



Ferroalloy research for sustainable development

FERROLEGERINGSINDUSTRIENS
FORSKNINGSFORENING

The Norwegian Ferroalloy
Producers Research Association



The Norwegian Ferroalloy Producers Research Association (Norwegian Abbreviation FFF) is an association founded by the Norwegian ferroalloys industry to carry out joint research on ferroalloy processes and products.

Through this research FFF aims to maintain the Norwegian ferroalloys industry's position at the forefront of developments in the production of ferroalloys and the supply of electrometallurgical technology and equipment.

It is our aim to pursue environmental improvement in the ferroalloys industry. Education of qualified persons to the staffs of the ferroalloys industry is an important part of our work. The research programme is also intended to support the education of student to a Ph.D level.

Our vision is Ferroalloy research for sustainable development.



Photo: Finnjord



Table of content

Members	4
From the chair of the board	6
Research activities, products	8
Success stories	14
Ongoing projects	18
Cooperation	24
Organization	27

FFF was formed in 1989

The FFF member companies employ directly 2400 persons and represent a turnover of NOK 16 billion

Current members:



www.elkem.com

One of the world's leading suppliers of silicon-based advanced materials with operations throughout the value chain from quartz to specialty silicones, and attractive market positions in specialty ferrosilicon alloys and carbon materials. Elkem has more than 6,800 employees with 29 production sites and an extensive network of sales offices worldwide.

Elkem has 1542 employees in Norway and total sales of 7.6 billion NOK.



Elkem Rana AS



www.eramet.no

With its three smelters in Porsgrunn, Sauda and Kvinesdal, as well as an R&D department in Trondheim, Eramet Norway is a world-leading producer of refined manganese alloys for the global steel market.

Eramet Norway has 532 employees and total sales of 5.6 billion NOK.



Eramet Norway Porsgrunn



www.finnfjord.no

Finnfjord is one of the world's most energy-efficient and environmentally friendly producer of ferrosilicon with a total production capacity of 100,000 tons of ferrosilicon. In addition, Finnfjord has an energy recovery system with a capacity to generate 340 GWh of electric power.

Finnfjord has 135 employees and total sales of 1 billion NOK.



