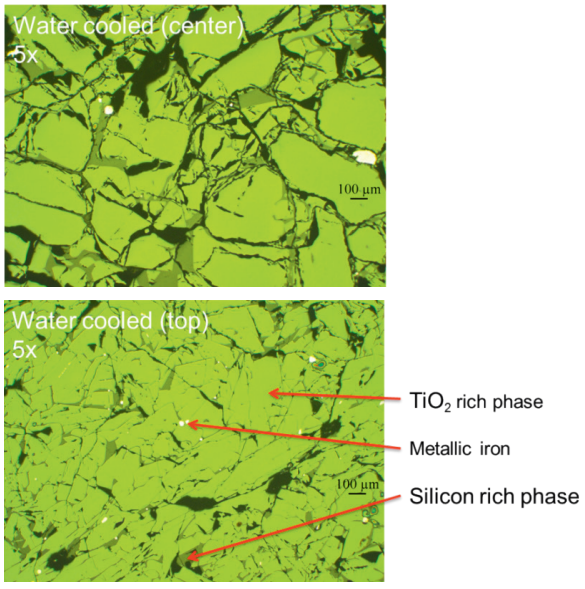



| Phase | $SiO_2$ | MnO | $Al_2O_3$ | CaO | FeO | $K_2O$ | Tot. |
|---|---|---|---|---|---|---|---|
| Circles | 0.1% | 93.0% | 0.4% | 0.2% | 1.0% | 0.0% | 94.9% |
| Grey | 30.8% | 58.9% | 0.2% | 6.4% | 0.5% | 0.0% | 97.1% |
| Darkest | 41.0% | 22.1% | 15.5% | 17.7% | 0.3% | 1.2% | 97.8% |

**Characterization of SiC for Si production.** In some modes of operation, large amounts of black SiC (α-SiC) is found in the high temperature zone in Si/FeSi furnaces. NTNU is working with SINTEF/Elkem to investigate how this material is formed. The focus is on the transformation of β-SiC to α-SiC, and characterizing the materials by SEM/EPMA, XRD and TEM. The large amount of silicon found formed in the SiC is an interesting feature worth further investigation.

**Trace elements in aluminium production** has been the focus in 2015 SINTEF studies. In 2015 vanadium is used as an example. In 2016 the focus will be on how different trace elements affect the operation.

**Slag properties in $TiO_2$** production has been investigated through summer student work at TiZir followed by project work at NTNU. Industrial slag samples with different cooling rates were studied by microscopy for both microstructure and mineralogy.



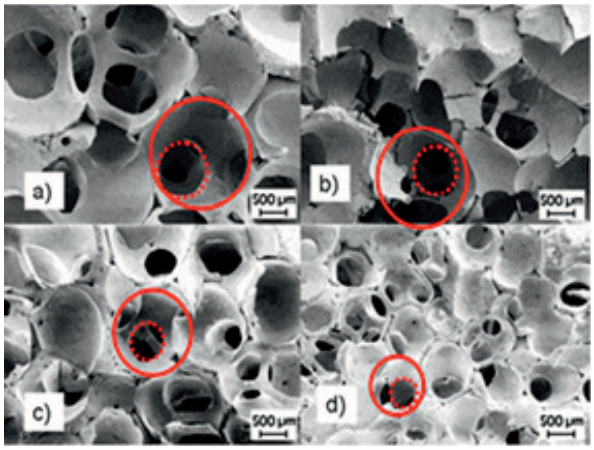
# 3 RECYCLING AND REFINING

***In refining and recycling of metals, the behaviour of impurities is the main focus. In RD3, increased knowledge of the thermodynamics and kinetics of oxidation-, refining- and waste utilisation processes, is the overall objective.***

*RD-leader: Dr. Anne Kvithyld (Senior Research Scientist, SINTEF)*

*Temporary RD-leader Dr. Martin Syvertsen (Research Scientist, SINTEF)*

*The figure shows an aluminium melting furnace with an aluminium melt covered with a (dark) dross layer. Ref: H. Fossheim, Alcoa Norway.*




*The figure shows Ceramic Foam Filters (CFFs) with different filter grades, i.e. (a) 30 PPI; (b) 40 PPI; (c) 50 PPI and (d) 80 PPI. The dotted circles are defined as the cell size, and the solid circles as the window size.*

## RESEARCH OBJECTIVES

- Identifying the effect of the presence of minor/ trace elements on aluminium oxidation/dross formation.
- Development of the thermodynamic and kinetic basis for Si refining.
- Recovery of metallurgical by-products and wastes, with or without residual metal content.
- Improving filter properties and filtration technology with the use of surface modifications and electromagnetically enhanced priming.

## HIGHLIGHTS IN 2015

**Aluminium short course.** In November 2015, a course on aluminium refining and recycling was arranged with special focus on oxidation/dross formation, metal refining/purification and gas treatment. In total, there were 25 participants in the course from industry, SINTEF and staff/students from NTNU.

**Aluminium oxidation.** In metallurgy, oxidation is both wanted and unwanted. In the aluminium casthouse, oxidation combined with aluminium melt turbulence, gives dross formation resulting in metal losses and reduced metal quality. The main focus in this topic is to develop a fundamental understanding of the effects of selected minor elements on the oxidation of aluminium by conducting small-scale experiments on model alloys with controlled chemistry to understand the effect of specific elements on the oxidation kinetics and product. The results from small scale experiments will be applied to industrial scale to increase the understanding of oxidation and reduce metal losses caused by oxidation.

**A simplified mathematical model for ladle refining of Silicon has been developed.** The model is able to qualitatively, and to some extent quantitatively, simulate industrial campaign measurements carried out in previous projects. For many impurity elements, the lack of available thermodynamic equilibrium data is an obstacle to accurate model development.

**Aluminium filtration.** NTNU is developing a new innovative method for inclusion removal combining electromagnetic modified priming and surface modified Ceramic Foam Filters (CFFs). Numerical simulations will be used to describe the fluid flow, the magneto hydrodynamics and the magnetic fields for different filter designs/surface modifications with experimental validation of the models.

# 4 EMISSION AND ENERGY RECOVERY

***Developing a comprehensive understanding of the emission from metallurgical processes is important for improved process control, abatement and reporting. In RD4, emission formation, measurement methodologies and standardisation are key research areas.***

*RD-leader: Professor Gabriella Tranell (NTNU)*

## RESEARCH OBJECTIVES

- Develop a fundamental understanding of the mechanisms and challenges for enhanced energy recovery in Al electrolysis and Ferroalloy production.
- Develop the knowledge base of the relation between emission formation, emission discharge, spreading and emission avoidance.
- Development of measurement methods, standards and tools to enable emission control.

## HIGHLIGHTS IN 2015

**PAH measurement campaign at Alcoa Mosjøen.** Polyaromatic hydrocarbon (PAH) is an undesirable air pollutant. In October, personnel from SINTEF took part in a PAH measurement campaign at Alcoa Mosjøen. The goal of the campaign was to try new measure-

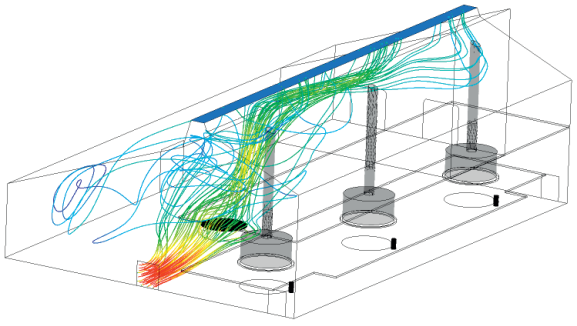
*The picture illustrates the sampling set-up during PAH measurements at Alcoa Mosjøen.*

ment methods and to do measurements from three different sampling points in the off-gas system from the anode factory. The first sample point was in the riser where raw unfiltered gas was sampled. The second sampling point was at the top of filter 1 that uses AHEX technology from GE (previously Alstom). The third sampling point was at filter 2, which is a baghouse filter. Some of the adsorption tubes sampled were analysed onsite with a portable GC/MS system fitted with a thermal desorption unit. The remaining samples were analysed by SINTEF in Trondheim after the campaign.

**Energy recovery.** A key challenge in Al off-gas heat recovery is to avoid or mitigate scaling. Scaling is the term used for the hard fouling layer deposited on surfaces in aluminium off-gas channels. It is composed primarily of alumina, and it is evident that the formation is influenced by flow and surface characteristics and by thermal and chemical conditions. A report aimed to summarize the status of prior work, related to dirty gas heat recovery from fundamental knowledge to commercial hardware was prepared. The report  is in preparation for a more comprehensive understanding of fouling in Al off-gas channels and on heat exchangers.  This will be very useful for determining gaps in knowledge, needs for further research and identifying promising directions of development.