Finnfjord AS



www.wacker.com

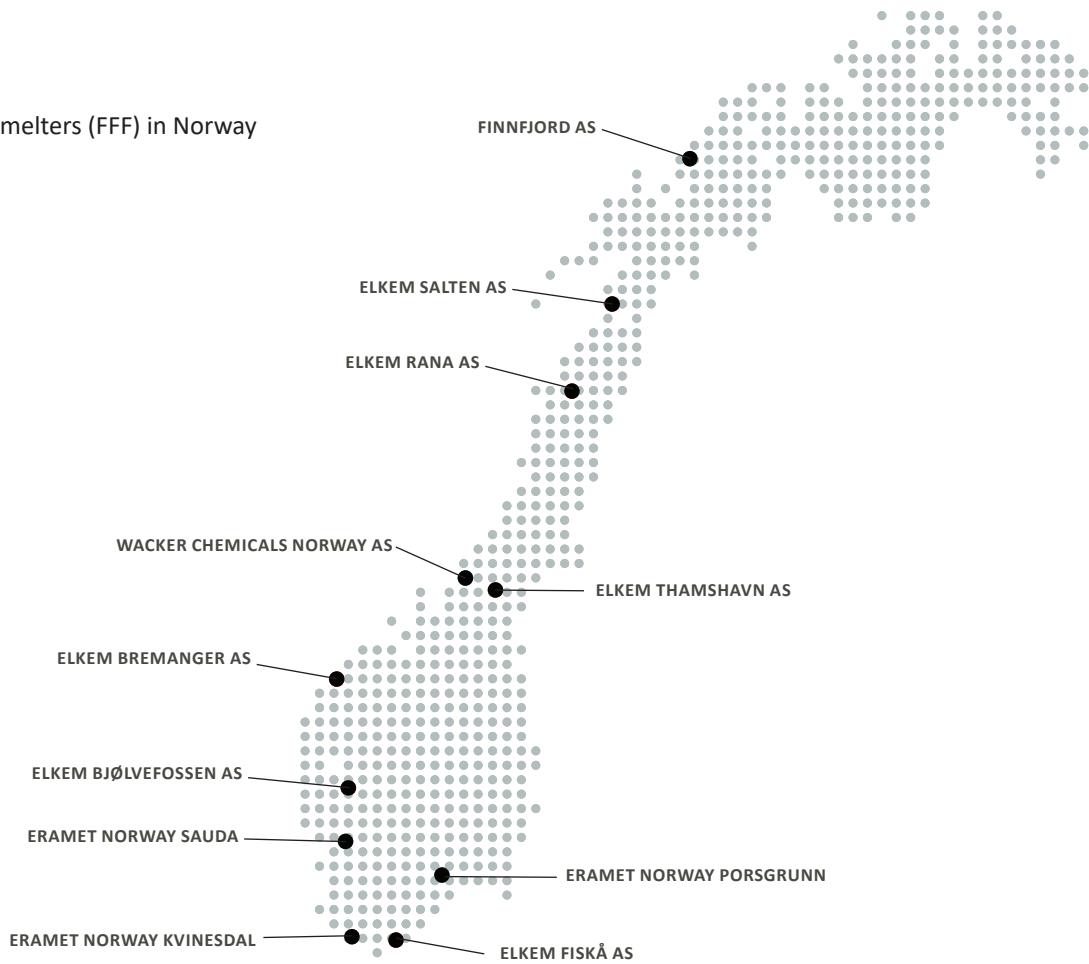
Metallurgical-grade silicon is one of Wacker's most important raw materials and is needed to produce silicones and hyper-pure polycrystalline silicon. Today we generate around a quarter of our silicon-metal requirements from the Holla production site.

Wacker has 210 employees and total sales of 1.4 billion NOK.



Wacker Chemicals Norway AS

Ferroalloy smelters (FFF) in Norway



From the chair of the board

2020-21 was special years for the companies in FFF due to the Covid-19 situation. Despite this we continued our work almost as normal although mainly in Teams meetings instead of physical ones.

We have had good discussions with Bellona during the period, starting with the seminar “Green power and green industry” and continuing to plan new seminars with the topic of biocarbon in Norwegian process industry, utilizing that FFF have worked on this topic many years already. We appreciate the educational discussions and good cooperation and look forward to continuing this in years to come.

We have had a process on establishing a new strategy and in that context some organizational changes. We now have groups for research management led by Benjamin Ravary, communication led by Viktor Myrvågnes and education led by Merete Tangstad. We see that the changes give more focus to how we will work with these topics.

The Process 21 reports have been published during 2020, and the main report in the beginning of 2021 and this has also

influenced our discussions and will be a topic in the strategy meeting in august 2021. The Green Platform has also been a topic that resulted in an application for a pre-project in 2020.

With participation in 5 running projects and centres with funding from the Research Council, FFF show that we still have many topics that need research to be able to increase value creation while at the same time ensure low carbon and environmental footprints from producing our important materials. To reach the goal of carbon neutral production I 2050, we need to continue the good work FFF has done since 1989.



Erlend Dårflot Olsen, Chair of the Board





RESEARCH ACTIVITIES - PRODUCTS

Photo: Elkem

Silicon and Ferroalloys – production in Norway

- Silicon – 225 000 tons
- Ferrosilicon – 265 000 tons
- Ferrosilicon master alloys – 56 000 tons
- FeMn – 300 000 tons
- SiMn – 230 000 tons

	Aluminium	Silicon	Ferrosilicon	Ferro/Silico-manganese
European production:	1 Russia	1 Norway	1 Russia	1 Ukraine
	2 Norway	2 France	2 Norway	2 Norway
	3 Iceland	3 Spain	3 Ukraine	3 Russia

Source: The Norwegian Pollutant Release and Transfer Register and Eramet Sustainability Report 2019.

Silicon and Microsilica

Silicon

- A wide range of silicon qualities are used as alloying agents in the aluminium industry. Aluminium-silicon alloys are widely used in the automotive industry due to the high strength-to-weight ratio, good corrosion resistance and good castability.
- Silicon is used for chemical applications and is the basis for the silicones industry and the production of fumed silica.
- Silicon is the starting material for production of polysilicon which again is the basis for production of semiconductors and solar panels.
- Silicon is also used in specialty applications in the ceramics and battery industries.

The world's most environmentally friendly silicon production for use in solar cells takes place in Norway

- The solar power market has doubled from 2018-2019 in Norway, and has since continued to increase. Assuming around 3 grams of silicon per Wp, production of solar panels with a total capacity of 3000 GWp will require the use of ~ 10 million tonnes of silicon with an estimated value of 60-100 billion NOK.
- Over 90% of the world's solar cells are made of silicon
- The world's most environmentally friendly silicon production for use in solar cells takes place in Norway.

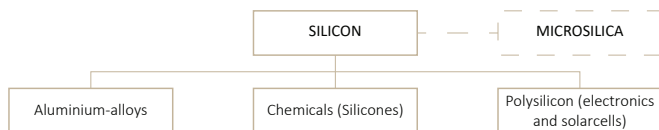


Photo: Shutterstock

Microsilica

- A wide range of microsilica qualities are used in the construction, oilfield and refractory industry.
- Microsilica is used to make the high-strength concrete that is essential for constructing the world's tallest buildings, such as the record-breaking Burj Khalifa in Dubai at 828 metres. Here microsilica is used to increase the strength of the concrete mix by its unique particle packing ability combined with pozzolanic reactivity.

*Burj Khalifa, Dubai, United Arab Emirates.
Photo: Elkem*



Ferrosilicon

- The metal industry uses a lot of energy, but is also a prerequisite for sustainable renewable energy production
- Wind turbines contain more than 70% steel
- Steel is an important material in hydropower which accounts for 93,4% of Norwegian power production. Here, steel is used in generators, among other things.

Ferrosilicon are used in the steel and iron industry. 3-4 kilograms of FeSi is used to produce one ton of regular carbon steel, whereas stainless steel requires 5-10 times.

FeSi increases the strength, hardness and corrosion resistance in the steel.

Ferrosilicon, master alloys

Elkem manufactures a wide range of inoculants, MgFeSi alloys and preconditioners for the production of cast irons. Alloys cover all foundry processes and iron specifications.



Photo: Elkem

Manganese alloys

Steel is the world's most widely used construction material in everything from structures, industrial equipment and cars to consumables.

Steel, and thus also manganese alloys that make steel ductile and durable, is an essential input factor in the transformation of important sectors such as energy generation and transport.

Robust, long-lasting infrastructure is also crucial to create economic development and prosperity to meet the many challenges that come with population growth, urbanisation, poverty alleviation and measures to reduce the negative effects of natural disasters.

Steel can potentially be recycled indefinitely without losing its properties, and the global recycling rate is now more than 80%.

The global consumption of steel has more than doubled since the turn of the millennium and is expected continue to increase in the years towards 2050.





SUCCESS STORIES

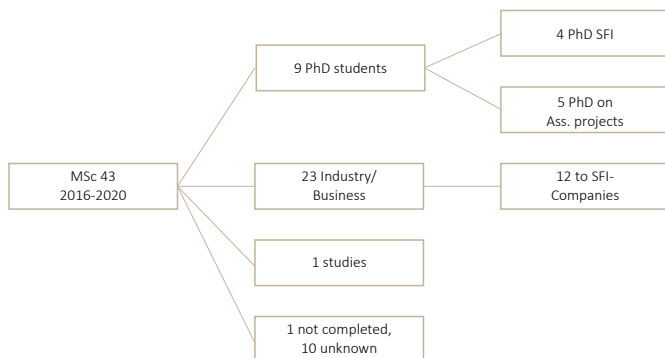
Photo: Geir Mogen / NTNU



Educated more than 70 PhD candidates since 1990

In close co-operation with NTNU, education is an important part of FFF's activities. In the period from 1990 until today, more than 70 PhD candidates have graduated with the support from FFF, the Research Council of Norway and other industries as aluminium.