*The figure illustrates scaling products from the electrolysis off-gas channel.*

**Dust Spreading.** A CFD model framework for dust spreading from hot metal surfaces was developed in 2015. It accounts for gravity, drag, turbulent dispersion and brownian dynamics. Important inputs to the model are particle size and density and dust release rate from a given source. The model allows the dust to be tracked as a concentration of particles both close to and far away from the source. The model was applied to a typical industrial metal plant. It was found that spreading of dust due to hallwind generated by the hot surfaces in the metal plant (i.e. natural convection) is more significant than hallwind due to external wind (i.e. forced convection).



*The figure illustrates the effect of hallwind on dust concentration in different locations in a ferroalloy plant.*

**Review articles.** Over the years, considerable expertise on the airborne emissions from the ferroalloy and aluminium industries has been built up within the SFI consortium and in the international technical/scientific community. To summarize the current knowledge, critical literature review articles are created 2015 and 2016. These articles will provide an updated state-of-the-art for the field of airborne emissions and mitigation strategies and also identify and prioritize among research needs in this field. These articles will serve as a basis for future activities in the SFI and elsewhere in the consortium. Three articles are under development; one for silicon and ferrosilicon production, one for manganese ferroalloy production and one for primary aluminium production.

# 5 MATERIALS AND SOCIETY

*The main aim of RD5 is to increase the public awareness of metal production and its benefits in a modern society.*

*RD-leader: Professor Leiv Kolbeinsen (NTNU)*

## RESEARCH OBJECTIVES

Metals are embedded in a wider system that incorporates both the economy and the society. This Research Domain has a special responsibility to identify opportunities and disseminate research aspects that can contribute to the understanding of the social value of metals and how they can support a sustainable development of society. Tools and instruments are:

- Life Cycle Thinking and Material Flow Analysis
- Standards for Emission Measurements and Reporting
- Industry networking and recruitment
- Exchange of best practices for industrial innovation.

## HIGHLIGHTS IN 2015

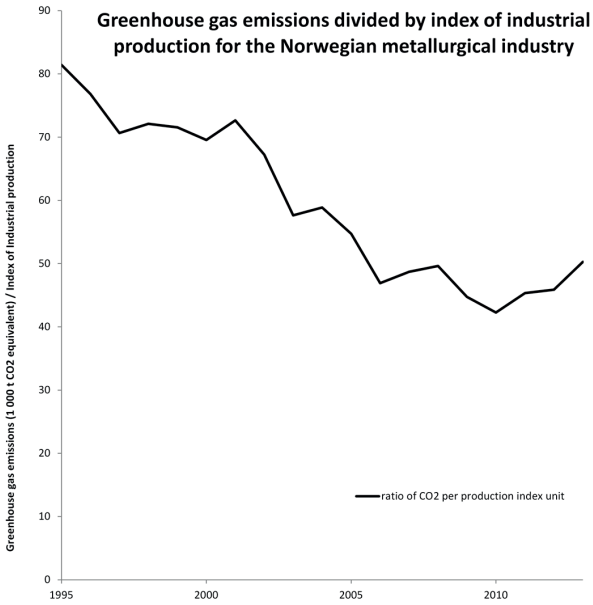
**Materials Flow Analysis and Life Cycle Thinking.** The main work is centred around the connection between materials, economy and the environment. A student will be involved in the assessment of the need for raw materials intelligence (RMI) from different stakeholders as well as the development of such RMI through models and scenarios for global trade-linked material cycles and their consequences for the environment. The PhD student will work mainly with a case study on aluminium, but will be involved also in other case studies in

order to enable learning across metal sectors. The results of this work will contribute, among others, to the development of a European Raw Materials Intelligence Capacity Platform (EU-RMICP).

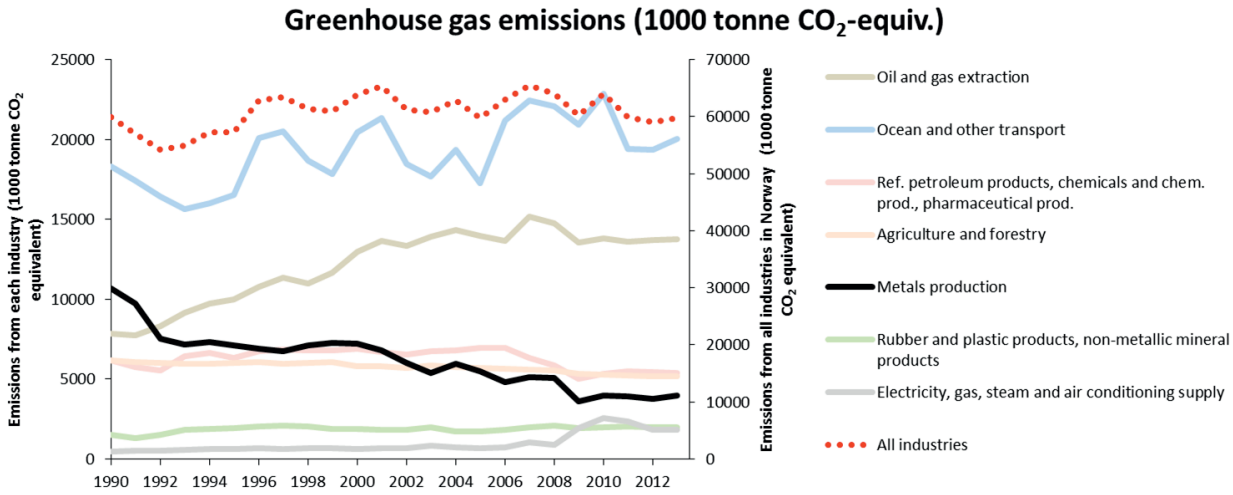
**Materials, Energy and Resources.** The main activity is materials and energy utilisation in society and the relation to the environment. A report in Norwegian on the Norwegian metal producing industry was made by a summer student, and was later translated into English in order to be used for broader dissemination.

**The role of the Metallurgical Industry.** The metallurgical industry should play a role in the transition to sustainability. The case studies "Red Mud" and "The Pedersen Process" were carried out in 2015 and aimed at bringing forward new solutions to old waste problems. The activity involved 2 summer students/student projects during 2015. A NTNU researcher will continue this work in 2016.

**Green Industry Cluster (GIC).** This activity was initiated in 2015 to develop a sketch of a possible industrial cluster or industry park to meet the envisaged demands on Norwegian process industry in the future. These demands and expectations are presently formulated by "Regjeringens ekspertutvalg for grønn konkurransekraft".




*The figures containing historic data illustrate that the Norwegian metal industry has had a stable production capacity over the last 20 years. In the same period they have had a considerable reduction in $CO_2$ emission.*



# INTERNATIONAL COOPERATION

**Prof Markus A. Reuter**

Helmholtz Institute Freiberg
for Resource Technology

**Prof Margaret M. Hyland**

The University of Auckland,
New Zealand

**Prof Oleg Ostrovski**

The University of New South Wales
(UNSW), Australia

**Jean-Pierre Birat**

CEO IF Steelman

An integral part of the Centre's activities is to cooperate with the best international industrial- and research communities and with disciplines connected to innovations within metal production. International experts will be invited to innovation events, workshops and as committee members for PhD defences. At the Kick-off meeting in June 2015, Jean-Pierre Birat was invited as a speaker with the presentation «Metallurgy in Society and Scientific excellence».

Participation in European and international projects is encouraged since it solidifies R&D&I links with allied institutions in Europe and overseas. During 2015 two applications were submitted to The EU Framework Programme for Research and Innovation - Horizon 2020. One with the title "Zero Waste, from iron and manganese oxides waste to valuable metal alloys and slags using novel carbon sources materials" and the other "CoMagPro, the development of an advanced technology for magnesium production in Europe".

The **Scientific Committee** (SC, leading academic experts) is an independent body providing an objective view with respect to the scientific quality of work planned/carried out. The leading international experts Prof. Reuter, Prof. Hyland, Prof. Ostrovski and Birat were appointed to the Scientific Committee in the autumn of 2015, and SFI Metal Production are honoured to have these highly qualified persons in our Scientific Advisory Committee.