The PhD students have been part of research projects together with researchers and coworkers from SINTEF and NTNU. 18 PhD students are today part of ongoing FFF projects. Master students within FFF projects are also a recruitment base for the ferroalloy industry.

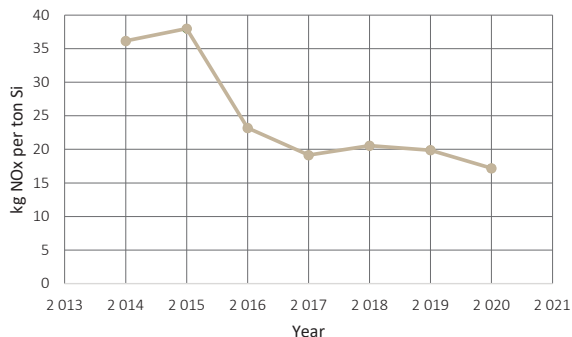


NTNU Campus, Trondheim

Reduction of NOx emissions from FeSi/Si

Common challenge - solved after 20 years of cooperation

Typically reduction in NOx after implementing new technology- kg NOx per ton Si produced



Elkem Salten. Photo: Elkem

The main environmental impacts regarding NOx are:

- Acid rain (oxygen depletion and global warming)
- Ground-level ozone (respiratory disorders)

40 publications from FFF 1995-2012

1997-2003	2009-2012	2013	2015	2017	2019
FFF initiated three research projects to understand more about formation of NOx in Si/FeSi production.	Models-Pilot testing PhD.	Furnace Measurements-benchmark-data models-design Presentation at Infacon XIII.	Technology implemented at Elkem Salten. A reduction of more than 40%.	The Elkem Innovation Award in 2017.	Implemented on all three furnaces at Elkem Salten and Elkem Bremanger. Reduced NOx emission by 50%. Support from NOx fondet.

Use of Biocarbon in the production of ferroalloys



Photo: Shutterstock

Facts about the use of biocarbon in the Norwegian Silicon- and ferrosilicon industry:

- The use of biocarbon is an efficient climate action. Combined with CCS, the use of biocarbon will be even more favorable.
- Technologies for sustainable production of biocarbon are ready for industrialization.
- Today, the use of biocarbon in production of Si/FeSi is around 20% of the total carbon used in Norway.
- A conversion to 100% biocarbon in the Norwegian Si/Fe industry, will require 5 mill fm3 wood a year, corresponding to 40% av todays logging.
- Biocarbon is expensive compared to fossil carbon. However, it is expected that CO2 taxes will balance the cost difference in the coming years.
- Predictable access and price on wood are crucial for industrialization.

1996	1997	1998-2001	2002-2004	2005-2007	2012	2014-2017	2018-2022	2019-2022
Increased use of use of biocarbon in the Si/FeSi industry.	Use of biocarbon in the Norwegian ferroalloy industry, pre-study.	Use of BioCarbon for reducing the CO2 emissions.	Environmentally friendly reduction processes.	Biocarbon for the production of ferroalloys.	Alternative carbon sources, FFF pre-study.	BioCarb+ Enabling the biocarbon value chain.	Reduced CO2 emissions. Develop methods for substituting fossil carbon in ferroalloys.	BioCarbUp Optimising the biocarbon value chain for a sustainable metallurgical industry.



ONGOING PROJECTS

Photo: Svend Grådahl / SINTEF

Controlled Tapping



Aim: Maximize metal yield and operation load and minimize hazardous tapping conditions. The focus for the Mn-producers is slag/metal separation while the Si/FeSi producers are focused on taphole gassing.