# RECRUITMENT

*In 2015, these up-and-coming young people were recruited at SFI Metal Production.*

PhD student
**Pyunghwa Kim**

Research topic: Reduction mechanism in the SiMn process

Supervisor: Prof. Merete Tangstad

PhD student
**Massoud Hassanabadi**

Research Topic: Electromagnetically Enhanced Priming of Surface Modified Porous Media

Supervisor: Prof. Ragnhild E. Aune

PhD student
**Sethulakshmy Jayakumari**

Research Topic: Silicon Carbide production during Silicon process.

Supervisor: Prof. Merete Tangstad

Post Doc.
**Sebastien Letout**

Research Topic: Numerical modeling of metallurgical production processes with a focus on the Si-Mn process

Supervisor: Prof. Merete Tangstad, Principal Scientist and Adjunct Professor Stein Tore Johansen and Senior Research Scientist Arne Petter Ratvik

PhD student
**Nicholas Smith**

Research Topic: Oxidation of liquid Aluminium

Supervisor: Prof. Gabriella Tranell


# DISSEMINATION, MEDIA AND OPEN ACTIVITIES

Twice a year, spring and autumn, SFI Metal Production bring together all partners for joint meetings. In 2015, we had a Kick-off meeting in June and the autumn meeting in October. In addition to these meetings, each research domain arrange their own meetings with focus on research results and planning. Workshops within special topics which are of common interest for both industry and research have also been carried through. The Norwegian metallurgical industry has long-term experience from industrial co-operation in R&D with SINTEF, Teknova and NTNU. This has already provided a breeding ground for further contact between the partners and several industry visits at the production plants have been carried out in 2015. The first scientific articles written under the umbrella of SFI Metal Production are in progress, some are already finished. Some of our dissemination work are presented below.

The **Kick-off meeting in June 2015** was the very first meeting with all partners present. This was a successful meeting with respect to both formalities and science. Here represented by a presentation of Professor Gabriella Tranell and the foursome Ragnar Tronstad (Elkem), Aud Wærnes (SINTEF), Gabriella Tranell (NTNU) and Trond Furu (Hydro) (Photo: Thor Nielsen)

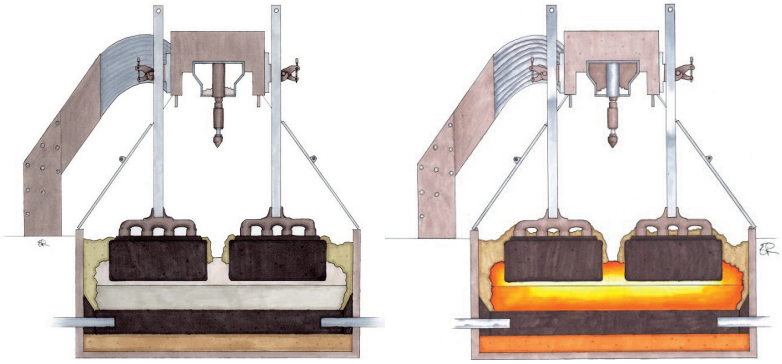

**Official opening** of the nine Centre of Research-Based Innovation in Trondheim in September 2015. Aud Wærnes, Centre Manager, presented SFI Metal Production and was handed the SFI Diploma on behalf of all our partners. *(Photo by NTNU, Thor Nielsen)*

**Autumn meeting in October 2015** with all Partners. The first day metal industry and environment was the main topic. Morten Onsøien (SINTEF) and Leiv Kolbeinsen (NTNU) continued the discussion with Bellona's Olaf Brastad after Olaf's presentation. The second day EU & Horizon 2020 opportunities were discussed, here represented by one of the discussions groups.

**Student – for future recruitments**
Presentation by Gabriella Tranell for recruitment purposes, given to students at Materialdagen.

During the summer of 2015, ten summer students did a fabulous work which has also been a success regarding recruitment of master and PhD students.

The drawing, which shows an Aluminium production cell, is made by the student Erik Dobloug Roede.




In 2015, we introduced **Newsletters** for the partners who have given this a warm welcome.

**SFI Metal Production in Media.**

Metal Production has been given media attention on several occasions in 2015. We can mention that the press covered the news when NTNU and SINTEF was awarded nine SFIs, and also the opening of the SFIs at NTNU/SINTEF.

Furthermore the industry partners have also published some articles about SFI Metal Production.

The picture shows an article in Adresseavisen from August 31 2015, about the excavation of furnace at Wacker Holla.


Mandag 31. august 2015 | Adresseavisen

» Silisiumproduksjon

*Når smelteovnen stenger, går forskere fra Sintef og NTNU inn for å undersøke det som ligger igjen i ovnen. Målet er en mer miljøvennlig smelteprosess.*

**Ovnen skal bli mer miljøvennlig**

During 2015, NTNU in cooperation with SINTEF have arranged **three scientific courses** for students and industry participants at Master /PhD level.

- Mn-fundamental course (September 21-22)
- Si-fundamental course (September 28-29)
- Al refining and recycling (November 10-11)

# ANNUAL ACCOUNTS FOR 2015

*The annual account for 2015 was higher than the budget due to high activity and a high in-kind contribution for all the Industry Partners during 2015.*

| Funding (1000 NOK) | Amount |
|---|---|
| Research Council | 6 105 |
| Host Institution (NTNU) | 1 647 |
| Research Partners* | 2 616 |
| Industry Partners** | 9 159 |
| **Total** | **19 527** |

| Costs (1000 NOK) | Amount |
|---|---|
| Host Institution (NTNU) | 4 433 |
| Research Partners* | 10 696 |
| Industry Partners** | 4 398 |
| Equipment | 0 |
| **Total** | **19 527** |

* *SINTEF, Teknova*

** *Hydro Aluminium AS, Eramet Norway AS, Elkem AS, Alcoa Norway ANS, TiZir Titanium & Iron AS, Glencore Manganese Norway AS, GE Norway AS (former Alstom Norway AS), Wacker Chemicals Norway AS, Fesil Rana Metall AS, Finnfjord AS*

# PERSONNEL INVOLVED IN THE CENTRE IN 2015

**Key Researchers**

| | | | |
|---|---|---|---|
| RD1 | Arne Petter Ratvik | SINTEF | Primary aluminium production, carbon materials |
| | Jan Erik Olsen | SINTEF | Modelling |
| | Stein Tore Johansen | NTNU/SINTEF | Modelling |
| RD2 | Merete Tangstad | NTNU | Si/FeSi and og Mn-alloys production, raw materials |
| | Eli Ringdalen | SINTEF | Si/FeSi and og Mn-alloys production, raw materials |
| | Espen Sandnes | NTNU | Primary aluminium production |
| | Asbjørn Solheim | SINTEF | Trace Element in Aluminium Production |
| RD3 | Anne Kvithyld | SINTEF | Aluminium refining and recycling |
| | Ragnhild E. Aune | NTNU | Aluminium refining and recycling |
| | Martin Syvertsen | SINTEF | Aluminium refining and recycling |
| RD4 | Gabriella Tranell | NTNU | Production of ferroalloys, emissions and environment |
| | Ida Kero | SINTEF | Emissions and environmental challenges |
| | Petter Nekså | SINTEF Energy | Heat recovery, heat exchangers |
| | Daniel Clos | SINTEF Energy | Heat recovery, heat exchangers |
| RD5 | Leiv Kolbeinsen | NTNU | Materials and society, Green Industry Cluster (GIC) |
| | Daniel Beat Mueller | NTNU | Materials and society, Material Flow Analysis (MFA) |

Photo: Elkem

**Administration**

| | | |
|---|---|---|
| Aud Wærnes (F) | SINTEF | Centre Manager |
| Marianne Lenes (F) | NTNU | Coordinator |
| Bodil Lervik (F) | SINTEF | Economist |
| Julie Brandhaug (F) | SINTEF | Coordinator |

**Visiting Researchers**

Jean-Pierre Birat from European Steel Technology Platform, Presentation «Metallurgy in Society and Scientific excellence.»