The tapping process is an important subprocess, deviations leads to a higher energy consumption, less metal yield and security risks. Advanced modelling of tapping shows how slag and metal exits the tapping hole mixed, and how metal and slag separation is affected by varying tapping parameters. It has been discovered that the temperature in tapped metal is substantially higher than previously believed for FeSi and Si. It has been observed that slag tapped from Si-furnaces are enriched in CaO and Al₂O₃. The SiO production rate is not affected by the quartz source, but very dependent of the temperature.

www.sintef.no/controlled-tapping

Reduced CO₂ emissions



Aim: Develop the basis for reduced climate effects from the production of Si, FeSi, Mn-alloy and TiO₂ slag to obtain 30% lower CO₂ emission in 2030 and zero CO₂ emission in 2050.

Most CO₂ emissions from the metal industry are caused by solid carbon used in the reduction process, results:

- In order for biocarbon to be able to replace fossil coal, it must result in a more efficient production of metal. A number of different biocarbon qualities are compared with fossil carbon.
- Carbon from biogas is a possible carbon source for the production of Mn alloys.
- Several current new technologies have been considered for further research. This has resulted in two spin-off projects- one on the use of hydrogen plasma in metal production and one to study electrolysis in manganese production.

www.sintef.no/reducedco2

Key figures

Project owner	NTNU
Project manager	Merete Tangstad
Duration	2017 - 2021
Budget	28 MNOK
Partners	Elkem, Eramet, Wacker, Finnjord, SINTEF, NTNU and MINTEK

Key figures

Project owner	SINTEF
Project manager	Eli Ringdalen
Duration	2018 - 2022
Budget	27 MNOK
Partners	Elkem, Eramet, Wacker, Finnjord, SINTEF, NTNU and TiZir

PAHssion - Industrial efforts towards zero-emissions of PAH



In PAHssion, the industry joins forces with the R&D partners to develop new and improved methods for PAH emission detection, quantification and prediction.

New methods for PAH emission monitoring and for testing new raw materials will result in new services offered on the market and improved guidance capability of laboratory subcontractors to the industry. It will also improve assessment of environmental footprints and limit associated costs for the industrial companies. Additionally, it will aid companies in selecting materials and design processes on the basis of anticipated emission behaviour. In total, this will create value in terms of new and improved measurement services, raw material selection, abatements methods, operational savings and new best practice guidelines. But most importantly, it will ensure that the industrial consortium partners can continue to operate in Norway.

www.sintef.no/pahssion

Electrical Conditions in Submerged Arc Furnaces - Identification and Improvements (SAFECI)

The project aims at establishing the basis for substantially reduced energy consumption. We believe that the total potential is in the range of 5-10 % of the energy consumption, where one per cent reduction for our partners corresponds to an annual saving of some 70 GWh.

The project intends to provide substantially new information on inner furnace conditions and how they can be measured/detected. The combination of physical and data-driven models will pave the way towards future digital twins. If successful, the project will supply a breakthrough within metallurgy, that will enable early detection of deviation from good operating conditions and ensure safe transfer back to suitable operation. Potentially, the project may also lead to improved knowledge-based guidelines for future furnace design.

Key figures

Project owner:	Elkem ASA
Project manager:	Ida Kero, SINTEF
Duration:	2019 - 2022
Budget:	20 MNOK
Partners:	Elkem, Eramet, Wacker, Finnjord, SINTEF, NTNU, Ferroglobe, Tizir, Eyde, Washington Mills, Norce, Fiven and SINTEF Norlab

Key figures

Project owner:	NORCE
Project manager:	Svenn Anton Halvorsen
Duration:	2021 - 2025
Budget:	19.1 MNOK
Partners:	Elkem, Eramet, Wacker, Finnjord and NTNU

Recursive - Reduced energy consumption by increased reduction volume

Recursive will contribute with knowledge needed to reduced energy consumption and CO2 emission pr ton of alloy from production of Si, Si- and Mn-alloys.