**Post Doc.:**

Sebastien Letout (M), France, 02.11.2015-01.11.2017, Modelling of SiMn pilot experiments/Comsol

**PhD:**

Punghwa Kim (M), Korea, 31.08.2015-30.08.2018, SiMn reactions

Sethulaksmy Jayakumari (F), India, 19.08.2015-18.08.2018, SiC in Silicon Processes

Nicholas Smith (M), USA, 17.08.2015-18.08.2018, Effects of Impurities on Al oxidation

Massoud Hassanabadi (M), Iran/Sweden, 01.10.2015-30.09.2018, Electromagnetically Enhanced Priming of Surface Modified Porous Media

**Project and master students**

| | | |
|---|---|---|
| Rune Stana (M) | autumn 2015/spring 2016 | Solidification of Ti slags |
| Siri Marie Bø (F) | autumn 2015/spring 2016 | Pedersens process |
| Sofie Aursjø (F) | autumn 2015/spring 2016 | Carbon lining materials |
| Erlend Lunan Bjørnstad (M) | autumn 2015/spring 2016 | Si refining |
| Håkon Olsen (M) | autumn 2015/spring 2016 | Rx rate in SiMn production |
| Claudio Sanna (F) | autumn 2015/spring 2016 | Si refining |
| Akshay Bhat (M) | autumn 2015/spring 2016 | Si refining |
| Marte Erdal Kjelstadli (F) | autumn 2015/spring 2016 | Quartz to crystobalitt |
| Joakim Holtan (M) | autumn 2015/spring 2016 | Reduction of Mn ore |
| Karin F. Jusnes (F) | autumn 2015/spring 2016 | Softing and melting of quartz |
| Sigmund Dahle (F) | autumn 2015/spring 2016 | Pedersens process |

# PUBLICATIONS IN 2015

**Reports**

Nedkvitne, Eirik Nøst and Kolbeinsen, Leiv, «En oversikt over norsk Metallindustri», NTNU 01.08.2015, report. (In Norwegian)

Lobo Stephen, Nedkvitne Eirik Nøst and Kolbeinsen Leiv, "An overview of Norwegian metals industry", NTNU 30.11.2015, report.

Clos, Daniel P. and Andresen, Trond, "Heat recovery from Al pot-gas in the SFI Metal Production Consortium", SINTEF 17.12.2015, report.

**Scientific/Scholarly presentations**

Halvorsen, Svenn Anton, (Teknova), "Metallurgical Scale-Up" , Mathematical Modelling in Metallurgical Industry, Kristiansand, 09.05.2015, speaker.

Tveit, Halvard, (Elkem /NTNU), "The use of Models in industrial processes", Kristiansand, 09.05.2015, speaker.

Furu, Trond, (Hydro, NTNU), "Through-process-modelling along Hydro Value Chain", Mathematical Kristiansand, 09.05.2015, speaker.

Olsen, Jan Erik, (SINTEF), "Modelling of metallurgical processes", Mathematical Modelling in Metallurgical Industry, Kristiansand, 09.05.2015, speaker

Johansen, Svein Tore, (NTNU), "Industrial pragmatic modelling", Mathematical Modelling in Metallurgical Industry, Kristiansand, 19.05.2015, speaker.

Wærnes, Aud, (SINTEF), "SFI Metal Production - Focus on Mathematical Modelling" Mathematical Modelling in Metallurgical Industry, Kristiansand, 19.05.2015, speaker.

Wærnes, Aud, (SINTEF), «Et historisk blikk på samspillet mellom forskning og forretning», Teknakonferansen 2015, Oslo, 10.11.2015, speaker

Wærnes, Aud, (SINTEF ), « SFI Metal Production og Norsk innsats for bærekraftig prosessindustri», Prosin-konferansen 2015, Arendal, 17.08.2015, speaker

Tranell, Gabriella, «SFI Metal Production - Interessant for dere studenter?», Materialdagen, Trondheim, 23.09.2015, speaker.

Kolbeinsen, Leiv, «Økt innovasjonstakt og implementering av ny kunnskap», Industri 2015, Bodø, 23.09.2015, speaker.

Kjelstadli, Marthe Erdal, "Kinetics and Mechanism of Phase Tranformation from Quartz to Crystobalite", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Stana, Rune Hagberg, "Solidification of Titanium Slags", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Olsen, Håkon Aleksander Hartvedt, "A Theoretical Study on the Reaction Rates in the SiMn-Production Process", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Myhre, Siri Marie Bø, "Operating Parameter of the Leaching Stage in the Pedersen Process", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Sørensen, Sigurd, "Conversion of Silica Frustules to Silicon Carbide", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Bhat, Akshay, "Boron Removal from Solar Grade Silicon, using Oxidative Gas Refining", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Sanna, Claudio, "Boron Removal from Silicon Using H2/H2O Gas Refining", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Aursjø, Sofie, "Intrusion of Silicon in Carbon Lining Materials" 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Holtan, Joakim, "Reduction of Manganese Ore with Quart and Limestone", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Vinje, Berit Johansen, "Recovery of Rare Earth Elements (REE) from Waste of Electrical and Electronic Equipment (WEEE)", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Bjørnstad, Erlend Lunnan, "Properties if the Bubble column in Oxidative Ladle Refining of Silicon", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Jusnes, Karin Fjeldstad, "Softening and melting of Quartz", 20th Int. Seminar on Materials Processes, Alto University, Finland, 19-20.11.2015, speaker.

Tangstad, Merete, "R&D in the silicon industry - the place of technological change", CRU - Silicon market Forum 2015, Istanbul, Turkey, 10.11.2015, speaker.

Photo: Hydro

**General Public**


Rasmussen, Liv Carlhamn, ¨A trip to warmer climes – furnace excavation in Bjølvefossen¨, Elkem Trainee 21.04.2015, https://elkemtrainee.wordpress.com/2015/04/21/a-trip-to-warmer-climes-furnace-excavation-in-bjolvefossen/

Åpning av 9 nye SFI-er¨, 18.09.2015 NT Faculty blogg http://blog.nt.ntnu.no/nye-sentre-for-forskningsdrevet-innovasjon-apnet/ og bilder, https://www.flickr.com/photos/ntnu-trondheim/sets/72157656574264124/

Norsk industri, «En anerkjennelse av norsk metallurgisk industri» 29.04.2015, http://www.norskindustri.no/Om-Norsk-Industri/Aktuelt/en-anerkjennelse-av-norsk-metallurgisk-industri/

Johannessen, Marit Flinder, «Forskningssenter skal styrke metallindustrien» 23.06.2015, press release at Elkem.no

SINTEF, «Forskningssenter skal styrke metallindustrien» , 23.06.2015, press release at Sintef.no http://www.sintef.no/forskningsaktuelt/sintef-materialer-og-kjemi/forskningssenter-skal-styrke-metallindustrien/

Molland, Halvor, «Forskningssenter skal styrke metallindustrien» , 23.06.201, press release at Hydro, http://www.hydro.com/no/Hydro-i-Norge/Pressesenter/Nyheter/2015/Forskningssenter-skal-styrke-metallindustrien/

Haugan, Idun, «Forskningssenter styrker metallindustrien», Gemini.no 24.06.2015, http://gemini.no/notiser/2015/06/forskningssenter-skal-styrke-metallindustrien/

Alcoa, «Grønnere teknologi med betydelig oppside», 26.05.2015 Industriavisen, http://www.industriavisen.no/print.asp?page=10&article=1359&msgpage=0&msgpost=0

Heggedal, Kristin, «Kvart milliard til nytt forskningssenter» 24.06.2015, NRK Trøndelag på nett, http://www.nrk.no/trondelag/kvart-milliard-til-nytt-forskningssenter-1.12424191

Hofstad, Sigrun, «Milliarder til forskning og innovasjon», 18.09.2015 NRK Trøndelag, http://www.nrk.no/trondelag/milliarder-til-forskning-og-innovasjon-1.12560530

Gemini, «Ni Nye Forskningssentre åpnet», 17.09.2015 Gemini -09-2015 http://gemini.no/notiser/2015/09/ni-nye-forskningssentre-apner/

Vinnes, Katrine «Nye industrielle SFI-senter åpnet» 25.06.2015, Norsk Industri. 2 http://www.norskindustri.no/Om-Norsk-Industri/Aktuelt/nye-industrielle-sfi-sentre-apnet/

Elkem, «SFI Metal Production», Elkem 07.07.2015, https://www.elkem.com/technology--innovation/long-term-rd/sfi-metal-production/

Langeland, Pernille og Wærnes, Aud, «Storsatsing på Norges metallproduserende industri», 15.06.2015 NT-Faculty blogg. http://blog.nt.ntnu.no/storsatsing-pa-norges-metallproduserende-industri/

Langeland, Pernille, «Tre nye sentre for forskningsdrevet innovasjon», 25.11.2014, NTNU-blogghttp://blog.nt.ntnu.no/tre-nye-sentre-for-forskningsdrevet-innovasjon/