The main objective in Recursive will be to increase the yield of valuable elements and to minimise consumption of energy and carbon by reactions that are not desired.

Topics for the project are:

- Conditions responsible for slag accumulations
- The slag properties going from primary slag to tap slag
- The effect on condensed materials in the low temperature zones
- The main conditions affecting bad tapping
- The effect of softening, melting and dissolution of quartz
- The formation conditions and properties of carbide banks

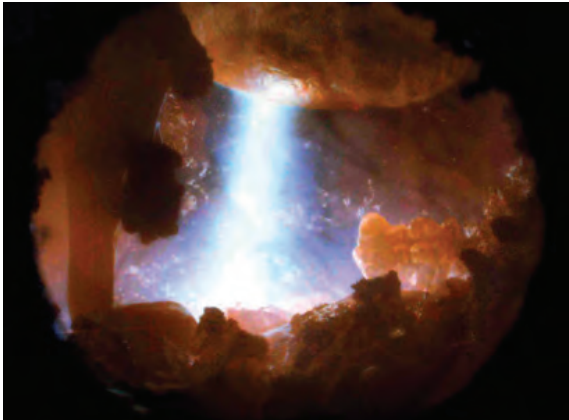


Photo: Elkem

Key figures

Project owner	NTNU
Project manager	Merete Tangstad
Duration	2021 - 2025
Budget	19.7 MNOK
Partners	Elkem, Eramet, Wacker, Finnfjord, SINTEF, NTNU and SINTEF

FME HighEFF

HighEFF has defined ambitious goals for development and demonstration of technologies that may improve energy efficiency and reduce emissions from industry.

Energy efficiency measures are to be considered as necessary and enabling for a transition to a low emission society, as presented by the IEA projections to meet the 2-degree target put forward in the Paris agreement. A kWh not used does not have to be produced.

Measures to reduce the energy consumption and emissions from the industry are often less costly than alternative measures. Energy efficiency measures will thus be very important for an optimal transition from a social economic and environmental perspective, and in order to maintain and increase value creation in society.

www.sintef.no/higheff



Photo: SINTEF

Key figures

Project owner	SINTEF Energy
Project manager	Petter E. Røkke
Duration	2016 - 2024
Budget	400 MNOK
Partners	41 partners including FFF companies, NTNU and SINTEF

SFI Metal Production

Vision: Resource efficient metal production from a clean industry.

Primary objective:

- Strengthen the innovation potential of one of Norway's largest land-based Industry
- Give the industry access to world class fundamental competence and candidates
- Collaboration platform for Metal Producing Industry, Academic and Research community in Norway.

Examples of Research areas:

- Modelling metallurgical processes.
- Investigate chemical reactions of sub-processes and their effects on surroundings and operation.
- Refining and Recycling of metals
- Energy- and waste recovery
- Emissions and measurements
- Mass Flow Analysis (MFA)

www.ntnu.edu/metpro



Photo: NTNU

Key figures

Project owner	NTNU
Project manager	Aud N. Wærnes
Duration	2015 - 2023
Budget	250 MNOK
Partners	SINTEF, NORCE, Hydro, Alcoa, FFF, Eramet, Finnfjord, Elkem, Wacker, Tizir, GE



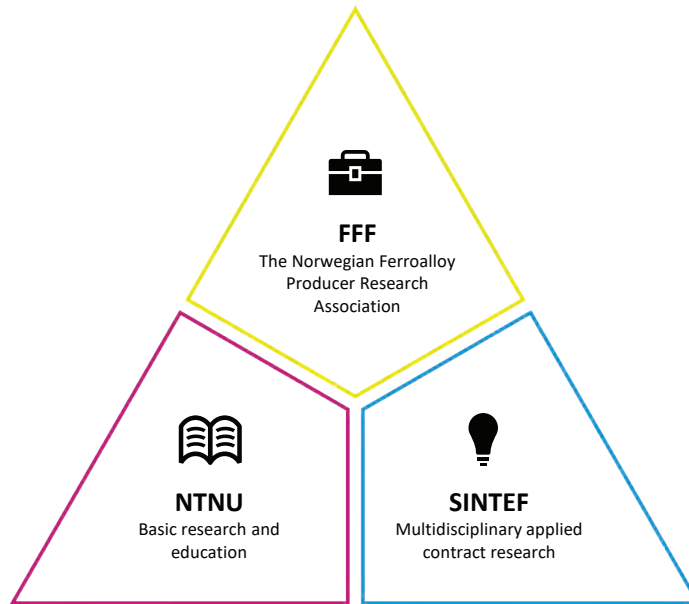
COOPERATION

**FINNFJORD
VISITOR**

**FINNFJORD
VISITOR**

Photo: Berit Fossum / SINTEF

Close working relationships between FFF, NTNU and SINTEF generate innovation and high quality research



Important partners



**The Research Council
of Norway**

www.forskningradet.no

The Research Council works to promote research and innovation of high quality and relevance and to generate knowledge in priority areas to enable Norway to deal with key challenges to society and the business sector. RCN is co-funding most of FFFs research projects.



www.bellona.no

An independent non-profit organisation that aims to meet and fight the climate challenges, by identifying and implementing sustainable environmental solutions.

FFF and Bellona work with long-term and key challenges between the process industry and society, climate and environment, and aim to seek technological solutions, develop tools and influence framework conditions that provide reduced emissions, increased energy efficiency, more efficient utilization of resource and a future-oriented, sustainable ferroalloy industry.



Norsk Industri

www.norskindustri.no

The Federation of Norwegian Industries works for framing conditions for businesses in sectors and industries. The most important task is to ensure that society understands how important a viable industry is for our future welfare.



INFACON
27-29 September 2021, Norway

www.infacon16.com

INFACON - the International Congress on Ferroalloys - the intention is to stimulate technical interchange on all aspects of ferroalloy production. INFACON contributes to the exchange of research and development covering the major and most of the minor ferroalloys. INFACON was arranged in Trondheim in 1995 and 2021.

The Federation of Norwegian Industries works for framing conditions for businesses in sectors and industries. The most important task is to ensure that society understands how important a viable industry is for our future welfare. A representative is observer in the FFF board.

Organization



Ferrolegeringsindustriens
Forskningsforening

www.ferroforsk.com

FFF is run by a board consisting of nine members, eight of whom are appointed by the member companies and one by SINTEF Industry which manages FFF. The Research Council of Norway and Norsk Industri are represented by observers at board meetings.

- Formed in 1989
- Key figures research: Budget 2021 – 4 mill € (incl. other industry partners)
- Total for the period 2000- 2021, appr. 45 mill €

Members of the board:

- Erlend Olsen, Chairman, Finnjord AS
- Viktor Myrvågnes, Elkem ASA
- Halvard Tveit, Elkem ASA
- Aasgeir Valderhaug, Elkem ASA
- Paul Calvert, Eramet Norway AS
- Sten Yngve Larsen, Eramet Norway AS
- Benjamin Ravary, Eramet Norway AS
- Birger Andresen, Wacker Chemicals Norway
- Merete Tangstad, NTNU and SINTEF

Observers:

- Astrid Brenna, The Research Council of Norway
- Sverre A. Høstmark, The Federation of Norwegian Industries

Administration:

- Aud Nina Wærnes, Coordinator, SINTEF
- Berit Fossum, Administrator, SINTEF



*Dog-house –
Improvement of the
internal environment*



Elkem



eraMET



FINNFJORD



WACKER

Ferrolegeringsindustriens Forskningsforening (FFF)
The Norwegian Ferroalloy Producers Research Association
c/o SINTEF Industry
P.O. Box 4760 Torgarden
NO-7465 Trondheim, Norway
Phone: +47 930 59 428
Enterprise/VAT No.: NO 894 297 662
Coordinator: Aud N. Wærnes (Aud.N.Warnes@sintef.no)



Ferrolegeringsindustrien
Forskningsforening

www.ferroforsk.com